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LANDSCAPE RESEARCH RECORD is published annually and consists of papers focused on landscape architecture subject areas. Each issue is a collection of papers presented at the Council of Educators in Landscape Architecture’s annual conference of that year. The conference theme is expressed as the subtitle of Landscape Research Record. The views expressed in papers published in Landscape Research Record are those of the authors and do not necessarily reflect the views of the conference planning committee or the Council of Educators in Landscape Architecture.

PEER REVIEW OF PAPERS: All papers published in Landscape Research Record have been reviewed and accepted for publication through the Council of Educators in Landscape Architecture’s peer review process established according to procedures approved by the Board of the Council of Educators in Landscape Architecture. Reviewers are recruited by track chairs and the editor from among conference attendees and other outside experts. The track chairs also serve as co-editors in the peer review process. The Council of Educators in Landscape Architecture requires a minimum of two reviews; a decision is based on reviewer comments and resultant author revision. For details about the peer review process and reviewers’ names, see Reviewers in Table of Contents.

IN THIS ISSUE: In 2022, the conference committee accepted 261 abstracts for presentation and rejected 51 abstracts. Authors of accepted abstracts were invited to submit a full paper. After the initial screening, a total of 37 papers were received but only 35 papers were selected and sent out for peer review. Finally, 18 papers were accepted for publications in this issue representing 8 out of 15 tracks available at the CELA 2022 annual conference. Most of the theme track papers are recruited for the Landscape Journal special issue while some others transferred to other relevant tracks by theme track co-editors. This issue of LRR does not have papers from the theme track. The organization of this issue follows the standard conference tracks listed in the Table of Contents.

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Welcome to the eleventh issue of Landscape Research Record, published by the Council of Educators in Landscape Architecture (CELA). In 2013, the CELA Board approved and adopted a procedure to become fully responsible for publishing peer-reviewed conference papers annually and named the publication Landscape Research Record (LRR). LRR is a post-conference publication and is published online only.

This eleventh issue of LRR is a collection of double-blind peer-reviewed papers previously presented at CELA 2022. After two years of canceled, and virtual-only conferences due to the COVID pandemic, the 2022 annual conference was the first in-person CELA conference with limited online participation options. The 2022 CELA annual conference was a comeback year for CELA academic and professional practitioners, students, and advocates at the beautiful landscape of Hyatt Regency Tamaya Resort and Spa in Santa Ana Pueblo, New Mexico from March 16-19, 2022. Nestled on 550 acres of land between the Sandia Mountains and the Rio Grande River, this venue was selected for its Native American cultural heritage, inspirational landscapes, vernacular architecture, and unique environment.

The 2022 annual conference focused on research, scholarship, and creative activity that highlighted the theme of “Evolving Norms” which started the discussions and debates responding to a disruptive phenomenon and a crisis that has introduced societal change, technological advancements, and pedagogical and scholarly innovations to inform the projected future. The 2022 conference also intended to celebrate the delayed centennial anniversary of the existence of CELA in-person. The 2022 conference formally added a new Resilience and Climate Action track, in addition to Evolving Norms: Adapting Scholarship to Disruptive Phenomena theme track.

This issue contains 18 high-quality double-blind peer-reviewed papers resulting from the 2022 annual conference. We hope you find them to be a collection of timely, insightful, and transformative scholarly work that enriches CELA’s dialogue concerning landscape education, research, and creative inquiry on societal change, technological advancements, and pedagogical and scholarly innovations.

Taner R. Özdil, Ph.D., ASLA
University of Texas at Arlington
Editor-in-Chief, Landscape Research Record No.11
CELA Past Vice President for Research & Creative Scholarship, 2022-2023
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DESIGN EDUCATION AND PEDAGOGY

Edited by Benjamin George, & Peter Summerlin
CONNECTING ETHICS AND EPISTEMOLOGY THROUGH METAPHOR

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1 ABSTRACT

It has been argued that metaphor is the basis for conceptual thinking and it has been shown that metaphor can aid learning. It has also been demonstrated through experimentation and historical studies that using different metaphors to describe the same problem can lead to different goals for improvement and, subsequently, to different courses of action. As such, uses of metaphor can greatly influence planning and design outcomes. This paper considers a narrow use of metaphor for design development through a framework that establishes and advances design as an argument for intentional change. The framework assumes a constructivist perspective in which a student gains new knowledge and synthesizes understanding by building upon prior experiences and understanding. In this framework, metaphor is used to provide a strategy to manage overall change and link concerns of ethics and concerns of epistemology. This connection calls for interrelated examinations of subjective and objective aspects of design thinking within an internally consistent argument. Relevant theories of metaphor from linguistics, cognitive science, law, public health, planning, and design are employed. Emphasis is placed on methodological and heuristic uses of metaphor, rather than discursive uses. Implications of metaphor as framing device within ethical and epistemological concerns are discussed. Second year graduate-level student projects done over several years provide examples. The work offers a basis to observe patterns of use and challenges with some metaphors for design development.

1.1 Keywords

Metaphor, Ethics, Epistemology, Design Process
1 INTRODUCTION

At the start of every project, a designer faces uncertainties about parameters or values of variables and ambiguities about relationships among variables. Areas of concern include the state of current conditions, criteria for a satisfactory outcome, and the ways and means to bring about change effectively (Newell, Shaw, & Simon, 1962). To move forward, various methods or techniques are used to represent and structure facts and assumptions. Individual methods are often combined such that the results of one method provide data for another. Additionally, the combinations are typically applied recursively to provide a heuristic learning process about the problem and possible resolutions. As sequences of methods are applied and tested for their effectiveness across projects—that is, as they are used successfully with different facts and assumptions related to different problems—they become generalized frameworks. Such frameworks provide a designer with a structured approach to practice that is independent of the qualities of any individual design problem. Specifically and significantly, generalized frameworks assume established a priori stable relationships among kinds of variables and information. Examples of such frameworks for environmental design include those by Alexander (1964), Lyle (1985), Rowe (1987), and Steinitz (2012).

While it might be readily accepted that generalized frameworks are helpful, it must also be acknowledged that they can be very different from one another with regard to ways individual methods are employed or emphasized. Further, it can be argued that the choice of a framework reflects the designer's willingness and ability to engage kinds of ambiguity among variables or features of a problem (Schrader, Riggs, & Smith, 1994). In this light, the use of a given framework explicitly or implicitly reveals something about a designer's fundamental attitudes about problem solving through what might be considered the contingent logic of a given design process.

One common technique to manage some ambiguity in planning and design is the use of metaphor (Casakin, 2006; Gerber & Patterson, 2013; Picon, Ponte, & Lerner, 2003; Solesbury, 2014; Unwin, 2019). A metaphor is a way to focus attention or filter perceptions about problems and resolutions. This paper considers the use of metaphor in design to relate concerns about ethics and concerns about epistemology. It does so within a generalized framework that views design development as making a form of argument for intentional change. This framework is summarized below and presented in greater detail in another paper (Shearer, 2015). In part, the motive for providing an expanded discussion on connections between ethics and epistemology is an interest in advancing this approach to design and pedagogy. More significantly, the last few years have seen increased scrutiny on the ways shaping the environment contributes to matters of equity and justice. Within professions, there are also questions about the production and application of specialized knowledge in situations where facts may be uncertain, underlying values may be contested, and the consequences of results may be pervasive or long lasting (Functowicz & Ravetz, 1993). Some have anticipated that changes associated with the Anthropocene—including climate change, increasing extreme weather events, urbanization, human migration, and biodiversity loss—will result in new societal orders and exacerbate political disagreement (Hoffman & Jennings, 2021; Lövbrand, Möbjork, & Söder, 2020). Under such conditions, attention to relationships between what is good and what is true are heightened and it becomes increasingly important to help students learn how to recognize their own constructions of thought and learn how to share those understandings with others. As such, connections between notions about what ought to be done and notions of cause-and-effect relationships through which the designer might act have, rightly, taken on (even) greater importance in design education and professional practice.

2 DESIGN AS ARGUMENT FOR CHANGE

The proposition that design can be understood as making an argument for change follows from the position that many problems addressed through design are not simply difficult due to uncertainty and ambiguity, but that they are also “wicked,” because there is rarely agreement on ways to prioritize public goods and benefits (Rittel & Webber, 1973). This situation is especially common in environmental design, which includes architecture, landscape architecture, and urban design. As such, a design proposal is not a solution in the sense of, say, a mathematical calculation with an unambiguously correct answer, but is a
reasoned opinion for change to be discussed, debated, and decided in contested and sometimes contentious circumstances. This positioning of design as argument for change can be considered part of a broader movement to address policy- and planning-level decision making (Fischer & Forester, 1993).

If this proposition is accepted, how is the basis for an argument started and advanced through a process of design development? An argument is a claim supported by evidence and logical reasoning (Toulmin, 1958). An important part of presenting any argument is explicitly revealing connections among facts, assumptions, and opinions. Doing so allows transparency for discussion and shared decision making. Reasoning for design is often highly contingent on an array of interconnected speculations in addition to whatever facts are available. Further, a particular challenge is that because design problems are ill-defined when initially presented to the designer, the process of making an argument begins with an initial best guess or generative proposition about how to proceed. Formally, this guess is an *abductive conjecture*. This conjecture is only “something [that] may be” (Peirce, 1934, p. 106), but it nevertheless serves to structure subsequent thought about the design problem (Cross, 2007). Developing the complete argument for change involves extending, testing, and aligning the abductive conjecture with the other kinds of thought that support a reasoned outcome. This process involves active construction and recursive reconstruction of the problem and its possible resolutions across levels of abstraction and methods of representation.

The abductive conjecture can be considered a speculative, “What if…?” question. The framework used in this paper posits five basic questions. Each question addresses a different aspect of problem definition and resolution. No matter which question is used to begin a design project (that is, which is the initial abductive conjecture), all five questions are asked and answered. Further, the questions are interrelated such that each serves as a sub-framing device for the others. When using this framework, a well-made design argument displays consistency of thought across questions and levels of abstraction.

This approach of making and extending an abductive conjecture is constructivist. There are many constructivist approaches to learning and understanding (Geelan, 1997), but it is sufficient for this paper to say that it is assumed the designer or design team actively builds on known schema to understand novel problems and possible resolutions. Abductive thinking has been positioned as reflexive and interpretive in the context of constructivist approaches to design (Deming & Swaffield, 2011). The framework has been considered by others for design thinking in different disciplines ranging from business (Rindova & Martins, 2021) to linguistic composition (Jones, 2021) to higher education (Catteral, Mickenburg, & Reddick, 2019).

Table 1 lists the five elements of the framework, the phrasing of the associated “What if…?” question, and dominant forms of representation for each element and question. The column on the right provides the emphasis of each element, which may be important relative to planning student exercises or for a designer's self-awareness.
Table 1: Elements of a Framework for Design Thinking to Make an Argument for Change.

<table>
<thead>
<tr>
<th>Framework Element</th>
<th>What if ... is/are changed?</th>
<th>Dominant form of representation</th>
<th>Emphasis of thought</th>
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<tr>
<td>Image of the World</td>
<td>Core Beliefs</td>
<td>Statements of facts and assumptions</td>
<td>Mysticism</td>
</tr>
<tr>
<td>Challenges • Opportunities</td>
<td>Transformable aspects of site and program</td>
<td>Context maps</td>
<td>Materialism</td>
</tr>
<tr>
<td>Vision</td>
<td>The comprehensive strategy for directing change</td>
<td>Metaphor</td>
<td>Idealism</td>
</tr>
<tr>
<td>Objectives</td>
<td>Available means to act and intended outcomes</td>
<td>Cause-effect models and systems diagrams</td>
<td>Pragmatism</td>
</tr>
<tr>
<td>Forms</td>
<td>Locations, dimensions, materials, and sequences of objects</td>
<td>Orthographic drawings, geometric models, and renderings</td>
<td>Realism</td>
</tr>
</tbody>
</table>

A diagram of the framework is presented in Figure 1. The outer arcs are labeled with the dominant kind of reasoning that link the elements. Labels on the inside of the arcs provide the underlying topic of philosophy that is engaged. Labels on the outside of the arcs provide a common language understanding. As indicated by the double-headed arrows, conjectures for each element directly influence consideration of the two adjacent elements and are reciprocally influenced by them. Moves along arcs provide bases for supporting claims of the argument. As indicated by the dashed lines that cross in the center of the diagram, conjectures in answer to each, "What if...?" question also indirectly influence and are indirectly influenced by the remaining two elements.

Starting near the top and right of the figure, the most abstract element of conjecture is one's image of the world. It includes all the facts known and beliefs held in the mind. It is accepted that one's image of the world is complex and may not be internally consistent. It provides a foundation for all other conjectures. Moving clockwise and through concerns of ontology or awareness, challenges•opportunities are fundamental elements in the world that could be changed. As the title suggests, they are neither inherently positive or negative. Water, sound, texture, and periodicity are examples. A given project may involve several challenges•opportunities. They are represented as context maps. Continuing clockwise and through concerns of ethics or normative principles, vision is a single overarching strategy to manage change that is possible by acting on the challenges•opportunities. A vision is represented by a metaphor and will be discussed below. Continuing clockwise through concerns of epistemology or responsivenes, objectives are specific aspects of the current situation that will be improved through designed change. That is, objectives reflect how the vision can be made operative with regard to social or biophysical aims. Objectives require the specification of cause-and-effect relationships. Systems dynamics diagrams provide an effective form of representation. Objectives may be assessed in quantitative or qualitative terms. Next, continuing through considerations of aesthetics or expressiveness are concerns of form. Least abstract, forms involve the composition of the design proposal including locations, dimensions, materials, and sometimes temporal sequences. Forms are represented by conventional design drawings and iconographic models. Forms are related to the image of the world through concerns of phenomenology or experience.
In broad terms, a final argument that results from this framework is: here are the designer's core assumptions about the world; given core assumptions, here is how a particular site and site use are open to change; given what is open to change, here is an overarching strategy to improve the current situation; given the strategy, here are the ways change can be effected to meet specific desired outcomes; given ways of change, here are proposed reconfigurations of things in space and in time; and given the reconfigurations, here is how the reconfigurations conform to or modify core assumptions. A final argument might also be done in reverse order: here are the designer's core assumptions about the world; given core assumptions, here are reconfigurations that conform to or modify them; given reconfigurations, here is how they are a response to the ways change can be effected to meet specific desired outcomes; given desired outcomes, here is how the set of objectives contribute to an overarching strategy to improve current conditions; given the strategy, here is how it engages aspects of the site and site use that are open to change; given the ways change is possible, here is how they relate to core assumptions about the world. Regardless of the direction of thought (or presentation), propositions or claims at one level of abstraction are used as rationale for claims about the others.

These descriptions of a final argument do not require that a process of design development follow either sequence. To the contrary, it is assumed that the initial abductive conjecture used to structure an ill-defined problem might be made based with any of the five “What if…?” questions. The actual choice of where to begin can stem from the preference or experience of the designer, the nature of the problem, or,
in instances of design education, the learning objectives of a course. Once made, the conjecture informs how the other four elements are defined and understood as the designer moves around or across the diagram. Like with other generalized design frameworks, working to align ideas and kinds of representation requires continual reexamination of all earlier conjectures. This process can, and often does, include revision of the abductive conjecture.

An important note on the initial abductive conjecture is that regardless of the starting point within a given project, the designer has great latitude with respect to sources of inspiration and degrees of originality. Conservatively, the answer to any initial "What if...?" proposition might be inspired by conventional practices or well-known precedents. Radically, the answer might be inspired by an unprecedented condition (or, phrased for the time of this publication, by a proposition for a “disruptive” practice or technology). A mix of conservative and radical impulses might transfer ideas from one social or environmental context to another community. Here, it must be emphasized—not simply restated—that this design framework is constructivist: The designer uses what is known as a basis to extend understanding about the problem and possible resolutions. Through exploration of the extensions, learning can occur. Applied in an educational context, this aspect of the framework requires instructors to consider the kinds and amounts of novelty students should engage over a single course or over a degree plan. Conservative design propositions can result in societally beneficial outcomes and demonstrate preparedness to enter professional practice, but they might not be sufficiently intellectually challenging for all advanced students. Radical design propositions can excite and may lead to resolutions needed to tame “wicked” problems, but they can also become overwhelming with attempts to work out details. With respect to this framework, untested questions include how students at different stages of a degree plan might be helped or hindered by different required starting points (different “What if...?” questions) or by instructional expectations about degrees of novelty. Also, of note for education and for professional practice, should an individual design project aim to dramatically change someone’s image of the world? Answers have been decided differently across cultures and historical eras (Kluber, 2008).

Following from this overview, the vision—overarching strategy to manage change—is typically represented by a metaphor. The vision does not exist in isolation. It is informed by its adjacent elements. On one side, the vision is informed by the fundamental ways the world is open to change by the designer and stakeholders. Connecting these possibilities and the vision are matters of ethics—values and associated kinds of conduct that are considered to be morally right or correct. Some matters about how to address any transformation will be proscribed by regulation or code, but these will not cover all possibilities (Van Gorp & Van de Poel, 2008). On the other side, the vision is informed by objectives and associated measures or indicators of impact. Connecting these models and the vision are matters of epistemology—knowledge about how the world works and how people can bring about change. The assumption underlying this three-part linkage is that wanting to do what is right or good is not sufficient to actually do what is right or good. Also, acting without a sense of what is right or good can result in unintended harm. Before looking at examples, the next section of this paper discusses relevant aspects of the theory of metaphor.

A final note on this section is that while the strategy for managing change might be the designer’s abductive conjecture used to start the design process (such as an instruction to students at the start of the semester, “We will begin with the The Green New Deal”), the emphasis of this paper is examining how the strategy (the metaphor) is used as part of the larger design development process. The examples that will be given follow from the arguments for change as articulated at the end of the design explorations.

3 METAPHOR

3.1 Conceptualizing Metaphor

Metaphor is so widespread and so important to thought that it is studied across many disciplines including linguistics, literature, cognitive philosophy, psychology, and artificial intelligence. It has also received considerable attention in planning, design, and art (Chupchik, 2003; Gerber & Patterson, 2013; Hausman, 1989; Unwin, 2019). At a most basic level, metaphor is a kind of figurative language in which one term, the source, is applied to understanding of a second term, the target. Source and target are usually understood in the context of different fields or aspects of life, so the comparison is across domains of
knowledge (Lakoff, 1993). Features of what is explicitly known about the source are conveyed for an implicit understanding of the target (Lakoff & Johnson, 2003). While new understanding or insight may be the intent, it is not guaranteed. Metaphors are context dependent, so without some basic understanding of the source term, new understanding of the target will not occur (Martinich, 2001). Further, metaphors are linguistically slippery, since source and target are not identical objects or concepts. The inherent linguistic falsehood of metaphors has prompted warnings against their use (Horsburgh, 1958). Such cautions have also been made within the design fields (Scott, 1914). Nevertheless, it has been demonstrated that strong metaphors aid efforts to grapple with topics that are currently not understood by a person or group (Secchi, 2013). For this paper, metaphors are viewed as a form of conceptual models (Barbour, 1974). In application, they are directed, but relatively open-ended (that is, not unbounded) heuristics for discovery and learning.

Before discussing the kinds of metaphor that can enable insight, two notes should be made. First, metaphor is not the only kind of figurative language or literary trope, but distinctions with allegory, metonymy, synecdoche, and irony are not needed for all discussions (Burke 1941). In the context of this paper, all forms of figurative language can be considered as functionally equivalent with metaphor. Second, it is recognized that while some thinking is done with verbal language, thinking can also be done without it. In this light, it is accepted that metaphors are not necessary for thought, but they can aid it (Katz, 1998). Not all uses or applications of metaphor are the same and distinctions can be made in several ways. Two approaches are highlighted to expand on their use for framing discussions that can advance arguments for design. The first approach distinguishes uses in terms of explanatory power. At the lowest level, a metaphor might denote a phenomena or practice with traces of linguistic flourish. An example is “the firm’s body of work.” In some of these instances, the metaphoric expression has become a literal expression over time. An example is “to curry favor” (Muir, 1985). These utterances occur frequently in everyday conversation, but do not extend or expand considerations about the world. A second kind of metaphor is comparative and is used draw out similar features between the source and the target. In these instances, the deliberate use of the word or phrase exploits some form of situational novelty to invite comparison between the source and the target. Examples are “boiling mad” and “cold as ice.” Finally, a third kind of metaphor draws attention to systematic similarity between source and target. That is, more than what might be considered surface-level commonalities, there are relational similarities among features (Black, 1962; Black, 1977). Examples are “an atom is like a solar system” (with electrons orbiting nuclei like planets orbiting a star). Extensions across domains can project physical, perceptual, or spatial properties to abstract concepts and render them more understandable (Bergen, 2012). Since such comparisons happen across otherwise distinguishable entities, they can provide a basis for learning (Steen, 2008). It has been offered those abilities to make analogical comparisons of this sort are a leading reason that humans are “so smart” relative to other animals (Gentner, 2003). In this approach to categorizing metaphors, the first two types are used in professional-level discussions, just as they are in conversations about other topics; however, since they do not explicitly challenge understanding, they do not contribute to problem framing or resolution. The third kind of use, which emphasizes systemic relationships, could be the basis for design development.

A second approach to categorize the use of metaphor distinguishes the level of belief the speaker has in the strength of the relationship between source and target (De Coster, 1978). Minimally but still significantly, discursive metaphors provide a basis for rhetoric and means to convince. Methodological metaphors offer rhetorical value, but also serve as heuristics to advance a line of inquiry. That is, these metaphors do more than set a tone for discussion, they influence the structure and understanding of sub-topics. Finally, theoretical metaphors express an a priori position on first principles. Methodological and theoretical metaphors differ by degree. While a methodological metaphor might be applied to approach one or a few problems, a theoretical metaphor is applied to all problems. Minimally, metaphors for planning and design are discursive. While this use might cynically be reduced to marketing and sales ploys, it remains the case that competing designs are alternative “courses of action aimed at changing existing situations into preferred ones” (Simon, 1996, p. 111). Strong metaphors for design development are also methodological because they offer a basis to extend and test thinking about means and ends. It is also possible that metaphors for design can be taken as theoretical. Kevin Lynch’s observed prevalent theories to shape cities provide examples: city as model of the cosmos, city as machine, and city as living organism.
The use of theoretical metaphors, though, raises a question about overreach. If the metaphor frames the problem and possible resolutions, it necessarily limits or even blinds its users in terms of goals and options for action. Christopher Alexander’s essay, “A City is not a Tree,” (that is, a city is not a tree diagram like the ones used in computational modeling algorithms) provides a lesson that methodological metaphors and related techniques for analysis present only limited perspectives and that metaphors are not ends in themselves (1965).

### 3.2 Metaphor within an Argument for Design

The framework for design thinking presented in this paper employs metaphor as a conveying an overall strategy to direct and manage change. By doing so, it follows from ideas that have been, perhaps, best articulated by Donald Schön on resolving problems. Schön is very much aware that a critical challenge in addressing social challenges is problem framing. To him, this framing is done through metaphors that underlie the stories told about the problem. He emphasizes that metaphor reveals a person’s or group’s perspective on the world—“how we think about things, make sense of reality, and set the problems we later try to solve” (Schön, 1993, p. 137). He refers to these perspectives as generative metaphors. An example is a mayor saying that, “crime is a cancer in the city.” Alternative “crime is …” metaphors could include: a disease, a plague, a beast, or a war. The generative metaphor not only calls attention to aspects of the present moment, it sets a direction for possible action (Schön & Rein, 1994). Notably, because generative metaphors can be so strongly connected to a person’s or group’s attitude about a problem, competing metaphors may contribute to an inability to reach a consensus about how to address it. For example, what is a negatively "socially uncoordinated" condition to some might positively allow for “personal autonomy” to others. The impact of alternative or competing metaphors (whether referred to as generative or not) to provide a cognitive stimulus for framing deliberations and plans for action has been examined in topic areas including climate change (Plusberg, Matlock, & Thibodeau, 2017), economics (Arrese & Vara-Miguel, 2016), health (Semino, Demjen, & Demmen, 2018), law (Glenn, 2006), and public safety (Thibodeau & Boroditsky, 2011). In situations where current metaphoric frames are in opposition, employing a new metaphor can provide a means for reconciliation; however, doing so may be easier said than done. More than a semantic re-mapping of conventional terms onto new expressions, a novel generative metaphor demands not just new vocabulary, but a restructuring or reconfiguration of the problem (Schön, 1993).

One aspect of the metaphors that warrants additional scrutiny for design is that they can provide a conceptual tool for how multiple aspects of a problem are combined. That is, metaphors provide a “calculus for and.” The need for such a model can be understood by considering some simple combinations. One grain of sand and another grain of sand yields two grains of sand. Each grain maintains its own physical integrity and the pair can be easily disaggregated. By comparison, one drop of water and another drop of water yields one drop of water—it is just a bigger drop. One grain of salt and one drop of water yields one drop of saltwater. The salt can be removed, but only at the expense of loss of water through evaporation. “Hybridity” has become an often-mentioned term to describe landscapes and landscape architectural practices (Amoroso, 2016; Bowring & Swaffield, 2004; Way, 2016). Assuming the word is not just as a decorative metaphor, what are the bases for the combinations? Also, what are the consequences of the combinations? In reference to the expression, some hybrid plants produce seeds, but others do not.

### 3.3 Metaphor and Ethics in Design

Efforts to improve a current situation require a notion of goodness. In this paper, goodness is understood as based on professional ethics and personal morals. It is uncontroversial to note that opinions about what is good vary by society and change over time (Malik, 2014). Beginning in the 1960s and 1970s, as concerns about pollution and ecological degradation became widely evident, the environment became a (more) formal referent as a topic within the study of ethics (Kawall, 2017). Attitudes towards these concerns continue to evolve and untangling relationships between ethics and morals is often difficult. For example, Oles has called landscape architecture an “uneasy discipline,” because of competing expectations between conventional, market-driven professional practice and more democratic co-design through public-participation (2015). Nevertheless, part of professional education is helping students understand their own beliefs and positions relative to changing areas of practice.
A comprehensive review of ethics as applied to design is beyond the scope of this paper, but two general concerns for design education and professional practice often pervade studio discussions. First are considerations regarding goodness for whom or for what. Perspectives on the former considerations can range from egocentric ethics, which are based on notions of individual self-interest, to homocentric or anthropocentric ethics, which are based on utilitarian interests of a society, to ecocentric, which are based on the intrinsic value of all living and non-living things. Positions might be combined, such as Merchant’s “partnership ethics,” which bring together ecocentric and social justice positions to advance human and non-human interests (1982). Second are considerations regarding goodness on what logical grounds. Perspectives range from dutiful ethics, which emphasize obligation to culturally significant places, to contract ethics, which emphasize responsibilities to legal and regulatory constraints, to pragmatic or utilitarian ethics, which emphasize the consequences of actions (Fisher, 2016). These perspectives, too, might be combined or operate within a hierarchy of preferences.

The premise that a metaphor can present ethical positions is demonstrated by everyday examples such as cleanliness being associated with morality and uncleanliness with immorality; up being associated with good or better and down with bad or worse. References to some terms, actions, or events in metaphoric constructions have been critiqued as culturally insensitive or politically exploitative (Fraser, 2018). Examples include imagery of the Holocaust or of physical disability. These points underscore that the successful use of metaphor can be dependent on the shared ethical and moral beliefs of the speaker and of the audience, not just shared content awareness.

The framework in this paper asks for an explicit statement on what elements or aspects of the world, relative to the project, are open to change. These aspects are called out as challenges-opportunities and provide the fundamental context for thinking about what is possible within the given project. The act of selecting these elements, which stems from the designer’s general awareness, is not inconsequential to ethical matters (Griffith, 2019). While each challenge-opportunity is like an independent variable, all are referenced or, at least referable, in the vision for managing change. It is in the progression of thought from the challenges-opportunities to the vision that questions of ethics or normative practices are highlighted, since the vision begins to establish how the elements are to be treated vis-à-vis how ways of combining or prioritizing may generally influence behaviors and thoughts of the design’s users (Verbeek, 2005).

### 3.4 Metaphor and Epistemology in Design

In addition to a motive to do good, efforts to improve a current situation also require an understanding of agency and of the potential consequences of action. The underlying epistemological question of design is how can the designer know—or, in a more limited way, can know within reason—if the design will serve its purpose (Galle, 2011)? There is some merit in thinking of conceptual scientific models as akin to literary metaphors (Black, 1962; Ricoeur, 1975) and, indeed, the premise that metaphors can support epistemological inquiry has a long history in science (Human, 2021). Just as metaphors in literature are based on semantic falsehoods but can still contribute insight, in science, “all models are wrong, but some are useful” (Box, 1979, p. 202). However, because practices of environmental design can have profound consequences on health, safety, and welfare, the kinds or degrees of falseness or wrongness between source and target can matter. Simply put, the metaphor should accommodate relevant and available facts as well as reasonable assumptions. With regards to design education, a constructivist approach might be questioned as it has been by some in the science education for allowing untruthful ideas to proliferate (for example, Ogborn, 1997). In design, though, the metaphor is only a heuristic to advance a satisfactory resolution of the problem. There is no claim of absolute truth—only of usefulness to transform an unsatisfactory situation into a preferred one. Further, today’s students will likely encounter professional challenges in their futures that present-day faculty have never confronted (or perhaps ever imagined). The rigorous use of metaphor—the mapping structural features and the projection of inferences—can improve their capacity to learn how to learn (Gentner & Markman, 1997; Wolff & Gentner, 2011).

Objectives of a design project are typically assigned by the client, but in most instances, designers must interpret what is intended. Also, some objectives may be at odds with others, so priorities must be established. Within the framework presented in this paper, reasoning about objectives is based on explicit relationships between cause and effect. Also, in line with Schön, the primary metaphor of the vision is used
to provide a frame for understanding each of the individual objectives. That is, any objective is imagined in
terms of the overarching strategy to manage change. In part, the reasons to do are constitutive and the
process provides a test of conceptual consistency. If the metaphor is truly generative, then it should provide
a way to structure objectives within the ill-defined problem. But, if thinking about an objective—thinking of
implementable ways to produce tangible improvements to the current situation—is difficult in relation to the
vision, then the vision (metaphor) is insufficient or inappropriate for the task. Casting the objectives in terms
of the larger metaphor is also done for reasons of rhetoric and persuasion. Referring to Section 3.1,
methodological metaphors, which call attention to systemic similarities, are also discursive in that they are
persuasive. It has been shown that extensions of metaphors contribute to a sense of the metaphor’s level
of sophistication and appropriateness. These effects reinforce an audience’s understanding. The use of
extended metaphors can also add to an audience’s sense of speaker’s competence (Oswald & Rihs, 2014).

The challenges•opportunities are also carried through the metaphor by being included in the cause-
and-effect relationships, which are typically represented as systems models and shared through diagrams.
Other topic-specific issues will also need to be included in these models. Ideally, these systems would be
quantified and spatialized, such that adding or subtracting a measurable amount of some entity here will
produce a measurable change there. Precise thresholds for success, which include how much of a “good”
is needed or how much of a “bad” must be eliminated, are valuable for decision making; however, the
complexity of coupled biophysical-social systems (or trebled biophysical-social-cyber systems) make it
difficult to provide accurate parameterization. General concerns related to uncertainty might allow for only
qualifiable change expressed as “greater/more” and “fewer/less.”

4 APPLICATION OF METAPHOR TO CONNECT ETHICS AND EPISTEMOLOGY

4.1 Introduction to Student Projects

Examples of the use of metaphor as a strategy for change come from a series of master’s level,
third-semester landscape architecture studios. The site for all of the examples is Waller Creek, which runs
along the eastern edge of downtown Austin, Texas. The creek empties into Lady Bird Lake, which is, itself,
a dammed section of the Colorado River. Some of the studios considered designs for the lowest 1.25 mile
stretch of the creek. In 1999, the City of Austin began studying the possibility of constructing a flood control
tunnel under this portion to reduce threats to life and property and to encourage urban development on
twenty-eight acres that would be removed from the delimited 100-year floodplain (Reis & Espey, 2008).
Construction on the tunnel began in 2011 and was completed in 2014. The infrastructure circulates a
managed flow along the lower mile of the creek. The controlled flow condition allows for stream restoration
and the development of new parkland. These efforts are being undertaken by public-private partnership
between the city and the Waterloo Greenway Conservancy (formerly the Waller Creek Conservancy). In
2011, and in anticipation of the tunnel’s completion, the Conservancy sponsored an international
competition to design a series of park spaces along the creek. After a winner was selected in 2012, the
studio turned its attention to the roughly 1.5 mile stretch of Waller Creek that runs through The University
of Texas at Austin campus. While the creek was once the remote eastern boundary of the original university
district, it is geographically now the center spine. It and an adjacent street form a busy thoroughfare for
faculty, staff, and students. The creek is also a focal point of the Dell Medical School part of the campus.

In both the downtown and campus versions of the studio, teams were comprised of three or four
students. Students self-selected their teams based preliminary visits and exercises that gave a rough sense
of similar attitudes about the project. While the site boundaries were pinned to the creek along its north-
south orientation, east-west boundaries were determined by each team. Three general programmatic
objectives were assigned: engage the creek, enhance the environment, and expand access. Teams had to
provide precise definitions for each objective, measures of performance, and the relationships to one
another (such as prioritization or inter-operability of the objectives). Teams were also asked to identify one
challenge•opportunity related to site conditions and one challenge•opportunity related to site use.

As mentioned above, the examples reflect the final articulation of arguments for change, so what
will be discussed is how the metaphor enables matters of ethics and of epistemology to be aligned. The
initial abductive conjectures that led to the line of reasoning for the argument varied by team and are not
discussed. The members of each team had what can be considered concordant, but not identical, images of the world. Positions and priorities that served as platforms for team formation often engaged professionally challenging issues related to how nature in an urban environment is conceptualized (or how biophysical functions and social purposes are reconciled). Nevertheless, even with similar core beliefs, differences of opinion occurred within teams and commonly acceptable positions had to be negotiated. The ability to refer to the framework and consider points in relation to the overall logic of the argument, rather than an opinion in isolation, aided the design development process. Sometimes it resulted in quick evaluation of competing stances. Other times it prompted reconsideration of critical assumptions. To the degree students were aware of the role of the framework in their deliberations, both outcomes contributed to constructivist pedagogy. It can be reported that no student group’s metaphor remained unchanged over a semester. Some metaphors were changed only slightly, but all evolved as the understanding of the problem and possible resolutions increased.

4.2 Student Projects

A selection of student projects illustrates the kinds of connections described above. As might be expected, not all metaphors were equally easy to extend to the challenges•opportunities and the objectives. 

*Liquid Infrastructure* (Harding et al., 2011) took its prompt from the creek and the (then) anticipated tunnel. As an assembly of concrete, water, and vegetation, it could be considered gray-blue-green infrastructure. The metaphor was also informed by discussions on the work of the cultural theorist Zygmunt Bauman, who has used the concept of *liquid* to describe fluidity of life in the early twenty-first century (Bauman, 2000). In this sense, the metaphor engaged something of the spirit of the place and the spirit of the times. The site challenge•opportunity was the creek’s floodplain, and this idea was extended to other kinds of plains that might be exposed to different forms of inundation. The program challenge•opportunity was meander. Here, the team exploited a word that can be both a verb and a noun. As a noun, it is located within a floodplain, so it allowed for considerable interplay of spatial and movement ideas. As a verb, it suggested a kind of informal recreation or willingness to explore. The reimagining of the objectives was treated very abstractly. Engage the creek was redescribed as *comfort*, enhance the environment as *service*, and expand access as *open*. Here, familiarity with Bauman and his notion of liquid allowed the phrasings to be not only apt, but also evocative and potentially compelling. Within the context of this literature, the individual systems models of three objectives were "liquid" in that they shared many of the same elements. The use of different aspects or qualities the same elements supported a consideration that any one thing was useful or significant in several ways. That is, for this group (literally) making the landscape and making sense of the landscape required multiuse and multivalent entities. Without such bibliographic knowledge, though, the objectives as reimagined can seem unrelated to the primary vision and, therefore, they may not significantly advance the argument for change. This observation points back to the earlier statement that the effectiveness of metaphors is context dependent.

*Acequia: Channels for Learning* (Duggan et al., 2013) referred to the drainage and irrigation structures built during Spanish colonization of semiarid regions within Texas (Meyer, 1983). The intentional use of the word was not to impose a new system of colonialism on the landscape, but an effort to help carry parts of the past into the future through some degree of transformation. That is, the aim was not to extend a tradition of hierarchy and exclusion, but to open up a new form of common practices (Hobsbawn, 1983). The site challenge•opportunity was basins, broadly considered to be any area that might collect some kind of flow and included basins for water, people, plant nutrients, and vehicles. The program challenge•opportunity was flows. As with the first example of student work, the two challenges•opportunities had close conceptual affinity. Engage the creek was reimagined as *create rooms*, enhance the environment as *connect habitat*, and expand access as *conduct flows*. While elements of the two challenges•opportunities contributed to defining the cause-and-effect relationships within the systems models, the phrasing was less influenced by the vision. Connecting habitat is something done in some landscape architecture projects, but while acequias can connect habitat, that was not the primary reason for their construction. Similarly, making outdoor rooms is an important professional practice skill, but acequias do not have rooms. As a result, while the systems analysis was very sound, some of the potential rhetorical value of the metaphor was not fully exploited.
String of Moments (Gilbertson et al., 2014) built on the common partii metaphor “string of pearls” for projects that involve the array of nodes along a line. The creek provided the string, and the pearls were recast as moments to evoke the combination of space, time, and experience—same place at different time yields a unique moment. The site challenge•opportunity was the moment itself. Some existing locations within the site were latent with “moment potential,” but the features of other locations needed to be changed to have that quality. The program challenge•opportunity was pulse, the insertion of energy that sparked the moment. Engage the creek was reimagined as pool (as in gather), enhance the environment as cycle, and expand access as pulse. The repetition of pulse as the program challenge•opportunity and the rephrasing of an objective, somewhat clouds the argument for change by conflating a fundamental feature or aspect of the environment open to change with an objective. Simply put, this dual use does not allow for an easy distinction between what can and what ought to be done. Clarifying requires not just a simple word substitution, but a much closer consideration of the ideas of temporality within the project.

Terracing Time (Lei et al., 2015) represents an example of an effort to employ a novel metaphor, since the phrase did not appear to have been used for any earlier environmental design projects. Further, while there are what might be related linguistic expressions that modify the continuity of time, such as cut time in music and time slicing as part of multi-user computer systems, terracing time does not appear to be strongly connected with any discipline. The advantage of such a term is that the designers do not need to worry about being compared to other projects that might share its use. The disadvantage is that they cannot rely on the audience possessing any awareness about design (landscape architecture) implications of the idea. The site challenge•opportunity was pool and the program challenge•opportunity was flow. The three objectives were defined to help explain the vision. Engage the creek was reimagined as sculpt for speeds, enhance the environment as slow the momentum, and expand access as split the currents. While “terracing time” is novel, the team’s focus on time can be understood as an engagement with a prominent—perhaps the preeminent—theme of landscape architecture. Garden historian David Coffin noted (here by paraphrase) that the Italians of the sixteenth century ignored the passage of time, mixing old with new (for example, the inclusion of ancient statuary and new building elements within Villa D’Este); the French of the seventeenth century tried to arrest the passage of time and make the perfect moment last for eternity (for example, Versailles); and the English of the eighteenth century reveled in the passage of time, planting dead trees and building fake ruins (for example, the Leasowes) (Shearer 2013). Perhaps extending Coffin, terracing time could be taken as emblematic of the late twentieth century Western notion of “making time.” Also, the metaphor and its accompanying re-worded objectives are in line with J.B. Jackson’s notion that landscape “is a space deliberately created to speed up or slow down the process of nature” (Jackson, 1984, p. 8). The idea of terracing can also be understood in relation to precedents of agricultural practices that allow crops to be grown on steep hillsides. From this perspective, there is benefit in finding a way to make productive use of otherwise unusable land. Unlike the other examples of student projects, terracing time offers a vision of process or of practice (that is, terracing) rather than a vision of product (that is, infrastructure, acequias, or strings). As applied in the studio project, the metaphor certainly provoked thought, but did it provide a strategy to manage change will result in a better landscape? Answers to this question hinged on the acceptance of an image of the world (including an image of design practice) in which creating new open-ended future opportunities and choices, rather than new specifically defined conditions, are sufficient criteria for “better.” Part of an assessment might also ask about opportunity costs: if the undefined opportunities created are, somehow, sufficiently beneficial given that resources were used to make the terraces might be better used on a more clearly defined or tangible outcome.

5 DISCUSSION AND CONCLUSION

The examples shared in this paper were selected because they are representative of the issues that have arisen when thinking explicitly about metaphor for landscape architectural design. The underlying challenges are not just the stuff of classroom exercises, since metaphors are also used in professional practice. For example, the four finalists in the international competition to design the lower portion of Waller Creek also employed metaphors. One team presented, Waller Creek: The Oasis (Turenscape & Lake|Flato, 2012). Another urged the city to Keep Waller Wild (Smith, TenEyck, & Rogers Marvel, 2012). The
combination of *Regeneration and Curation* provided a novel construction (CMG & Public Architecture, 2012). The winning entry was *Waller Creek: A Chain of Parks* (MVVA & Phifer Architects, 2012). These proposals could have been a basis to compare metaphors.

From the perspective of an educator working with the students to think about design as an argument for change, it can be observed that the concept of metaphor is well known both through formal education and through experience. Using a metaphor with rigor has advantages, but exploring the ambiguity is establishes and testing the limits of its extension can be difficult. It can even sometimes be frustrating for students. Referring to the premise that a metaphor is a conceptional tool, if all goes well in the design development process, the metaphor will elucidate the finished product. If all does not go well, it can be tempting to say, “It’s just a metaphor. Let’s get on with the real work.” But an important part of design is establishing a frame that gives order to ill-defined problems. Working with and through generative metaphors is very much a part of the “real work.”

By way of a concluding comment, a character in a Sir Walter Scott novel quipped, “Metaphors are no arguments” (Scott, 1863, p. 160). The point is well observed since metaphors are based on semantic falsehoods. Nevertheless, a metaphor is meaningful if it can be used to inform a decision and, more narrowly, if “its meaning is analyzable in terms of the difference it makes to the decision taken” (Kaplan, 1964, p. 43). Across numerous aspects of society, metaphors establish frames for description, discussion, debate, and decision-making. The selection of an effective metaphor to help argue for change is, in part, rhetorical, since its use is intended to help persuade. It must also be constitutive and help organize an argument for direct actions that can lead to a better future. This aspect engages ethical questions about the kinds of places designers and members of a society want to create (Throgmorton, 1993). It also engages questions of epistemology and how designers can test the possible success of proposals.

It was noted that design frameworks serve to manage ambiguity for ill-defined problems. The use of metaphor in the design framework described here makes productive use of the ambiguity that exists between knowing why and knowing how, between ought to do and can do. More strongly, it follows a line of thinking in which, “the relation between elements themselves ambiguous to some degree generates a new and larger range of significance. And the relation serves at the same time to as a mechanism of integration, indicating the direction along which unification of the multiple meanings is to be achieved” (Kris, 1952, p. 258). By making connections between issues of ethics and of epistemology, metaphors in this framework aim to sit between strict positivistic, rational-actor decision making systems in which all disagreements can be settled by facts and relativistic turmoil in which no preference for an outcome can be made (Rein & Schön, 1993). This kind of thinking is needed to address the challenges of our age in which greater scientific knowledge, environmental change, and accompanying social transformations can be anticipated.

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FORENSIC HYDROLOGY: THE GREAT BLACK SWAMP

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1 ABSTRACT

Purpose: This paper outlines the pedagogical methodology and outcomes of Forensic Hydrology, a landscape architecture seminar currently in its second iteration that explores new approaches to studying hidden hydrologic systems.

Study Area: The Great Black Swamp, a 17,600-acre swamped forest located in northwest Ohio and eastern Indiana was cleared of vegetation and drained, replaced with tile drained agricultural fields. The invention of the Buckeye Traction Ditcher improved the speed of tile drain installation. Soon tile drains covered the footprint of the swamp, significantly altering the existing swamp land. This has affected the water quality and ecology of the region and Lake Erie. Tile drains carry nitrogen and phosphorus from fields to ditches that feed into the Maumee River, causing algal blooms in Lake Erie. Remnants of the swamp are evident in conservation lands, subtle topographic shifts, and seasonal flooding.

Methods: The seminar investigates the swamp via four focus areas: society, ecology, infrastructure, and economy. Student teams collect research weekly to share with the group and fuel discussion on new discoveries and synergies between the focus areas. The students use historic documents coupled with GIS data and site visits. The shared resources and research are leveraged for individual projects centered on narrative ‘forensic’ visualizations of the swamp and its history.

Students study visualizations like the Sanitary and Topographical Map of the City and Island of New York by Egbert Viele. The Fisk map of The Alluvial Valley of the Lower Mississippi, as well as, the report produced for the U.S. Army Corps of Engineers called the Geologic Investigation of the Alluvial Valley of the Lower Mississippi River. Anatomical drawings, x-rays, crime scene diagrams, and contemporary landscape architecture drawings provide additional framework for the forensic hydrologic visualizations.

Importance: Between 1780s to mid-1900’s the state of Ohio lost more than 95% of its wetlands. Public perception of swamp and wetlands has changed, but the Great Black Swamp has retained a negative narrative. The Great Lakes hold 21% of the world’s freshwater supply. With global water demand projected to increase by 55% between 2000-2050, how we manage our water, especially agricultural land will become critical.

New forensic hydrology visualizations of past swamp and wetland ecologies that helped manage flooding and clean water can help the public understand complex hidden hydrologic conditions. They can serve as a call to action or can inspire new hybridized landscape typologies.

1.1 Keywords

Infrastructure, Hydrology, Narrative, Visualization, Forensic

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2 FORENSIC HYDROLOGY

Forensic hydrology is the study of the movement of water to determine the cause of a given incident or the potential outcome of a future event. It is a potential tool for landscape architects to address the complexities of designing with water. As landscape architects, we are skilled at redirecting, pooling, and draining water. Water may be a driving force in a design, dictating program, revealing opportunities and constraints. With cities densifying, agriculture and industrial practices changing, and a more erratic climate, our relationship with water is both critical and challenging. Water remains a finite resource and as designers engage with a growing number of projects centered on hydrology, we must ask ourselves, what do we really know about water? Perhaps more importantly, what do we really know about the system we have created, neither natural - as we often depict it - or controlled as we imagine it to be? Without the forensic knowledge of our hydrologic history, how can we suggest the best strategies for design?

Figure 1. Great Black Swamp (2022). Drawing by Daniel Ibba.

Forensic is a term not often associated with design. Commonly aligned with the sciences, it has in recent years expanded to other disciplines. In the late 1970s, geoscience sub disciplines such as forensic geology, forensic geochemistry, and environmental forensics emerged (Hurst, 2007). Within the latter the specialization of forensic hydrology developed. These disciplines often 'identify potential sources of contamination' by testing for the presence of various trace chemicals in legal matters (Hurst, 2007). Although these practices are valuable, they have a limited scope and often concentrate on a discrete site and issue. Additionally, the outputs are conveyed in formats that are legible to a small audience within the geosciences and are not easily understood beyond this field. More recently, forensic hydrology expanded to engineering, evolving from the broader practice forensic engineering.

With the expansion of the term forensic into new disciplines, perhaps we can examine its potential application to landscape architecture. To apply forensic hydrology to landscape architecture a core understanding of the natural hydrologic system, how it functioned, and the reasons for its alteration are paramount. Additionally, examining the cultural shifts in engineering water at various scales and the rapid
pace at which we developed a new hydrologic language. Visual tools can be developed to clearly communicate these histories and current challenges facing water.

3 SEMINAR STRUCTURE

Students studied the ecological, economic, cultural, and infrastructure influences on the Great Black Swamp, in northwest Ohio and eastern Indiana. They visited the former swamp, met with Black Swamp Conservancy, and assembled their research and field findings into a seminar book. This helped the students develop a clear narrative of the swamp and compile unified base maps based on historic mapping and GIS. The maps became a resource for many students’ final projects. With the baseline information aggregated, the students were well versed in the variety and complexity of narratives found within the landscape of the Great Black Swamp. With this foundation, students were tasked with identifying a narrative for the swamp. With a storied past, present, and future not all information could be included. Students selected a lens for their narrative. To facilitate the exploration of narrative development and visualizations, we looked at imagery where hidden systems were revealed. This included work by landscape architects and allied professionals, but also looked to historic medical drawings. Students expanded this examination when they developed proposals for their final projects. They presented their proposed final projects via a pecha kucha pitch where they outline the project, share precedent images, discuss materiality, and scale. Class discussions on project proposals further the design development of the work. Students then proceeded to execute their animations, models, and drawings.

The seminar employed the flipped classroom approach. This is defined by students encountering information outside of the classroom rather than experience a traditional lecture (Bok Center). Although, the course includes a lecture, the primary structure of the class student led discussions and knowledge sharing. The course is also flexible, with two phases, data collection and individual (or small group) projects.

The seminar is for advanced students who have had two prior courses dedicated to representation and completed a series of studio courses. As such, the topic of landscape representation has been previously introduced and is not the sole focus of the seminar. Unlike in studio courses, this seminar dedicates roughly half a semester to studying the site.

3.1 Data Collection

Students work on the data collection in four groups. Each group studies one focus area: ecology, economy, culture, or infrastructure. The focus areas have been adapted from the first iteration of the seminar. They could be adapted in further seminars to reflect the attributes of the study area. During the first iteration of the seminar, taught remotely in autumn 2020, Forensic Hydrology: Iuka Run, the focus areas were history, digital current conditions, and physical site documentation. The changes to the focus areas were driven by two factors. One being study area size, Iuka Run is significantly smaller. Iuka Run is a former stream that ran through a few neighborhoods and Ohio State University’s campus in Columbus, Ohio. Its small footprint provided opportunities for detailed site documentation including tree species identification, mapping of manhole covers and storm drains, and soil collection. This was not viable for the Great Black Swamp study area. The second change was a response to observed behavior in studio and seminar courses. This behavior included students who enjoyed historical research repeatedly working on that area of site analysis and not on current conditions (such as GIS or basemap collecting). Students who were less interested in participating in historical research focused on current conditions. Additionally, this made it more difficult for students to make connections between current and historic conditions. The new focus areas require that every group include history and use archives and other online resources and every group understand current conditions. This shift has also been made in studio courses.

The students find drawings, writing, photographs, public records, videos, among others for their focus area. Weekly each team reports their findings and share their evidence, similar to detectives meeting to discuss a case. Students present the findings and the class discusses the strengths and weakness of the evidence. For example, what information is missing, what may make a map clearer, is a technique being used particularly compelling? This also allows students to share resources they may have discovered and
brainstorm solutions for missing information as a group. During the first iteration of the course students used Miro to make a digital mind map of the study area. This iteration did not use Miro, instead opting for a class folder system on a shared drive. This limited the ability of students to examine all the evidence at the same time. It did not impact the quality of the work but impacted the speed in which students were able to make connections. To conclude the data collection portion of the course students worked as a class to compile a seminar book. This acted as a baseline resource for the students during the remaining semester.

### 3.2 Proposed Projects

Once students have concluded the data collection, they are asked to pitch a final project. Students were informed earlier in the semester to think about what a final project may look like as they learned more about the study area. Students were able to work in small groups or individually. This was an option students were afforded for a few reasons. Students work differently, some thrive working independently and others with collaborators. Some students wanted to pursue more complex projects and learn new programs together. The twelve student seminars included four group projects and three independent projects.

A lecture prompts students to look beyond landscape architecture representation and discover methods used by other disciplines to convey hidden elements or to tell a story of place. Work included, but was not limited to visualizations by Scape, Dlandstudio, Harold Fisk, Egbert Viele, Kate Asher, the Center for Urban Pedagogy, Ian McHarg, Anuradha Mathur, Charles Bell, and Galen. They are asked how these may be adapted to fit the study area and their chosen narrative of place. Students are asked to limit their narrative, as it would not be possible during the course of a semester to visualize all they have learned about the site via the data collection phase. Some examples include limiting the narrative to infrastructure, ecology, or a specific issue (such as algal blooms) in the study area.

Students are asked to deliver an abbreviated *petcha kutcha* including precedent images, timeline for completion, and sketches or other references for their project. This may include a list of computer programs, tool, and/or materials they may be using to execute their vision. By allowing the students to select their project, students can focus on building a new skill or one they can select to work with a technique they enjoy. Many of them have taken this as an opportunity to learn animation or experiment with programs or techniques they have briefly used in other courses. During the first iteration of the course, taught remotely, many students opted for using hand building and drawing rather than digital techniques. The students expressed that they chose working by hand due to the long periods of time they were on the computer working remotely and as stress relief. This year the course was taught in person, the students are still given the flexibility to choose how they would like to work. The presentations conclude with a lively discussion from the group about the proposed projects. At this time we also reflect on the ambition of the project within the proposed timeline.

The students receive feedback and begin working on their project. Additionally, we discuss experimentation. That there is not one correct way or one answer, that they are trying something new. The process and their ability to adapt to any roadblocks is what will make their project a success. The final result may not be what they had originally intended and that is ok. There often aren’t many opportunities in education, or practice, to experiment and innovate with it being ok if it doesn’t work. A seminar can be an ideal place for this type of design thinking.

Students continue to work on their project with weekly progress meetings during class. Seminar courses meet for three hours once a week. This allows them to have dedicated time outside of studio and other obligations to focus on their project. We conclude the semester with each student or group sharing their work and having a discussion about the different approaches.

### 4 THE GREAT BLACK SWAMP

A brief history of the swamp will provide additional context for the students work. A dense swamp forest extended across a million acres in northwest Ohio and eastern Indiana (Levy, 2017). The area was once covered with 2 miles of glacial ice from the Wisconsin Glacier (Chang 2020). When the glacier receded, remnant geology allowed the swamp to form straddling the Maumee River. A basin of clay soil
topped with fertile black loam allowed dense beech-swamp, ash, linden, elm, hickory, cottonwood, and maple trees to emerge (Kaatz, 1955). The western portion of the swamp was filled with 3-8 ft tall grasses (Kaatz, 1955). The absence of trees resulted from limestone deposits in areas a foot beneath the surface (Lopez, 1982). Sandbars found in the swamp provided for oak openings within the swamp landscape (Lopez, 1982). The swamp landscape was complex, home to plant and animal species and void of human intervention.

Indigenous people set up villages on high land at the edge of the swamp and would occasionally use the swamp to hunt (Lopez, 1982/ Mollenkopf, 2000). Once colonizers reached the swamps edges it proved an obstacle for westward expansion. The surface of the swamp was covered with water throughout the year. The swamp was teeming with mosquitos, water moccasins, and wolves (Lopez, 1982). The swamp was not held in high regard, remarks such as “My great terror, the Black Swamp, is passed” were frequent and well documented (Mollenkopf, 1999). The swamp remained undisturbed as land around the swamp was fought over and westward expansion continued.

4 THE SWAMP FIGHTS BACK

Eventually, the obstruction of the swamp by colonizers moving north to Michigan demanded action. Tired of circling around the swamp, construction began on a road. However, the Treaty of Granville sparked a series of subsequent treaties that dispossessed indigenous people living near the swamp of much of their land and had given them the swamp in return (Kaatz, 1955). In order to construct the road, they needed to acquire the land back (Lopez, 1982). In 1808, road construction began of a 120 foot-wide passage (Lopez, 1982). Trees were felled along the roads route and used to make the roadbed, tree stumps were stacked along the roads edge (Lopez, 1982). Logs were placed in the center of the road and burned (Lopez, 1982). Mud from the center of the road was scooped out and shallow ditches were formed on each side (Lopez, 1982). Less than a year after the roads completion it was deemed unpassable and known to be the worst road on the continent (Lopez, 1982). Movement on the road was slow, sometimes less than a mile a day, resulting in the construction of 35 inns to facilitate the 34 mile journey (Lopez, 1982). Today the road is marked by U.S. 20. This was the first, but not the last attempt to generate a path through the swamp.

A second attempt at road construction looked to the western grassy portion of the swamp (Lopez, 1982). Hulls Trace, constructed as during the War of 1812, took a new approach. The road was first made using logs to form the roadbed, called a corduroy road (Adamich, 2021). However, the logs would sink into the swamp, be replaced and sink again. A new approach was developed to make a planked boardwalk road (Lopez, 1982). The ride was smooth, but the road was narrow, and two carriages could not pass each other (Lopez, 1982). One carriage would have to move into the mud to let the other pass (Lopez, 1982). The planks could easily displace with seasonal flooding or with fast moving carriages, the road was also subject to roting (Lopez, 1982). The road crossing the swamp was only a portion of a larger road, that marked the first federal highway constructed. Evidence of the road is visible today at Monroe’s River Raisin National Battlefield where logs are still visible (Adamich, 2021).

Rail was next to attempt to conquer the swamp. A route from Sandusky City to Maumee Bay was constructed with piles being driven as deep as possible (Lopez, 1982). Then track was laid on top of the piles. The piles swank into the swamp and the rail line was another victim of the swamp. Finally, the Wabash-Erie and Miami-Erie canals were built. The canal was only 4 feet deep, resulting in long periods of winter freeze where the canal would not be usable (Lopez, 1982). Additionally, the sides of the canal were earthen and subject to damage. This limited the speed of boats as they navigated the canal (Lopez, 1982). If damaged, the potion of the canal would necessitate being drained for repair. The earthen wall also made the canals structure subject to flooding and could wash away (Lopez, 1982). Twelve years after construction it was deemed uneconomical to operate. Determining a way through the swamp was not the only struggle colonizers faced and lost to the mighty swamp.
5 DE-SWAMP

The transformation from forested swamp to fields of corn and soybeans was arduous and built on the successes and struggles of road construction, colonial settlement within the swamp, and displacement of indigenous peoples. Farmers attempt to convert the land were initially realized by digging small furrows between narrow bands of crops (Kaatz, 1955). Water could be collected in the furrows and carried to a ditch. However, this piecemeal system was not sufficient with individual land owners developing their own drainage strategies (Kaatz, 1955). Additionally, landowners did not want to yield portions of their land for the collective good of moving water out of the area (Kaatz, 1955). This changed with the passage of a law in 1859 to implement a system of public ditches (Levy, 2017). However, the taxes for the ditch construction could equate to the original cost of land. It also was becoming apparent that ditches alone could not compete with the swamp and an underdrainage system would be required (Kaatz, 1955).

Tile drain factories were not found in the area and were too expensive for most farmers (Kaatz, 1955). Farmers experimented with techniques including laying stones or saplings in a below grade trench and constructing V shaped drains with wooden boards (Kaatz, 1955). These continued to not meet the needs of the farmers. The discovery of clay below the swamp led to the construction of local tile factories (Kaatz, 1955). The industry grew fast, in 1870 there were 5 factories, just 10 years later there were more than fifty (Kaatz, 1955, Levy, 2017).

With an inflow of industry and swamp land now viable for agriculture, the trees of the swamp were felled (Levy, 2017). Used to construct houses, furniture, and Ohio’s ever-expanding rail network (Levy, 2017). By 1920, evidence of the swap had been erased and replaced with agriculture, rail lines, and a larger population (Levy, 2017).

6 ARCHITECTURE BOOM, ALGAE BLOOM

The invention of the buckeye steam traction ditcher would provide a quicker and less labor-intensive method to install tile drains. Without tile drainage network to keep the swamp at bay, agriculture had not been viable (Chang 2020). The network, similar to city storm drains, carries water out of the field, into a ditch, and finally to a river or stream within the Maumee River Basin into Lake Erie. This alters the speed of water entering the lake (Chang 2020). The water also carries nutrients like nitrogen and phosphorous and sediment. The concentration of nutrients and sediment in Lake Erie have resulted in algal blooms in the lake. Algal blooms have led to bans of swimming and other water-based recreation, impacted residential water supply, and harm aquatic ecosystem with repercussions on commercial fishing (Wines, 2014).

Evidence of the swamp exists in springtime after rain events when puddles form revealing land that hasn’t been tile drained. Masses of trees provide a relic of the density and character of the swamp. Efforts of the Black Swamp Conservancy (BSC) appear on 160 properties covering 21,010 acres marking efforts to bring back the swamp (Black Swamp Conservancy). Their projects remove tile drains and plant new swamp ecologies, but they also believe agriculture and nature can co-exist (Chang 2020). The erasure of the swamp took time, those driving through the area see a dramatically different landscape that one that existed one hundred years ago.

7 SEEING THE SWAMP

Once the students completed their data collection, they proposed visualization projects. A physical model including the Great Black Swamp study area and Lake Erie highlights the relationship between the tile drains that carry nitrogen and phosphorus from agriculture fields to the lake (Figure 2). Unregulated farms are shown in red and population density is shown in grayscale. Algal blooms in 2003, 2011, 2015, and 2020 are etched into acrylic by a laser cutter. Colored pencil was then used to deposit pigment into the laser cut depressions to show the blooms coverage within the lake. The base of the model includes a printed map generated in GIS and illustrator topped with a sheet of acrylic. The algal bloom layers can be
removed and viewed individually, or different years can be overlapped to reveal bloom hot spots. The hotspots are concentrated at the mouth of the Maumee River, as well as, in shallower water typically found on the coast and western Lake Erie. Surface water temperature for each year is also included in the maps key. Sculptural and work with layered acrylic by David Batchelor, Orna Feinstein, and Janell James served as inspiration for the model.

Figure 2. Model of Algal Blooms (2021). Model by Grace Vannatta.

Figure 3. Great Black Swamp Timeline (2021) Drawing by Zachary Osterday.
Video game City 2048 inspired the development of a timeline comprised of axonometric tiles (Figure 3). The game features square tiles that can be moved to build a city. Tiles with different densities of urbanity are combined to build your city. To apply this concept to the swamp tiles, depict a transformative
action to the swamp and reflect both surface and subsurface conditions. Tiles were arranged as a timeline and paired with text and dates further to explain the landscape transformation. Rhino and Illustrator were used to generate the tiles. This strategy allows each tile to provide a high level of detail without the spatial limitations of mapping or drawing to scale would provide.

Two animated projects employed different strategies to narrate the swamp. The first project focused on hydrologic adaptation in Woods County (Figure 4). The student looked at computational drawing by Carl Lostritto. They also looked at the work of Anuradha Mathur, Harold Fisk, Kate MacLean, Galilei Galileo, Lawrence Halprin, Gustave Narrier, Cara Walsh, Danika Cooper, Jeff Wall, Alexander Daxbök, C.R. Van Hise, and W.S. Bayley. The animation begins with the watersheds in the county based on topography, creeks, streams, and rivers gradually are rendered onto the surface. Next red lines are added, beginning in the southern area of the drawing, these show natural water flow and accumulation for each waterway. Dark gray is used next to highlight the locations of artificial tile drainage. The gray continues to darken until it is black to conclude the animation. The animation is on a 20 second loop and is projected next to a printed map showing all the layers together. Originally, the map was intended to be made via a hybrid of digital printing and drawing with the zund. Zund is a machine with an arm that can cut or draw digital files onto different surfaces. However, once the data was generated in GIS, it was clear that the use of the zund would be prohibitively time intensive and was not used in the final product.

The second project developed a sectional timeline through the lens of ecology. The animation pans over a static continuous section, which feature audio of birds, chopping down of trees, and construction activities among others (Figure 5). The animation begins with the Wisconsin Glacier receding and the formation of the swamp. The animation transitions into emerging ecologies within the swamp such as beech, hickory, and oak species, later elm and ash appear. Human interaction of the swamp begins with indigenous people and later colonial settlement and the decline of local timber wolf population. Following Ohio receiving statehood the animation focuses on the construction of Maumee Road Lands, still evident today as route 20. The construction of the road and subsequent inns along the road lead to reduced canopy density and wildlife habitat along the corridor. The further development of roads and canals continued to alter the swamp. The evolution of tile drain infrastructure and discovery of natural gas further diminishes the swamp ecology. Tile drains and ditches allow for intense agricultural production to develop. CAFOs (concentrated animal feeding operations) also emerge in the swamp during the animation. Today’s landscape is reflected by an expanse of corn and soybeans that has replaced a dense forested swamp. The timeline proposes a new future, an amended landscape where pairings of agriculture and wetland ecologies work in concert with each other. Later saplings are introduced, and a transmigrated swamp emerges with a rich ecological landscape. Students looked at time-lapse videos of plants growing, sectional drawings of forests over time, and a sectional animation by Scape’s Costal Adaption Plan for Louisiana.

8 CONCLUSION

The second iteration of this seminar maintained the use of a wide range of techniques and included stronger narratives. In part, this attributed to the second iteration of the course and the challenges of working remotely versus in person. In addition, the scale and complexity of the landscape increased from the Iuka Run site studied last year. However, working remotely with Miro provided a pin-up space that more closely represented a mind map of a detective. This allowed students to see connections between different research areas could more easily be established. The same effect would not be possible without a dedicated work space and a healthy printing budget.

The scale and complexity of the site facilitated an abundant discovery phase with great deal of information available for students. The scale of the site did not lend itself to the same level of intimacy as the previous year, where site visits were frequent, and the mapping of individual trees and storm drains could occur. Instead students were able to visit prototypical conditions within the study area, buy visiting the whole study area would not be practical or plausible within a semester. The scale also became challenging for some students who couldn’t include the desired level of detail at a swamp scale map illustration. However, this yielded new avenues for the students to pursue. In the future a smaller study area with similar amount of resources would be ideal. Potential sites could include the Gowanus Canal,
Chicago Sanitary Ship Canal, Harlem River, Buckeye Lake, portions of the Cuyahoga River, Washington City Canal, Flushing Meadows Corona Park, Collect Pond, among others. The course allows students to collaborate on research and propose their own project. The course provides a structure and framework while giving students significant agency to propose and develop their own visualization of The Great Black Swamp.

9 REFERENCES


REDUCING FEAR AND LOATHING IN THE DESIGN STUDIO

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1 ABSTRACT
Few in-coming landscape architecture students feel confident in their creative abilities. As studio instructors, it is excruciating to watch students struggle with fear and anxiety as they approach their assignments. Students' lack of confidence awakened by the design process, studio environment, and brain physiology, results in some students developing unproductive behaviors or dropping out because they believe that they are not creative enough to succeed. Even after graduating, these emerging professionals may continue these destructive patterns, such as last-minute production, which is not a behavior encouraged in a professional setting, or conducive to an emotionally healthy and well-balanced life.

Many of these unproductive behaviors and ways of thinking, such as procrastination and fear, are well documented, but seldom are they and the scientific research explaining them discussed in depth and integrated into design studio activities. This paper shares the research, reflective exercises, and strategies implemented in sophomore design studios at Kansas State University and Colorado State University. The studio activities guided students in understanding their thinking and resistance while providing tools that encouraged productive behaviors and shifted their mindset past their fears and insecurities to production. In addition, this paper showcases student results with examples of their reflective statements and visual images in which they addressed their fears and anxieties. Through discussions and activities students gained awareness of their internal thinking, creative process, and realized they are not alone, which in turn made the design process less intimidating.

1.1 Keywords
Creativity, Premature closure, Resistance, Fear, Design process.

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The process of creating, making, or writing can be intimidating for young designers. Based on the authors’ observations teaching in the studio environment, students’ lack of confidence and fear are awakened when confronted with the nonlinear process, multiple possible solutions, and not knowing if the outcome associated with the creative process will be good enough. The experiences associated with these conditions tend to create fear and anxiety for many students that result in resistance to beginning and immersing themselves into an assignment or project. These feelings of fear and being exposed can be exacerbated when students are asked to share their incomplete thoughts in front of classmates. These fears are the most common emotions underlying students’ resistance to production. As faculty we witness this regularly.

Without addressing these emotions and the resulting behaviors, as faculty, we can unknowingly contribute to student’s poor emotional health while increasing their self-doubt as creative people. In addition, the unproductive behaviors learned in design studios may potentially remain with these emerging professionals and lead to detrimental habits in the workplace. This paper highlights a teaching strategy, implemented concurrently within sophomore landscape architecture studios at Kansas State University and Colorado State University, to help students identify, reflect on, and change their individual behaviors that result in reduced anxiety, greater production, and increased learning.

2.1 Students are Underprepared for Creative Activities in College

Children enter school eager, curious, and more accepting of themselves as creative beings. Creative acts, such as drawing, writing, and making come easily to young children; they don't ask questions and they don't judge their performance or the outcomes. “By the time they reach high school, their perception of their creative abilities has changed; only a small percentage of high school students identify themselves as creative” (Souza, 2016, p.244). In college, many students pursuing a design education often discover that they are afraid of making a mistake, hesitant to begin exploring ideas, and anxious when the outcomes are unknown. Many think they should be able to accomplish a task on their first attempt, are distressed when there is not a single or simple solution and become frustrated when the outcome isn't perfect.

There are many challenges faced by faculty and students that contribute to students being underprepared for engaging in design activities in college. One of the most important factors is that the majority of elementary and secondary education do not prioritize the nurturing of creative abilities and often it is repressed (Alencar et al., 2017). The traditional educational system was originally developed to meet the needs of industrialism, focusing on three primary areas: economic, cultural, and personal. The system teaches economics, so students are prepared to earn a living and be financially resourceful. They are taught about various cultures, so they have a deeper understanding of the world, and they are encouraged to develop their individual aptitudes and sensibilities (Robinson, 2014).

There are two ideas underlying the hierarchy of the traditional educational systems that incorporate hidden values and prioritize some skills over others. The first idea is that the most useful subjects taught in school lead directly to employment at high paying jobs, such as being a lawyer or doctor. Generally, jobs in the creative arts are not considered to be financially stable or lucrative, except for a few people with extraordinary talent. As a result, some students are discouraged from practicing and pursuing the creative arts, such as theater, music, art, or design. The second idea is that intelligence is measured by academic performance and ability. Primary and secondary education systems have been designed to prepare students for entrance into the university. They have not been established to help students find and develop their talents; if those talents fall outside of the preferred subjects within the educational system (Robinson, 2014). The system is not focused on nurturing or developing confidence in artistic skills and creativity. So, it is understandable that many students arrive in a college design studio intimidated by writing, drawing, and making that run counter to these established systemic barriers. These negative experiences and perceptions of themselves as creative individuals generate fear and anxiety blocking them from engaging in design learning.
2.2 Resistant Thinking and Fear

“What’s hard is sitting down to write. What keeps us from sitting down is Resistance.”

Steven Pressfield

Writing, drawing, designing, or any creative art may provoke resistant thinking. Resistance is “any act that rejects immediate gratification in favor of long-term growth, health, or integrity. Or, expressed another way, any act that derives from our higher nature instead of our lower. Any of these will elicit Resistance” (Pressfield, 2002, p.22). For some people this thinking has little impact, but for others it can be very damaging to their emotional and creative selves by generating stress, interfering with relationships, and impacting one’s overall health. Even educational activities can build resistant behaviors (Pressfield, 2002, p.18).

The authors’ observations indicate that for most student’s resistance takes the form of a low-level fear or dread, which poses as an obstacle to production and hence an obstacle to learning, deep thinking, and developing more advanced design skills. In the past, emotions (such as fear), unproductive behaviors, and how the brain works have not been discussed as part of the design studio. Instead, it is just assumed that students will ‘figure it out’. While as faculty we’d like to believe that students’ fear will just go away with practice, this is not realistic. We must help them understand the basis for their individual fears and practice techniques for moving past resistance.

Fear is a basic and valuable human emotion. It is not possible, nor is it desirable, to eliminate it so students can create more freely. Instead, it’s necessary to help students understand that fear is primal, instinctual, and programmed into our nervous system. The fear responses can be activated by threats that are real, such as being pursued by a bear, or perceived, being called on to answer a question in public (Layton, 2005). Whether the threat is real or perceived doesn’t matter; we instinctually respond. Behaviors associated with the fear response, such as anxiousness, heart racing, fleeing, hiding, or freezing serve the larger more important purpose to protect us from danger and ensure our survival. It is well documented what happens physically when we experience fear, where the reaction occurs in the brain, how it physically manifests in our bodies, and that it is experienced differently by each person (Layton, 2005).

When students enter college, many of these emerging designers are unaware of how their emotions, preconceived notions about the design process, and behaviors effect their ability to direct their design process. Ultimately, if not addressed, students may develop poor behaviors and distorted beliefs, such as only some students are talented, and they are not. These behaviors and beliefs about themselves may lead to unproductive habits, such as procrastination, in the workplace. Overcoming fears related to the act of making is individual and must be addressed within themselves. Our approach is to open the black box by supporting students and making them aware of why and how they think or behave, what triggers affect their behaviors, and create the conditions for them to succeed. Overcoming resistance and developing healthy behaviors is not just important while in school. Our objective is to teach students healthy behaviors to make them successful as a student, but also in their future careers.

3 OBJECTIVES

The three main objectives for introducing and openly discussing with students the research and strategies for overcoming resistant thinking in the design studio environment are: 1) introduce good behaviors that reduce students’ anxiety and increase their overall mental and emotional health; 2) assist students’ in being reflective learners as they identify emotions and behaviors that contribute to resistance; and 3) increase students’ productivity and learning.

4 METHODS AND RESULTS

The framework implemented in the sophomore design studios at Kansas State University and Colorado State University focused on using reflective exercises to assist students in better understanding themselves and increasing ownership of their learning and supporting them by providing the research about
resistance and strategies to overcome undesirable behaviors. The semester was divided into two main parts: 1) student reflections, and 2) research and strategies on the topics of perfectionism, procrastination, frustration intolerance, premature closure, myth of multitasking, and health and wellbeing. The exercises during the first eight weeks focused on students’ practicing self-reflection and identifying their beliefs and fears that result in resistant thinking and behaviors. During the second half of the semester, each week research on a new topic and strategies to overcome it was presented then followed by an activity that required students to select strategies to address behaviors they would like to change. They were to reflect on their fears and behaviors, and to develop an awareness of how this limited their productivity.

4.1 Student Reflections

Inclusion of reflective learning activities in a studio engages students “to explore their experiences in order to lead to new understandings and appreciations” (Boud, 2001, p.10) and reveal “evidence of one’s evolving thought process, documenting valuable, often fleeting glimpses of understanding” (Stevens & Cooper, 2009, p.3). During the first eight weeks, the studios were designed with reflective writing activities in which the students responded to one question per week thus, giving time for a focused mindset and structuring their thinking. The reflective questions were designed to help students recognize and disclose personal weaknesses (which for some students can be a particularly daunting undertaking) and strengths. Structuring the reflective writing activities aided students in accepting and undertaking their personal challenges while also establishing support if they were burdened with feelings of self-doubt. Including reflective practices in the studio enabled students to become aware of, understand, and appreciate their own creative and thinking methods thus increasing their self-confidence leading to self-improvement.

In “Fostering Creativity in the Design Studio: A framework towards effective pedagogical practices,” Hargrove explains the challenge of self-management. Self-management “involves learning one’s strengths and weaknesses as a creative problem solver, and finding ways to utilize the strengths and mitigate or work around the weaknesses” (Hunt & Urton, 2013, p.4). To encourage self-management, students were asked to respond to the following reflective questions. The samples of student responses included below were selected to reflect common sentiments.

- Question 1 - Do you feel like you are a creative person? Has this changed over time?
  40 student responses. Main response themes: 9 students - creativity diminished since childhood; 10 students - constant growth of creativity since childhood; 12 students - ebb and flow of creativity since childhood; and 11 students - anxiety limits creativity.

  Student response samples:
  
  “I feel that I am a creative person, but I feel that I have lost some creativity as I’ve gotten older. I now have a harder time coming up with new ideas and finding time to just relax and let myself work on something fun like drawing. The times that creativity comes really easy for me is when I have to do some problem solving, whether that be in class or in my personal life. But overall, I think that I’m still a creative person.”

  “What I lack is the confidence. Using my creativity, I find myself falling into a downward anxious spiral. I think too hard about every detail, and second guess whether I am doing things correctly. When I am able to ignore that anxiety, I would consider myself creative.”

- Question 2 - What are your strengths and weaknesses related to creativity?
  40 student responses. Student responses varied with no main themes identified.

  Student response samples:

  “Some of my strengths related to creativity are I feel like when given a task I can easily find creative solutions such as with projects in this class of simple everyday projects like arrange the living room. I also feel that another one of my strengths with creativity is that for the most part I can usually come up with some sort of concept to start with and then I can keep working on it to develop
it more without sticking to that one idea entirely. But that being said I feel that some of my weaknesses are that I procrastinate, especially when it comes to school and class projects, and this causes me to fall behind and not develop my ideas as much as I could've. Another weakness of my related to creativity is that I am better at coming up with creative solutions to daily problems more that I am at coming up with concepts and ideas for my work and this is something that I want to get better at so that way I can take my skills and talent to that next level and be full prepared for a professional environment.”

“I like to think of creativity as a learnable skill, and for me it is just that, a skill that I am learning and constantly improving. With learnable skills comes strengths and weaknesses, the latter of which isn’t one that people like to think about as much so that’s where I’ll start. I feel that one of my biggest weaknesses is a lack of knowledge when it comes to techniques. I struggle a lot with figuring out how to do things to make them look like I have pictured in my mind’s eye, but that is something that I am improving because every day I learn something new. What I would consider to be a strength for my creativity, is that I see things in a different way than most people. I always take a different approach to solving problems, whether it's a better way to do it, or if it's less efficient, it's still a different way and that's what I feel is the basis of creativity. Anyone can draw an image, but it's the way that you do it differently that defines your creativity.”

“I haven't ever really thought about what my strengths and weaknesses are related to creativity, but one of my biggest weaknesses is probably continuing with one idea or design that's strong but then eventually disliking it the longer I work with it. Then I wonder how much better my work would have been if I went a different route and used a different design but ultimately, it's too late to turn back or restart. I think a lot of people struggle with this and feel the same way, but this is one of the biggest things I struggle with in the creative process. I can understand why it's important to know your strengths and weaknesses and now I'll try and pay closer attention throughout this semester.”

• Question 3 - What challenges do you encounter in the creative process? How do you overcome these challenges?

40 student responses. Main response themes: 15 students - creative/thinking blocks; 15 students – difficulty starting and/or procrastination; and 7 students - fear of judgement.

Student response samples:
“Some challenges that I encounter in the creative process are if I think it will be good enough for someone else to judge. I get very critical when it comes to my own ideas thinking that I didn't go far enough or take enough of a risk. I also get stumped on just trying to create something in general that would coincide with the project or task at hand. Ways that I have overcome this is that I basically just get started, the more I think about it, the more frustrating it gets. I've learned throughout the years that when faced with something that seems difficult, the best way to get over it and get it done is to just go. Getting something down is the base and moving up from there gets easier the less you think about it. It definitely comes down to mind over matter when in the creative process.”

“One challenge that I encountered this week was a creative mental block. I wasn't able to put my thoughts and ideas about one of my designs onto the paper that was sitting in front of me on my studio desk. I sat there looking at it and drawing doodles that were of no value to me for far too long, and eventually I decided to just go out to the sight and get a physical grasp on my design. Once I got to the sight, it didn't take me long to start putting my thoughts on to paper, and before long I had roughly drawn out all of my concepts. My solution to the mental block was simply putting it in a new perspective and getting out of the space that had me stuck.”
“I have problems starting. The very first step is really hard for me, and then starting the next step. Anytime I have to actually start creating something I have issues. I overthink it a lot instead of just going for it to see if it is good. I get too scared to try to put my writing utensil to paper. To fix this I’m working on just doing really outrageous ideas and then slowly pulling back to regular ones. This helps me because the crazy ones seem like a joke so I don’t have to think to hard about them.”

• Question 4 - You have created quiet time to begin a design project or writing assignment. You have all the tools you need and are ready to go. Then an hour later, your page is still blank. What the heck happened? You were ready to produce and nada. Why were you resistant to begin? Resistance is that inability to start, and it takes various forms for each of us. Maybe you have the urge to respond to emails or check social media. Maybe you react physically-you get sleepy, headaches, or hungry. Describe your resistance - the behaviors, emotions, and activities that distract you from starting your work. Be specific and describe your thought process and why you feel you allow resistance to prevail?

42 student responses. Student responses varied with no main themes identified.

Student response samples

“I feel my resistance begins with perfectionism. I get stuck in my head and perseverate on multiple ideas trying to figure out what would be best. My reaction is often to do other things, or I feel physically sleepy. It’s difficult to describe my thought process as I find myself often spinning with thoughts. I often force myself to start knowing that I can re-do a project. I do feel that when I procrastinate, I run myself up to a deadline and I am forced to finish the project. When there is a deadline and I am coming close to the deadline, I do the work and am forced to accept the flaws I see and turn in the project. Perhaps it’s my fear of something not being good enough that drives this behavior.”

“My resistance comes in all shapes and sizes. Sometimes I become distracted by physical stimuli and the craziness all around me, and sometimes I mentally begin to procrastinate and that messes with my senses and drains me of my energy. The one that happens most often is that I become distracted by outside variables. I am easily one of the worst procrastinators to have ever walked this planet, and that means that when there is work to do, my brain will start to notice every little thing around me and try and make me focus on anything but the task at hand. I could see the tiniest flash of movement out of the corner of my eye, or hear a sound from the other end of the studio, and before I know it, I'll be scrolling through Instagram on my phone or surfing the web and 30 minutes has passed by.”

“There are many things that prevent me from starting my work. Typically, the sheer amount of things that I need to get done prevents me from getting any of it done, as I just do not know when to start. When I do start, I tend to start with the easiest assignments and work up to the harder assignments, but I typically reach a roadblock with this approach.”

• Question 5 - How do you begin developing a conceptual idea for a design project?

39 student responses. Main response themes: 9 students - review precedents/inspiration; 12 students - site analysis/visit and identify site problems; and 7 students - brainstorming and sketching/writing initial thoughts.

Student response samples:

“It’s good to start brainstorming and sketching all the ideas you have until you come up with an idea that you feel is the best. I think it’s hard to get started on projects like this where you feel there is nowhere to start but just getting some ideas down and starting to sketch, I think is a great way to start. Also, research for this project and be aware of the site’s conditions and its surroundings and
what type of layout will be compatible with the site. Keeping in mind the community that is going to be occupying the area as well.”

“One way that I start developing a concept is to look at precedents and examples to help giving me ideas and get my mind flowing with concepts for a design.”

“First I look at the site and try to see what is currently existing and how it impacts the area. Sometimes I look for a problem that I think needs a solution, or for something that is lacking in the area, and try to build off of that.”

4.2 Research and Strategies
An important part of helping students develop awareness of their resistant thinking and behaviors was to share current research and discuss in more detail the complex emotional, physiological, social, and cultural reasons for being fearful and resistant when beginning something new or during the creative process. The weekly discussions during the second half of the semester, included more in-depth focus on topics of: procrastination, perfectionism, premature closure, frustration intolerance, the myth of multitasking, and health and wellbeing. Included in each presentation was a range of strategies for overcoming these resistant behaviors. The following text excerpts are highlights from the presentations.

Perfectionism
Resistant thinking demands that only perfection will be merit of one’s time. Perfectionism is a primary obstacle to making and is experienced with varying degrees by all (Egan, 2014, p.1). Healthy levels of perfectionist thinking nourish perceptions of craftsmanship, increases precision within designs, and builds purpose and drive for final outcomes while unhealthy perfectionism includes setting high standards for oneself and simultaneously slamming oneself for not reaching such high standards (Shafran, 2018). Perfectionism can involve not just the pursuit of high standards for oneself, but also having high standards for other people (a professor) and believing that others have high standards for you (one’s family). Endless perfectionist thinking can negatively impact self-esteem and feelings of worthlessness may develop (Shafran, 2018). A key in understanding perfectionism is knowing how to be less self-critical and how to separate self-worth from high benchmarks (Levetin, 2014, p. 200). “All agree that for some people perfectionism is unhelpful and can clearly be separated from the healthy pursuit” (Shafran, 2018). An unhealthy perfectionist mindset may increase anxiety, emotional feelings, and behaviors, such as “poor concentration, rumination (e.g. thinking about a mistake made in a task over and over), repeating tasks (e.g. rewriting and editing something over and over), excessive amount of time spent on tasks, avoiding tasks, list making (being over - thorough), and hating to waste time and, as a consequence, being over - busy” (Shafran, 2018, p.194).

Strategies of overcoming perfectionism: Thinking my work is not good enough.
- Remind yourself it’s just your ego.
- Just produce something.
- Don’t focus on the end product, focus on the process.

Procrastination
People with perfectionist behaviors, students, and the general population tend to procrastinate (Egan, 2014, p.1). The behavior of procrastination is defined as “the voluntary delay of an intended course of action despite having the opportunity to act and expecting to be worse off for the delay” (Wieber, 2010). Research has shown that 50-80% of college students practice moderate to vigorous procrastination habits (Gustavson, 2017; Kim, 2015). Procrastination is tied to perfectionism in which one will avoid beginning the task in fear of not reaching the high benchmark, not being perfect, and failing (Shafran, 2018). “Procrastination is the most common manifestation of Resistance because it’s the easiest to rationalize. We don’t tell ourselves, “I’m
never going to write my symphony.” Instead, we say, “I am going to write my symphony; I’m just going to start tomorrow” (Pressfield, 2002, p.34).

**Strategies of overcoming procrastination:** Overwhelmed by an assignment.
- Prepare and break the assignment into smaller tasks.
- Begin with a simple task you can accomplish easily to get the momentum going.
- Reward yourself when it is complete, then move to the next task.
- Reduce distractions.
- Ask questions.

**Strategies of overcoming procrastination:** Low energy.
- Play music that is motivating.
- Change your method of working, such as drawing by hand instead of using the computer.
- Create an accountability pact.
- Go outside.
- Don’t wait for motivation.

**Frustration Intolerance**
Engaging in creative acts, such as designing, writing, drawing, painting, and making requires the ability to tolerate frustration and discomfort. Frustration and discomfort shape shift constantly taking on slightly different forms for each person, but intuitively one knows when one is experiencing frustration intolerance. Frustration intolerance is the inability to withstand feelings of frustration that occur when one experiences difficulties or disappointment (Yao, 2010). Typically, young and emerging design students and artists have a low frustration tolerance due to their inability to identify the emotion of frustration, and limited knowledge of how to overcome it. Each person has personal beliefs and behaviors that kick in when discomfort appears; they may walk away from the blank page, choose to begin activities that are easy but not important, or create excuses for not beginning or progressing. They walk away from tasks because they are overwhelmed, don’t know where to start, or are concerned that the process will be challenging. They anticipate they won’t be able to tolerate the frustration encountered during the process. This anticipation of difficulty can prevent them from beginning. Or when a phase of the project is slow and tedious, they lose interest and become distracted by another, more interesting activity. This is frustration intolerance. However, like strengthening any muscle, through repetition and increasing challenges, they can strengthen their ability to tolerate the discomfort of creative and courageous acts, such as not knowing where to begin, not knowing if the outcome will meet their expectations, or if the ideas will be liked by others. Tolerance involves strengthening our resolve to overcome obstacles, and at the same time, accepting that somethings are unchangeable.

**Strategies of overcoming frustration intolerance:**
- Accept failure as part of the process.
- Expect and accept that there will be frustration and human error; and that this is anticipated and acceptable.
- Be okay with not getting it right and having to start over.

**Premature Closure / Divergent Thinking**
Often, students consider the first attempt at making “complete,” “done,” or “finished” which imposes limits on their own creativity (Hunt & Urton, 2013, p.270). Its one’s willingness to be flexible while searching for an answer and one’s willingness to find fault within their thinking. When one narrows their thinking and at best have a—first—basic—predictable—outcome, they are surrendering to resistant thinking. This behavior, known as premature closure (“the degree to which one keeps an open mind” (Karpova, 2011, p. 56) is based on the understanding that creative processes necessitate a person to keep an open mind and to work attentively with an assortment
of information (Kim, 2006). In the design process, one might begin with an obvious solution and feel the desire to stop. But with a breadth of openness, they dive deeper and they test multiple ideas and different ways of exploring and making all while not knowing or trying to predetermine the outcome. One must aim “to keep an ‘open mind’ where incomplete figures are not closed by the quickest route, but through irregular lines or not at all” (Humble, Dixon, & Mpofu, 2018, p. 34).

Premature closure might be a reaction to the feeling that one will run out of time because of deadlines. Laziness and not caring can give it strength. But, mostly, premature closure is rooted in a lack of curiosity. Just needing an answer is not a good answer. Waiting for the teacher to tell one what to do inhibits personal motivation while restraining your uniqueness. By closing one’s mind, you abruptly end with the straightforward, status quo. The willingness to postpone having an answer is okay.

To cultivate an open mind—a deliberative mind, one must sow a tolerance for the vagueness, be flexible in thinking, and imagine contrasting courses of action. With open minded thinking, a person explores various ideas and with careful questioning binds relationships together (Powers, 2018). Open minded individuals embrace dissimilar thoughts, ways of life, and outlook while questioning one’s own point of view. Open mindedness empowers one to be wrong while sifting through, examining, questioning, and deliberatively linking information for the best solution (Powers, 2018). “In essence, it is consuming a lot of information and then creatively connecting this information to solve the problem at hand. Or, as Steve Jobs put it, “connecting the dots” (Powers, 2018).

Divergent thinking is a part of being open minded. This spur-of-the-moment, continuous, non-linear thinking generates many budding, varied, fluid, and unrelated ideas that link information with the question or problem at hand. Research completed over the last 50 years evince that divergent thinking gives breath to creative processes and activities (Karpova, 2011, p. 56). This creative breath elicits that if enough ideas are produced, some will be novel and inventive while conforming to the constraints of the question or problem (Tversky, 2011).

In the creative process in problem solving, both divergent and convergent thinking skills are iteratively needed. Whereas divergent thinking seeks to create many swift, entangled concepts with an open mind, convergent thinking brings forth a focus on a singular, disentangled idea—one at a time—to strengthen coherence, thoroughness, and detail (Tversky, 2011).

**Strategies of overcoming premature closure:**

- Produce multiple alternatives.
- Consider opposites and unexpected connections.
- Ask yourself, “What if...” as well. Don’t be afraid to challenge your own assumptions.
- “If common wisdom says to zig, consider zagging” (The People Brand, 2018).

**The Myth of Multitasking / Slow-motion Multitasking**

In today’s society, efficiency and productivity are highly valued. Designers and students are under a lot of pressure to achieve maximum productivity with minimum wasted effort. This pressure to be productive and one’s desire to be efficient with their time leads to the belief that multitasking is good, and doing multiple things at once will help one more quickly achieve their goals. However, current research provides evidence that the effectiveness of multitasking is a myth. Multitasking does not improve productivity. Instead, it impedes the potential for developing more in-depth and creative thoughts. In fact, students that multitask regularly often have lower cognitive capacity (Miller, 2017). Our brains have limited capacity for simultaneous thought. While one may believe their brain is processing thoughts simultaneously when listening to a lecture and searching social media, that is not the case. Instead, their brain is really just switching between tasks. When the brain is constantly moving back and forth between various unrelated thoughts, there are breaks and time is lost. If one’s brain spends time just moving back and forth, there is limited ability to move the thoughts forward.

Instead of multitasking, it is better to single-task or slow-motion multitask. The first strategy
for single-tasking is to reduce distractions. It is normal to be tempted by many thoughts and activities, so one needs to be aware of their personal distractions, whether it’s Facebook or doing laundry, and plan to limit these temptations. This may include turning the notifications off on one’s phone. A second strategy is to block out time to single-task. For example, write for 30 minutes without other distractions. If one loses focus, walk around for a few minutes and then go back to the task. Also when single tasking, begin with the most important task to ease the feeling that something more important needs to be done and reducing the temptation to multitask.

Strategies of overcoming multitasking:

- Avoid temptation and go “off-grid”. Put away your cell phone. Turn off your email/web access for a while.
- Block out time to single task. Tell yourself that you will work on project X and nothing else for the next few hours.
- Prioritize. Work on your most important tasks first. Then you won’t feel pressure to multitask.
- Be self-aware and resist. Recognize that humans have the temptation to multi-task but that it is not effective.

Health and Wellbeing

Discussions on healthy behaviors and wellbeing support students’ creativity, help them move past resistant thinking, and are critical to living a healthy and balanced life while in school. As faculty, we want them to develop habits that support their health so they can discover their creative energies and carry with them productive behaviors as they enter the profession world. Often students believe the stereotypes that designers, artists, and poets must suffer to create great work; or that depression, alcohol, limited sleep, or drugs will make their work more imaginative. In these discussions, we aimed to remove stereotypical thinking while focusing on five practices that encourage health and wellbeing: 1) activity and exercise, 2) eating healthy, 3) managing stress, 4) making art and journaling, and 5) sleep.

The more that scientists study the brain, the more they identify that movement is interconnected to memory and learning (Souza, 2016, p. 269). “Studies have shown that creative problems, in fact, can be solved by walking, particularly in nature, thanks to physiological changes in the brain that lead to lower frustration and stress, boosted engagement and arousal, and higher levels of meditation and enhanced mood — all of which can help us come up with more creative connections” (Kaufman, 2015, p. 41). Managing stress necessitates discussions on mindful practices and how to be ‘in the moment’, which includes conversations about controlled breathing practices, journaling, and art making activities to reduce stress, increase alertness, and boost one’s immune system. Discussing mindfulness behaviors teaches students a variety of methods to rebalance themselves and their thinking. The importance of sleep is highlighted to bring awareness to sleep deprivation and how ‘all-nighters’ poorly affect one’s brain (Levitin, 2014, p. 187), the three distinct kinds of information processing that occur during sleep which includes unitization, assimilation, and abstraction (Levitin, 2014, p.184), and pre-bedtime priming which is the process of considering a problem needing to be resolved immediately before bed; this behavior escalates the prospect that during sleep the answer will be revealed (Time, 2018).

Strategies to nurture health and wellbeing:

- Activity and exercise: be active, exercise regularly, and go for a walk.
- Eating healthy: avoid excessive amounts caffeine and sugar, consume fewer processed food, and drink plenty of water.
- Managing stress: be mindful, meditate, practice controlled breathing including the five finger breathing method and the coherent breathing method, practice time management, and listen to music.
• Making art and journaling: doodling, writing, exploring ideas, and collecting images on the page. Coloring mandala and grid pattern activities “for 20 minutes is more effective at reducing anxiety than free-form coloring for 20 minutes” (Curry, 2005, p. 83).
• Sleep: sleep 7-9 hours, establish a bedtime routine, sleep in a cool, dark, and quiet room, and don’t pull all-nighters.

4.3 In-Class Activities
Each presentation was followed by an in-class activity related to the topic. The activities ranged from having students discuss their design process struggles with classmates to drawing a picture using their non-dominant hand of a change they would like to make to reduce stress and resistance. These activities guided students to: 1) develop a stronger understanding of the potential causes of, and behaviors associated with resistance, 2) reflect on their emotions and behaviors specific to them and, 3) construct a framework for creating good habits, thoughts, and behaviors that result in enjoying the design and making process.

The repetition and time devoted weekly to these conversations and exercises was important to demonstrate to the students that this content was valued and integral to the course; and not a single lecture about time management that was introduced once and then forgotten.
4.4 Reducing Fear and Loathing Collage

As a final pursuit in the Reducing Fear and Loathing design studio activities, students were instructed to build a fun and creative collage (9 in. x 9 in.) using images, found objects, and words to express their feelings. This collage is a visual reminder of and means for navigating the obstacles that result in resistance and keep them from creating. For this assignment, students were asked to review their notes from previous workshops and identify two or three behaviors and thoughts that resulted in resistance and develop a list of potential tools and strategies that they can reference to modify their resistant behaviors and quickly move forward. The intent of this collage is for each student to create a personalized visual reminder of what to do when they experience resistance.

Through this series of short lectures and exercises the faculty focused on assisting students in becoming more aware of their beliefs, emotions, and behaviors related to the process of making. The intent is that each student will use this time to build a mindset and habits that become the foundation in their journey of becoming a more confident creative person.
Student samples of the visual reminders developed for the final assignment.

Figure 3. “A Delicate Dance Between the Two” Dakota Frederick (2021).
Reproduced with student’s permission.

Figure 4. “Simple Effective Solution” Claire Schneider (2021).
Reproduced with student’s permission.
6 CONCLUSIONS

Many students arrive in the design studio underprepared for engaging in creative activities and unaware of the self-imposed resistance they may encounter when asked to engage in the design process. Based on our observations and student responses to the reflective questions about their design process, students’ feelings of fear and being overwhelmed resulted in resistant thinking and behaviors. It is our contention that if we as faculty want students to develop healthy behaviors that make them successful as a design student and also successful in the professional office setting, faculty should incorporate conversations and reflective activities into the design studio to assist students in understanding their resistance.

The responses given by students in this semester-long endeavor confirmed that students think they have the potential for creativity, they are concerned about being judged by others, they experience blocks, they sometimes struggled getting started, and they distract themselves. During the semester, we observed students using the terms presented in class and being more comfortable talking about their fears and resistance. By stressing the importance of reflecting on emotions and behaviors that result in resistance, and developing individualized strategies for changing behaviors, students gained awareness of their internal thinking and insight into their own and their peers’ creative processes.

We hope this paper will contribute by encouraging faculty to incorporate activities and discussions in studio courses that assist students in understanding themselves and in developing healthy behaviors that reduce anxiety, increase productivity, and result in deeper learning. These activities are meant to help students gain insights about the emotions and behaviors that hold them back in the design process, and to provide strategies that help build their confidence in maneuvering around their resistance each time they encounter it, no matter how it manifests. They can understand it, talk about it, laugh at it, and then implement tools and techniques to address it allowing the learning process to deepen.

7 REFERENCES


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THE GEM3 VERTICALLY INTEGRATED APPROACH TO A GEODESIGN STUDIO: ALIGNING STUDENT DESIGN-THINKING AND PROJECT NEEDS OF A TRANSDISCIPLINARY PROJECT

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1 ABSTRACT
Addressing complexity and uncertainty about the future requires integration and alignment of education and research through transdisciplinary approaches. The Geodesign process (Steinitz, 2012) systematically aligns researcher-based modeling with stakeholder-driven assumptions about a place and its future. Within an NSF EPSCoR-funded Project, researchers have been tasked with creating scenarios to depict various trajectories of change which may occur across the landscape. The GEM3 (Genomics by Environment: Modeling, Mechanisms, and Mapping) Geodesign Studio demonstrates this process through application of Geodesign to an applied semester studio project to address an increasing population and recreation issues for two regions in Southern Idaho. The purpose of this study provides a framework for evaluation and application of student outputs of a Geodesign studio into an active research project. The framework employs a mixed-methods approach aligning landscape planning education competencies with inputs from a transdisciplinary project. The method consists of two components: a) studio participants utilize stakeholder and researcher input variables into scenarios, and b) scenario evaluation consisting of hotspot analysis (Getis & Ord, 1992) with a statistical regression to validate variables. Results of these methods advance research in the following areas: 1) creation of a transferable framework for scenario development and evaluation, 2) creation of scenario depictions, and 3) provision of an evaluation metric integrating student-driven research into research. This evaluation contributes to pedagogical landscape planning competencies (Brundiers & Wiek, 2011) to demonstrate strengths within geodesign as a tool for heuristics in education. This approach imparts a framework to further pedagogical competencies while simultaneously advancing transdisciplinary research.

1.1 Keywords
Design education, Landscape planning, Scenarios, Geodesign
2 INTRODUCTION

The Geodesign process systematically aligns researcher-informed data with stakeholder-driven assumptions about a place (Steinitz, 2012). Outputs of this process can potentially take the form of projective scenarios (Hulse et al., 2009; Petit et al., 2019). Within the GEM3 (Genomics by Environment: Modeling, Mechanisms and Mapping) project, researchers from the Social Ecological Systems (SES) team have been tasked with creating scenarios to depict various trajectories of change which may occur in future land use and land cover models as well as hindcasting models of the past (Trammell, 2018). These predictive models are depictions of externalities of human management decisions and/or biophysical impacts on species genetics and adaptions to their environment (Steinitz et al., 2005; Mahmoud et al., 2009; Shearer, 2009; Iverson Nassauer and Corry, 2004).

As a component of the Mapping SES conditions effort, the Fall GEM3 Vertically-Integrated Geodesign studio course was established to formulate outputs. These outputs have provided initial and/or secondary drafts of the scenario land use and land cover change representations as well as graphics to elicit and elucidate stakeholder feedback (Ferguson et al., 2017; Eanes et al., 2019). Outputs of the course intend to advance the research in the following areas: 1) creating a simplified and transferable workflow for scenario development, and 2) creation of draft scenario depictions for GEM3 Mapping. The GEM3 Geodesign studio intends to provide drafts of these scenarios as well as analytical representations (e.g. climate projections, development density, land cover change, etc.) to be potentially used within stakeholder meetings. As a learning outcome, students will have the opportunity to develop their skills within five competencies in design and planning: a) systems-thinking, b) interpersonal and transdisciplinary, c) anticipatory, d) normative, & e) strategic (Wiek et al., 2011). Student outputs from both courses are intended to be evaluated to determine consensus with spatially explicit assessment tools (Getis and Ord, 1992; ESRI 2016). The draft scenarios as student outputs are meant to provide for further scenario and alternative future development with the GEM3 project. The consensus from this study will provide researchers and stakeholders with key areas of impact through hot spot analysis (ESRI, 2016). The studio course was offered and advertised to students from diverse backgrounds, perspectives, and life experiences. Access to remote desktop connections as well as virtual platforms were made available for access in various locations in the state and region.

Figure 1: GEM3 VIP Geodesign Studio Timeline. This graphic illustrates where the GEM3 Geodesign studio scenarios fit into the GEM3 SES scenario process.
2.1 Project Purpose and Overview
This research intends to provide educators and researchers with a framework to align transdisciplinary research with education, establish a model for course delivery in scenario planning and analysis, and create a method for analyzing and determining consensus from various student-driven, stakeholder-informed scenarios of change. The heuristic approach provides pathways for transdisciplinary research course delivery by providing conduits for student learning which evoke mental shortcuts to address uncertainty and bias (Tversky and Kahneman, 1974) in landscape architecture and planning education. Student outputs were evaluated to determine geospatial consensus thus providing an indicator of learning within the studio and key areas of impact within the scenario suite for each region. This consensus, an agreement among the student group concerning key variables, attributes, and their conditions, indicates learning as the convergence of concepts and tools delivered within the studio through a heuristic. Modules of the course included self-directed analysis, design, and evaluation (Figure 1).

2.2 Current Methodologies for Scenario Development and Geodesign in Landscape Architecture and Planning Studios
Courses in scenario planning and analysis in landscape architecture and planning programs have had success in delivery of information and methods for creation of scenarios and evaluations (Albert et al., 2015). Through mixed-method approaches, student learning can be achieved through short course and semester-long delivery of the Geodesign process (Steinitz, 2012; Albert et al., 2015). However, alignment with active research projects can be a difficult undertaking due to adherence to timelines of research delivery, instruction of course deliverables, and activation of learning objectives. This research attempts to provide students with the sense of ‘stake’ or agency by participating as modelers and stakeholders (Ferguson et al, 2017) within a landscape planning studio setting. In the studio introduced in this paper, students were presented with various frameworks to create ‘shortcuts’ within the process which were driven by uncertainty and bias heuristics (Tversky and Kahneman, 1974). The intent of this process provides students with a catalyst to develop new conceptual understandings about carrying out a research project through transdisciplinary thinking in research methodologies (Kliskey et al., 2021).

2.2 Application of Heuristics
Being that this was a transdisciplinary project with students from backgrounds in various levels of their education, a framework to address new ways of addressing uncertainty and bias heuristics was applied to course development, content delivery, web-tool application, and theoretical development in an expeditious manner. This research operationalized the Nobel Memorial Prize awardees’, Amos Tversky and Daniel Kahneman’s, key contribution of a set of heuristics to drive decision-making amidst uncertainty and bias (Tversky and Kahneman, 1974). The following section describes each uncertainty and bias heuristic applied to module development in the GEM3 Geodesign Studio.

‘Representativeness’ as a concept provides decision-makers, students in this case, with a judgement call to understand which data, events or phenomenon are inherent in a particular process. ‘Availability of instances’ or scenarios offers individuals with the possibility to model or formulate understood processes into a set of scenarios to understand frequency of change. ‘Adjustment from an anchor’ asks individuals to review predicted outcomes through various metrics or indicators of change as to denote nuance between instances or scenarios (Tversky and Kahneman, 1974). This project evokes these heuristic concepts to guide student learning and development through a landscape planning studio.
2.3 Alternative Futures and Scenarios

Scenario analysis is a robust method for dealing with uncertainty (Schwartz et al., 1996), both in terms of mechanistic understanding (Carpenter, 2002) and human endeavors (Bradfield, 2005). We can develop scenarios in a number of ways to explore a number of future states, depending on the goal of the project (Mahmoud, 2009). Normative scenarios can be used to help generate support and coordination for a desired set of future conditions (Nassauer and Corry, 2004), while exploratory scenarios can be used to identify future states under a given set of assumptions (Hulse et al., 2009). These assumptions can be based on stakeholder input (Baker et al., 2004), expert knowledge (Steinitz et al., 2005) or by data-driven patterns identified using geographic information systems (Hulse et al. 2009; Jahanishakib, 2018). We propose utilizing all three to generate a complete picture of what adaptive capacity and adaptive potential might look like for various regions. In many cases, scenario analysis focuses on few key drivers of change to explore future conditions. A more comprehensive approach is to utilize critical uncertainties, the most uncertain and potentially significant forces in a region, to frame multivariate scenarios that explicitly tackle the uncertainty in those forces (Shearer et al., 2006). This approach is especially robust when combined with spatial models of the scenarios, called alternative futures (Steinitz et al., 2005). Alternative futures (AF) assessments provide a way to explore plausible options for the future of a region or community based on stakeholder interests in the region or community (Hulse et al., 2009). AF assessments organize, generate, and simulate both qualitative and quantitative data to represent models of change. Plausible trajectories of change are tested through researcher-developed spatially explicit mechanistic models and/or stakeholder-guided assumptions (Iwaniec et al., 2020, Nassauer, 2011). Through various tools and methods of inquiry, the combination of data and assumptions from stakeholders works to ground-truth key uncertainties of environmental change for the near and long-term future (Trammell, 2018), that will, in part, come from the modeling described above. Multivariate scenario narratives are used to describe and relate a series of plausible future actions to the SAG (Stakeholder Advisory Group) who express to what extent the scenarios represent observed reality, with iterations to ensure agreement by both the research team and stakeholders (Baker et al., 2004; Shearer, 2009). Subsequent sessions aim to validate scenario models for each trajectory of change and develop adaptation strategies that will be spatially represented as a set of alternative futures. Utilizing feedback about future conditions from the stakeholders and experts, a suite of impact models will be developed that help stakeholders understand the implications of each of the future scenarios (Trammell, 2018).

2.4 GEM3 Project Scenarios

The National Science Foundation (NSF) Established Program to Stimulate Competitive Research (EPSCoR) Genes by Environment: Modeling, Mechanisms and Mapping (GEM3) project in Idaho seeks to explore how organisms, and the systems in which they live, adapt to changing environments in order to inform future management practices through stakeholder-driven, researcher-based future scenario modeling. This transdisciplinary research project aligns researchers with capabilities in landscape planning, environmental science, bioinformatics, complex modeling, ecology, fisheries science, genomics, geospatial science, remote sensing, and social-ecological systems (SES) coupled from placed-based assumptions from stakeholder advisory groups (SAGs). The GEM3 project established scenarios through Geodesign (Steinitz, 2012). Upon future model completion, researchers were tasked with evaluating scenario efficacy through performance metrics to determine alternative futures of landscape change models (Steinitz, 2012). The change models are depictions of stakeholder-informed, research-based assumptions (Shearer, 2009) of how the landscape may be depicted in 2050 for two regions in southern Idaho: Teton Valley and the Owyhee region. These sites were selected as they are the most impacted by projected development and land use change within the region, particularly because of increased recreation and a decrease in sagebrush habitat. These threats are primarily due to population increase within the regions. Teton valley has experienced a growth rate of 3.74% within 2021 alone with population noted as 13,615 residents circa 2021. With a population of 12,133 residents, Owyhee county has a relatively low annual growth rate (0.847% in 2021), however residents from larger neighboring communities, such as Boise, recreate within the Owyhee region.
Throughout the progression of the GEM3 project, researchers have identified core themes per each scenario based on stakeholder input. Stakeholder engagement practices were utilized during the process to formulate these core themes as ‘critical uncertainties.’ In the methods section, Table 1 depicts stakeholder-driven scenario parameters and their associated themes (column titles) for both regions. The following sections provide background for Geodesign, and describe how this transdisciplinary research process was provided to students in a studio.

2.5 Geodesign and the GEM3 Geodesign Studio

Geodesign hinges on the central question, “How do we get from the present state of this geographical study area to the best possible future?” (Steinitz, 2012). This iterative process aligns stakeholder input along with landscape analysis, design, and revision through consensus or success metrics. The process works through key questions to understand critical processes of a place, and how well these processes and systems operate. Subsequently, potential changes are identified, incorporated and evaluated. This process typically relies on coupling of research-based models and stakeholder input. Through a Geodesign framework, various scenarios and alternative futures can be established to provide stakeholders, policy makers, and clients with various permutations of the future established by subject matter experts or stakeholders. Within the GEM3 Geodesign Studio, the process was used as a mechanism to establish scenario development (Steinitz, 2018; Albert et al., 2015).

The GEM3 studio course intends to use a Geodesign process to address uncertainty for two regions in Idaho: Teton Valley & the Owyhees. Students within the course were from varying backgrounds and grade levels (undergraduate and graduate students) in fields such as geography, landscape architecture, architecture, and planning. The intended course outcomes were to review relevant literature to understand current research within geodesign and alternative futures, while learning applicable methodologies for analytical, planning, and evaluation. The course objectives are as follows: a) integrate interdisciplinary research within planning outputs by way of geodesign, b) utilize tools for geospatial analysis and suitability mapping, c) create alternative futures for the regions, and d) evaluate the scenarios and futures based on evaluation metrics.

These regions, Teton Valley and the Owyhee Region of Idaho, were selected by the GEM3 SES (Social Ecological Systems) team as project demonstration study areas with two, previously selected stakeholder groups associated with each area. Within the project, stakeholder-driven critical uncertainties (Shearer et al., 2006) included the following thematic concerns for both regions: a) ‘Will economic dynamics change for the region due to increased recreation’, b) ‘Will impacts occur in sagebrush habitat due to unmanaged recreation’, c) ‘Will private lands become developed and transition from agriculture to a recreation-based economy’, and d) ‘How will recreation, housing development, and climate change affect wildlife habitat and migration.’ We utilized these uncertainties to influence representations as future projective scenario maps to be utilized within stakeholder meetings. As drafts, these future scenarios depictions as well as analytical representations (e.g. climate projections, population growth, increase in recreation, land cover change, etc.) were used to elicit feedback from the stakeholder group. For the purposes of the studio, the students did not have interaction with the stakeholder group, however, they were presented with the critical uncertainties as well as GEM3 Scenario data. Students were then tasked to develop scenarios based on their system understandings and analysis.

Student outputs from the course were intended to be evaluated to determine impact through various assessment tools to understand uncertainty and bias heuristic consensus. As a learning outcome, students have demonstrated competency (Wiek et al., 2017) in scenario planning to analyze relevant variables within a SES, apply analytical outputs to a land use and land cover plan per a stakeholder-informed scenario, and evaluate the alternative future representations to understand nuance and impact per each scenario.

Students were provided with a database consisting of layers and features relevant to each site. Feature classes included the following: National Land Cover Data (NLCD) (USGS, 2012), population density projections (US Census Bureau, 2020), Cropland Data Layers (CDL) (USDA, 2020), along with access to ESRI’s Living Atlas (ESRI, 2019). Students applied analysis, designs and evaluation through a web-based spatial tool created specifically for design called Geoplanner (ESRI, 2019). Through use of
ESRI’s Geoplanner, students had access to various tools to create weighted raster overlays to run suitability for various scenario interventions. Student outputs were compiled into a ‘Hub’ to record the process for delivery and dissemination.

The 14-week studio course was offered and advertised to students from diverse backgrounds, perspectives, and life experiences. Access to remote desktop connections as well as virtual platforms was also made available. The course was divided into 4 modules of delivery: Module 1: Analysis, Module 2: Design, and Module 3: Evaluation. Each module and applicability to the associated Tverksy and Kahneman Heuristic is explained in subsequent paragraphs.

Within Module 1: Analysis, students were presented with exercises to understand Geodesign literature and examples through case study investigation through presentations and reports. Students were then presented with the GEM3 stakeholder scenarios. After relevant exercises with analytical tools in ArcGIS online and Geoplanner, students were asked to construct and run various forms of analysis to answer the questions “How is the study area operating?” and “Is the study area working well?” (Steinitz, 2012). This module aligns with Tversky and Kahneman's notion of representativeness (Tversky and Kahneman, 1974) by asking students to make a judgement about relevant data, analytical tools, and presentation through a method of representing complexity in the SES.

Module 2: Design consisted of exercises to determine what changes might occur for the year 2050 under the assumptions of the GEM3 stakeholders. Students were given rates of change for each system in their assigned scenario and subsequently asked to design land use and land cover ‘change model’ (Steinitz, 2012) representations of how the assigned scenario may unfold (i.e. an Alternative Future). Students were given the following land use and land cover classes to construct proportions based on the scenario parameters: Agriculture Protection Zone (APZ), Wildlife Protection Zone (WPZ), Fire Risk Zone (FRZ), Developed Areas (DA), Managed Recreation Area (MRA) Invasive Species Risk (ISR) area, Unmanaged Recreation Area (URA), and Water Conservation Area (WCA). The applied heuristic within this module was availability of instances or scenarios (Tversky and Kahneman, 1974). This heuristic was selected as it asked students to determine plausible development and change based on their assigned scenario.

Module 3: Evaluation, asked students to compare their scenario design with the other students’ scenarios to understand proportion of area in each scenario or where fellow students understood growth or change to occur. The students used this exercise to revise their scenario designs based on understandings of the entire suite of scenario comparisons. The heuristic of adjustment from an anchor (Tversky and Kahneman, 1974) guided the development and delivery of this module as specific implications and values became apparent in their scenarios of change.

3 RESEARCH OBJECTIVES

Research conducted within this project intends to inform the following objectives: a) provide a framework for studio course uncertainty and bias heuristics delivery in the context of scenario development, b) present alignment of an active transdisciplinary research project and a landscape architecture and planning studio, and c) present a formalized methodology to evaluate consensus from student scenario outputs. These objectives provide landscape architecture and planning education with a workflow to effectively activate student learning through provision of a mechanism for content delivery and an evaluation instrument to determine the occurrence of learning among a studio cohort. Results and conclusions of this research are presented with the intention of providing educators and researchers in landscape architecture and planning programs with a mechanism to align research projects and studios concurrently.

4 METHODS

The methods section describes applicable data as well as the process used to formulate consensus within both the Owyhee Region and Teton Valley of southern Idaho. The process consisted of scenario formulation and validation as a student output. A scenario consensus evaluation for both regions was conducted amongst the group to demonstrate transdisciplinary research thinking.
4.1 Stakeholder-informed, Student-driven Scenarios and Data Utilized

Prior to conducting the studio course, GEM3 SES researchers conducted surveys, interviews and stakeholder meetings to determine scenarios, themes and critical uncertainties (Shearer et al., 2006) for each region. Table 1 depicts scenarios for each region and their associated 'uncertainty themes' as well as their rates of change per each scenario. These permutations were used by students to parameterize and calibrate their land use and land cover change models in Module 2: Design. Population growth utilized current and projected census data from the 2020 census at the block group. Students used climate data as RCP (Representative Concentration Pathways) values from CMIP6 (Common Management Information Protocol version 6) as well as SSPs (Shared Socio-Economic Pathways) (Doelman et al., 2018) from the International Panel for Climate Change (IPCC, 2021). Recreation proportions were guided by scenario assumptions and land use data. Socio-Economic data used National Land Cover Dataset (NLCD) (USDA, 2012) development classes as a proxy for understanding growth and change. Fire modeling data from USDA LANDIS (USDA, 2022) data provided areas of impact within specified areas. Aquifer levels (IDWR, 2021) as well as NHD data provided students with past and current data to compare for the study. Wildlife migration and habitat also used NLCD data classes as a proxy for scenario development. Table 1 describes each of these parameters and permutations for each scenario in both regions.

4.2 Scenario Consensus and Evaluation

Upon completion of modules delivered within the course, a consensus analysis was performed utilizing Getis Ord GI* (Ord and Getis, 1995; Mann, 1945; Kendall and Gibbons, 1990) statistical tools, specifically Hot Spot Analysis (ESRI, 2016) to determine key areas of impact and consensus for each region. The tool indicates 'hot' and 'cold' spots by statistically testing significant variables by their cluster of high and low values. Areas with statistically significant high values are transferred into bins deemed 'hot' whereas low value clusters are placed into 'cold' bins (ESRI, 2016). Within this project, the tool demonstrates consensus among student outputs thus signifying agreement that occurred within the project. This agreement illustrates student learning through transdisciplinary research thinking by way of conceptual collaboration established amongst the group. A geospatial statistics test using Moran’s Index (Moran, 1950), which is also referred to as Moran’s I, was used to test for autocorrelation to refute the null hypothesis that clustering occurred by random chance. Basically, Moran’s I measures similarity in observations and if the occurrence of these observations is based on a specific set of variables or variable. These tests were used in a sequence to first measure student alignment amongst the studio (Hot Spot Analysis), and to subsequently test for statistical significance or errors (Moran’s I).
### Table 1. Owyhee and Teton Valley Scenario Parameters

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Population Growth</th>
<th>Climate (RCP, Precip, Heat)</th>
<th>Recreation</th>
<th>Socio-Economic Change</th>
<th>Fire</th>
<th>Water</th>
<th>Wildlife Migration and Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destroying Boise’s Playground (Owyhee)</td>
<td>Growth increased beyond trend</td>
<td>RCP 8.5, decrease in precip.</td>
<td>Increase in motorized recreation and trail usage</td>
<td>Small increase in commercial</td>
<td>Increase in fire risk</td>
<td>Decrease in aquifer levels</td>
<td>N/A</td>
</tr>
<tr>
<td>Ecological Conservation (Owyhee)</td>
<td>Slight increase in population</td>
<td>RCP 2, low decrease in precip.&amp; heat</td>
<td>Decrease or limited recreation</td>
<td>Increase in economic incentives for ecology</td>
<td>Increases but controlled</td>
<td>Water BMPs causing increase in aquifer</td>
<td>N/A</td>
</tr>
<tr>
<td>Managed Recreation (Owyhee)</td>
<td>High increase</td>
<td>RCP 4.5 to 6, moderate decrease in precip.</td>
<td>Increase however managed</td>
<td>Increase due to influx of tourists</td>
<td>Increases but controlled</td>
<td>Water BMPs causing increase in aquifer</td>
<td>N/A</td>
</tr>
<tr>
<td>Keep Teton Wild (Teton)</td>
<td>Mod population growth</td>
<td>RCP 4.5, Moderate increase in heat and precip.</td>
<td>Small reduction of ag and decrease in recreation</td>
<td>Slight increase</td>
<td>Slight increase and controlled</td>
<td>Increase in water quality BMPs</td>
<td>Wildlife corridors and protection increases</td>
</tr>
<tr>
<td>Sustainable Mountain Community</td>
<td>Mod population growth</td>
<td>RCP 4.5, Moderate increase in heat and precip.</td>
<td>Increase in recreation</td>
<td>Slight increase</td>
<td>Slight increase and controlled</td>
<td>Increase in water quality BMPs</td>
<td>Increased protection, population centers impacted</td>
</tr>
<tr>
<td>Recreation Sprawl (Business as Usual)</td>
<td>High population growth</td>
<td>RCP 6.5, moderate increase of heat and decrease in precip.</td>
<td>Moderate growth of recreation areas</td>
<td>Moderate increase</td>
<td>Moderate increase</td>
<td>Decrease in water quality and quantity</td>
<td>Habitat quality decreases</td>
</tr>
</tbody>
</table>

### 5 RESULTS

Upon completion of all modules, students constructed various scenarios of change for both regions. Each student was assigned a specific scenario for one of the regions. The entire suite of scenarios was modeled through ArcPro software for advanced users or through ArcGIS Online for students with beginner and intermediate geospatial software skills. Students combined all scenarios into one platform, Geoplanner (ESRI, 2019), which was used to evaluate scenarios under various indices. An example of the graphic user interface for the web-based tool is provided in Figure 2. Results of this component, demonstrate students' abilities to create, evaluate and revise their scenario depictions (Figure 2) by influence from other student inputs. Students’ initial responses were either very coarse or at a fine grain in resolution, however post Module 3: Evaluation, student’s revised designs to meet a standard previously set by the cohort. Figure 2 depicts outputs of scenario configurations for the Teton Valley Idaho watershed from two students. Students revised their own work following review of other students’ scenario representations.
Figure 2: Example of student outputs through ESRI's Geoplanner. This example provides a geospatial depiction of a scenario as well as a set of indicators for Teton Valley, Idaho comparing two scenarios (Recreation Sprawl & Sustainable Mountain Community) of change for the valley. Various charts were used in Geoplanner to determine proportions of change per each scenario.

5.1 Scenario Evaluation with Consensus

Following scenario creation, various geospatial analytical tools were used to identify key areas of impact which denote agreement throughout the cohort. Consensus indicates a high level of agreement within both study areas across each scenario suite per the specified region. These results indicate areas of impact across all scenarios from the perspective of the GEM3 Geodesign Studio participants.

Figure 3: Histogram of Scenario Consensus for the Owyhee Region and Teton Valley Idaho.

Results from the Moran's Index (Moran, 1950) indicate low spatial autocorrelation through analysis of both regions. In the Owyhee Region, statistic tests indicate a z-score of 453 thus stating that random clustering is less than a 1% chance, refuting the null hypothesis of spatial autocorrelation. The z-score within the Teton region at a score of 2068 based on hotspot analysis of all student scenarios, denote a likelihood of less than 1% clustering by random chance thus providing statistically significance of clustering occurring at 97.18%.
6 CONCLUSIONS: Application of Heuristics in Scenario-based Learning

Results indicate that through scenario-based studio delivery, significant student consensus has been achieved for key areas of impact for across the suite of scenarios for both regions. The consensus indicates a heuristic approach (Tversky and Kahneman, 1974) for course delivery was successful for aligned transdisciplinary ideas from the studio. Student learning in tandem with a research-based scenarios project is achievable through platforms of delivery in a 14-week course for student learning at all levels. Refined scenario depictions provide the GEM3 SES research with draft scenarios as well as an expedited and statistically significant method to determine agreement amongst scenario depictions. In short, the modules of course delivery align student learning competencies with GEM3 research objectives for further scenario development.

7 DISCUSSION: Determining Heuristics in Pedagogical Course Delivery

Current shifts in our understandings of systems-level modeling and research require bespoke ontological discourse in our methods to address uncertainty (Thompson et al., 2020; Markolf et al., 2018; Ollivier et al., 2017). Our pedagogical practices in landscape architecture and planning are no different. This research intends to address and impart both needs for furthering our ontological conceptions of systems and solutions through scenarios education. The application of the uncertainty and bias heuristics (Tversky and Kahneman, 1974) for shortcut pathways of learning in scenario development provides a framework for studio course delivery to engage students at various levels for successful outputs. Similarly, alignment of transdisciplinary research and education as a new norm for learning can aid in application within course delivery of landscape architecture and planning studios. The alignment of research and application gives students and learners a sense of ownership as well as agency to better inform decision-making. There is a need for furthering research to leverage agency for students to transition into future practice, research, and continuing education. This course framework aims to address this need.

Similarly, further assessment of development in scenario-based, studio course delivery must be conducted to understand roles, impact for learning, and issues within the process. The evaluation of overall alignment of shared understandings amongst the student group demonstrates statistical significance; however, further methods to understand if student learning occurred needs further exploration. Further research requires qualitative and quantitative tools for learning evaluation to determine achievement of course and learning objectives. Proposed future research regarding studio configuration and evaluation
may consist of the following: a) pre- and post-course surveys to evaluate learning through self-assessment, b) geospatial metrics per each scenario based on variables and their significance, c) assessment of similar applied heuristics within other courses from various fields, and d) potential reconfiguration of studio modules to incorporate multiple iterations of designs through revision. Furthering research through transdisciplinary methods can be achieved through application of similar stakeholder/student engagement exercises with student-driven outputs, however further research requires learning and achievement success metrics.

This project and similar projects have the potential to significantly align education with research to improve local and regional understandings of systems, implications of designs, and iterations of the designs. In education, this research proposes heuristic-based modules for course delivery and structured courses applying a Geodesign framework to bolster student learning through anticipatory and systems-thinking competencies (Wiek et al., 2017). Paradigm shifts in our current education system can be addressed by scenario researchers’ capability and need to align teaching, scholarship, and service through similar studio frameworks to vet stakeholder assumptions (Ferguson et al., 2017; Steinitz, 2018). In terms of broader impacts, this research attempts to address these shifts by application in an active research project within a studio course. Furthering education and research is a need within our education and implementation-based networks, and preparation of students for future possibilities within both fields may be a focus within our education practices for the future of landscape architecture and planning.

8 ACKNOWLEDGMENTS

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9 REFERENCES


ABSTRACT
Design and planning are integral for sustainable development goals, including but not limited to: environmental protection, economic opportunities, and social justice (Khan et al., 2013; Wheeler, 2004). The application of key educational tools for achieving sustainable development and integrating theory with practices has produced a new paradigm in education called Education for Sustainable Development (ESD). This study focuses on the undergraduate course Foundations of Sustainable Systems, where students created postcards with images and text expressing their understanding and position on sustainability in a distilled and compact format. This study identifies what themes of sustainability students believe are essential and considers how the results have changed in different years.

The analysis uses a sequential explanatory mixed-method approach to identify themes and changes in student views. The research findings show that this open-ended teaching strategy can instill motivation and a positive attitude towards understanding sustainability in students. Understanding and identifying students’ thinking is critical in moving forward with a comprehensive vision to achieve a successful sustainability focus. In addition, identifying students’ learning will allow design and planning programs to improve their curricula and help educators advance the awareness to fully and explicitly integrate sustainability into their education offerings.

1.1 Keywords
Education for sustainable development (ESD), Landscape architecture education, Thematic content analysis
2 INTRODUCTION

Education is a vital strategy for achieving sustainable development (Bokova, 2015; Seelos & Mair, 2004; Vucetich & Nelson, 2010; Yli-Panula et al., 2020) due to the role in providing the knowledge necessary for society to adopt more sustainable practices. The United Nations Decade of Education for Sustainable Development stresses incorporating the theory and practices of sustainable development into education (Buckler & Creech, 2014). The integrating theory and practices movement caused the advance of a new paradigm in the education field, the Education for Sustainable Development (ESD) (Barlett & Chase, 2004; Blewitt, 2014; Kishita et al., 2018). ESD includes the characteristics of sustainability which consist of three dimensions: economic, social, and environmental (Lozano, 2008), allowing students to understand the importance of global, social, and human changes (Komiyama & Takeuchi, 2006).

Due to societal, economic, and environmental considerations, ESD became recognized as necessary for all levels of the educational system, including higher education (Bedawy, 2014). ESD aims to nurture future generations, encourage them to make informed decisions, and resolve complex problems (Chen & Liu, 2020), while also motivating them to gain knowledge, values, and theories related to sustainable development (UNESCO, 2019). These goals indicate a connection between ESD and the design and planning field. For instance, given the long-term environmental and social impacts of planners' decisions (Bolan, 1969; Sandercock, 1997; Wheeler, 2004), design and planning education is integral for sustainable development goals, including, but not limited to: environmental protection, economic opportunities, and social justice (Khan et al., 2013; Wheeler, 2004). Among design and planning disciplines, landscape architecture (LA) has experienced a crisis of theory and practice during its development. These trials and errors have influenced future landscape architects who "need to continuously ask and respond to the complexities of the natural and built environments" (Ozdil, 2021). These aspects strongly call for the advance of ESD in the LA field to provide insights and directions to LA education and practice.

This study aimed to identify the students' thoughts regarding sustainability to improve LA courses with the hope of influencing their philosophies and attitudes towards sustainability (Leeming et al., 1997; Mangas et al., 1997). Understanding students' thinking is critical to moving forward with a comprehensive vision and successful curriculum with ESD since there are many positive outcomes (Cotterell et al., 2019; Ferreira & Tilbury, 2012; Howlett et al., 2016; Rogers, 2001). Therefore, the study tried to analyze students' reflections about sustainability using an assignment in an LA course (Cotterell et al., 2019).

2.1 Conceptual Framework

Epistemology is an area of philosophy related to the nature and justification of human knowledge (Hofer & Pintrich, 1997). Epistemological beliefs allow researchers to play an essential role in the concept of teaching and learning (Schauss & Sprenger, 2019). As the current research explores students' thinking and beliefs about sustainability and how these ideas frequently appear, this approach can be a suitable theoretical approach for postcard content analysis research. Above all, this conceptual framework can gather subjective evidence based on individual studies and allow researchers to understand what they know from firsthand information (Creswell & Poth, 2016). For example, students taking a sustainability class might interpret sustainability based on their experiences, knowledge, or cultural backgrounds.

2.2 The Analysis of Visual Content

In this study, postcards from students show the construction and representation of essential images on sustainability. Visual content analysis is indispensable for the postcards, including images and text. For instance, Garrod (2009) assessed photos and postcards by focusing on comparing visual materials and identification of image composition. Many qualitative researchers have been interested in analyzing the visual content using photographs (S. E. Bell, 2002; Garrod, 2008, 2009; Hao et al., 2016; Kerkhoven et al., 2016; Rose, 2016; Sleipness, 2014). Hao et al. (2016) suggest interpreting the photos as a research method. Travel brochures or guidebooks are also used as a visual content study in the travel and planning field (Bhattacharyya, 1997; Edelheim, 2007; Hunter, 2008; Jenkins, 2003). Most travel brochure studies
focused on images rather than the writing of materials for analyzing brochures, but some researchers integrated images and text as a whole content (Ramachandran, 2005; Sleipness, 2014). According to Bell (2011), visual content variables consist of dimensions, such as size, color, or positions, and should be representative for analysis. Thus, the visual analyzing process needs to make clear definitions and criteria.

Another approach to visual content is to analyze the frequency of particular elements, such as the arrangement of images and embedded messages. This approach focused on identifying the frequency of elements, the arrangement of images and text, as well as the color used to identify the relationship between variables (Jenkins, 2003). Since visual or image analysis describes the appearance of specific themes, and often exceeds the text content or words spoken (Berger et al., 1972; Sleipness, 2014), researchers need a more profound insight when dealing with the images' latent content.

3 RESEARCH OBJECTIVES

This research seeks to understand and interpret important ideas embedded in students’ postcards. Due to the similarities between the postcards and travel brochures, both having descriptions and photographic images, this research followed literature analyzing travel brochures. This study interpreted texts and images of 90 postcards. The analysis procedure was to interpret images first, and then interpret texts or descriptions to identify overall students’ thinking. The goals of the study are to identify students’ ideas about sustainability through their postcards and to explore the principal student beliefs and attitudes regarding sustainability in 2016 and 2020 through their postcards, then to categorize and compare the themes of these postcards, and to find the congruity and differences.

This study addresses the following research questions:
RQ1. What ideas are reflected in the students’ postcards?
RQ2. What are the dominant attributes of students’ perceptions regarding sustainability, as presented through 2016 and 2020 postcards?
RQ3. Is there congruity between 2016 and 2020 postcards concerning the frequencies of attributes?

4 METHODS

This research used a sequential explanatory mixed-method design (Creswell et al., 2003) to examine what undergraduate students captured as a vital idea in sustainability by analyzing the students’ postcard submissions for their midterm assignments in the LA course.

Using thematic qualitative analysis (Stemler, 2000), the study explores students’ ideas and attitudes on significant aspects of sustainability. The current study also deductively generated constructs from literature and refined these based on the image and texts of the postcards. Lastly, the study quantified the frequencies of identified prominent themes and constructs to examine how their priorities change and differ between the 2016 and 2020 data sets.

4.1 Overview of Process

The explanatory designs in most research papers show that researchers collect qualitative data, analyze the qualitative data, and then build on the qualitative data for the quantitative analysis (Harrison, 2013). The current research process involves a two-phase explanatory design (Greene et al., 1989). The results of the first method (qualitative) influences the second method (quantitative). In other words, the study collected the data simultaneously but analyzed it sequentially.

Initially, the current study conducted a literature review regarding sustainability education and the thematic analysis research method approach. Secondly, this study selected 90 postcards. The Data samples consist of assignment submissions from a project in the Foundations of Sustainable System course in the LAEP department (LAEP 2039), instructed by Professor Carlos Licon. The LAEP 2039 course aims to help students understand a comprehensive sustainability vision while also explaining concepts of system approaches regarding issues and dimension of sustainability (Licon & Anderson, 2019). Thirdly, this study analyzed and coded 90 samples using the NVivo program, a software for performing coding
analysis for qualitative research, and a thematic analysis approach for identifying and determining individuals’ understanding of subjects (Stemler, 2000). During the coding process, this study used a six-phase process for thematic analysis (Braun & Clarke, 2006; Vais moradi et al., 2013) to classify codes into themes and patterns and interpret the meaning of the product. Lastly, this research used a Chi-Square analysis to examine the relative frequencies with which the qualitatively derived categories occurred.

4.2 Research Samples
The sample consists of 90 postcards (50 postcards from 2016 and 40 postcards from 2020 Fall semester submissions) completed as a midterm assignment for credit within an LA course. To conduct the card-making mission, the instructor asked students what sustainability is, how we communicate this idea, what embedded lessons we are delivering via implementing our concept and how we can better understand it, etc. (Figure 1). This task aimed to understand students’ attitudes and beliefs about sustainability, make the students think about or pursue activities using ideas from the lesson, construct a sustainable development practice, and send a message for future generations. After studying a broad range of ideas on sustainability, students can select a place, design, or theme, such as create, preserve, recover, remake, remove, produce, measure, protect, enjoy, promote, build, deliver, represent, or change, among others. The answers should represent students’ ideas about sustainability and communicate these ideas effectively to others. Also, the ideas should be included in a four-and-a-quarter inch by six-inch postcard (4¼" by 6"). The submitted postcards consist of various shapes, materials, and contents (Figure 2). For instance, some formed a diagram, sketch, or map, while others also used paper money, leaves, or grains of corn for popcorn. In this paper, I argue that identifying and interpreting the cards’ contents is necessary because these might reveal students’ unconscious or conscious thoughts regarding sustainability.

4.3 Qualitative approach: Thematic analysis
Researchers required students to express their thinking by making graphic content with one-hundred-word statements representing their ideas about sustainability. This qualitative approach followed deductive and inductive approaches from thematic content analysis (Braun & Clarke, 2006; Maschi et al., 2019; Vais moradi et al., 2013; Walters, 2016).

First, to analyze the latent meanings of images and text contents in postcards, we used thematic analysis to identify patterns or themes within qualitative data (Braun & Clarke, 2006). Its low reliance on a specific theoretical lens enables researchers to identify and analyze patterns and meanings using flexible approaches in their research (Braun & Clarke, 2006; Nowell et al., 2017). The current study used NVivo to code participant’s language (Miles & Huberman, 1994) and adopted a combination of inductive and
deductive thematic analysis. According to Braun & Clarke (2006, 2012), a six-phase approach to thematic analysis is an effective way to gain more profound insights into data, make the coding process quicker and easier, and develop themes confidently (see Figure 4). Thus, we followed six phases by coding postcards' image and text context to conduct a deductive thematic analysis. This analysis has 'top and bottom' and 'back and forth’ features (Walters, 2016).

![Diagram of six phases of thematic analysis](image)

Specifically, in phases one and two (Initialization), we reviewed visual and textual data of postcard submissions to familiarize ourselves with the data, considered the meanings within the data, and tried to find potential codes for developing themes. After reading and scrutinizing the data set to understand essential ideas and highlighted meanings, we developed an initial coding scheme. In phases three to four (Construction and Rectification), we read students’ descriptions several times and reduced the codes to categorize initial subthemes by describing students’ ideas. This study identified 32 subthemes based on the meaning units as an inductive approach in this stage. Initial subthemes were organized by clustering similar codes. Then, we adopted seven existing sustainability themes and abstracted students’ ideas and subthemes to define and name themes in phases five and six (Finalization). As a result, the main themes are named environmental, economic, social, socio-economic, socio-environmental, environmental-economic, and integrative. Finalized themes are related to research questions (Braun & Clarke, 2012) and sustainable development indicators (Spangenberg & Bonniet, 1998; Turcu, 2013; ul Haq & Boz, 2020). This study changed descriptions and classified codes into themes and patterns and tried to represent students' ideas in the products during the coding process. Notably, the coding process was conducted thoroughly and comprehensively by a member checking that someone on the team double-checked the coding process to validate this work.

4.4 **Quantitative approach: Frequency and Chi-square test of independence**

This study evaluated the joint frequency of themes and years using the Chi-square test of independence by comparing observed frequencies and expected frequencies (McHugh, 2013). In this case, we applied the Chi-square test to whether the joint frequencies of the respective themes occur with likelihoods greater than chance. The current study also conducted Z-tests of proportion to determine whether the 2016 group and 2020 group were different from each other. Specifically, this research asked about the predominant attitudes of students’ depictions regarding sustainability. We hypothesized that the probability of themes or depictions about sustainability presented that students’ priority is changing.
RESULTS

5.1 Qualitative Results

The research followed inductive and deductive coding and used 32 sustainability indexes from related studies as an initial coding guideline (Spangenberg & Bonniot, 1998; Turcu, 2013; ul Haq & Boz, 2020). As a result, researchers analyzed 290 codes for the 2016 year (N=51) and 244 codes for the 2020 year (N=39). The thematic analysis found that for students in 2016, sustainability was more likely to emphasize human interaction with nature while students in 2020 highlighted environmental resources and an existential mindset that reflects values and what makes life worth living (Prinds et al., 2014). Students' concentrated ideas regarding sustainability found the following:

[Sustainability] is 'human interaction with the environment; a preservation; a balancing act; how we humans interact with the environment and how we live our day to day lives; conscious and conservative use of resources; replenishing the resources an important part of living on this earth, etc.' [2016]

[Sustainability] is 'a mindset that requires action at every turn; hope to restore and preserve than overshoot the resources; creating a balance between the input and output in our lives and nature; the act of using natural resources without the worry; the ability to remake and renew; avoidance of the depletion of natural resources to maintain an ecological balance, etc.' [2020]

Additionally, most of the students' postcards described the important aspects of sustainability, focusing on environmental and integrative themes more than other themes, such as social, economic, and socio-economic. The following are identified students' descriptions and reflections regarding sustainability.

The descriptions show that many students tended to be aware of the urgency of waste issues in the ocean and land. Students also highlighted a comprehensive approach with philosophical thinking for achieving sustainability. While considering the complexity of sustainability, students emphasized various themes in sustainability; however, the majority focused on environmental and integrative themes.

[Environmental (Resources natural)] 'a lot of plastic, trash, waste, and recycling; we should widespread composting, and only use durable, recyclable materials; a lot of plastic in the ocean shows how unsustainable our current methods of packaging and disposal; as a nation, we need to be more aware of our resource usage and how much we waste daily; living in America we often don't realize that there is a limit on the amount of resources in the world, etc.'

[Integrative (Mix)] 'are there a variety of solutions that incorporate all these aspects in varying ways; sustainability can be defined that society, economy, and the environment are all equally satisfied; a closed-loop system looks to strengthen sustainable concepts by removing the waste from a system; do you feel confident that the planet is on a course that leaves it in an acceptable condition for future generations once you are gone; if you want to anything to change in this world; you need to represent sustainability means, etc.'

5.2 Qualitative Results

5.2.1 Frequency of Themes

Qualitatively identified themes were coded as categorical variables and subject to a frequency analysis using NVivo and Excel. Students' sustainability themes in 2016 and 2020 showed that the environmental theme was used most frequently in 2016 (22.76%) and 2020 (36.07%). Also, the mix/all topics in integrative themes followed the second highest frequency in both 2016 (21.03%) and 2020 (22.95%) (See Table 1).
<table>
<thead>
<tr>
<th>Themes and Subthemes</th>
<th>Years</th>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2016yr</td>
<td>2020yr</td>
<td></td>
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<tr>
<td><strong>Environmental</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources (natural)</td>
<td>66 (22.76%)</td>
<td>88 (36.07%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Housing &amp; Built environment (Man-made)</td>
<td>8 (2.76%)</td>
<td>2 (0.82%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service &amp; facilities (infrastructure)</td>
<td>4 (1.38%)</td>
<td>3 (1.23%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eco-efficiency</td>
<td>0</td>
<td>3 (1.23%)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Global impact</td>
<td>10 (3.45%)</td>
<td>8 (3.28%)</td>
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<tr>
<td><strong>Economic</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business activity</td>
<td>22 (7.59%)</td>
<td>9 (3.69%)</td>
<td></td>
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<tr>
<td>Labor productivity</td>
<td>1 (0.34%)</td>
<td>0</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>0</td>
<td>3 (1.23%)</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Technical and economic efficiency</td>
<td>9 (3.10%)</td>
<td>3 (1.23%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvability</td>
<td>9 (3.10%)</td>
<td>1 (0.41%)</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>15 (5.17%)</td>
<td>13 (5.33%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sense of community</td>
<td>2 (0.69%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crime and safety</td>
<td>0</td>
<td>1 (0.41%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equity</td>
<td>0</td>
<td>3 (1.23%)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>4 (1.38%)</td>
<td>6 (2.46%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social involvement</td>
<td>20 (6.90%)</td>
<td>11 (4.51%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy</td>
<td>0</td>
<td>1 (0.41%)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Conscious</td>
<td>12 (4.14%)</td>
<td>13 (5.33%)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Socio-environmental</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservation policies</td>
<td>0</td>
<td>1 (0.41%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental justice</td>
<td>3 (1.03%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global stewardship</td>
<td>16 (5.52%)</td>
<td>8 (3.28%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk-Intensity</td>
<td>4 (1.38%)</td>
<td>2 (0.82%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threat to Health</td>
<td>2 (0.69%)</td>
<td>1 (0.41%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport Intensity</td>
<td>1 (0.34%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Socio-economic</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business ethics</td>
<td>2 (0.69%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consume sustainably</td>
<td>1 (0.34%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fair trade</td>
<td>1 (0.34%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green technology</td>
<td>1 (0.34%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income level and distribution</td>
<td>0</td>
<td>1 (0.41%)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Enviro-economic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>5 (1.72%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green technology</td>
<td>1 (0.34%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource intensity of production</td>
<td>7 (2.41%)</td>
<td>6 (2.46%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Returns and investments</td>
<td>2 (0.69%)</td>
<td>1 (0.41%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Services</td>
<td>1 (0.34%)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Integrative Mix</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mix</td>
<td>61 (21.03%)</td>
<td>56 (22.95%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>290</td>
<td>244</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.2.2 Comparison of students’ attitudes in different year

This study indicates a difference in two different years and student thinking on sustainability and their ideas (See Table 2 and Figure 4). We expected most students to show a positive attitude because sustainability consists of positive meaning. However, the plurality of students showed neutrality and reflective attitude in 2016 (43.45%) and 2020 (36.48%). The postcard study emphasized the predominance of an environmental theme among the seven main themes. This research found that students’ concentrated ideas about sustainability were environmental themes, which focused on natural resources, and integrative themes. The next part of the study sought to investigate statistical changes in students’ ideologies between 2016 and 2020.

### Table 2. Comparison of Students’ attitudes

<table>
<thead>
<tr>
<th>Attitude</th>
<th>2016yr</th>
<th>2020yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Praise</td>
<td>43 (14.83%)</td>
<td>33 (13.52%)</td>
</tr>
<tr>
<td>Suggestions</td>
<td>67 (23.10%)</td>
<td>68 (27.87%)</td>
</tr>
<tr>
<td>Negative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concern</td>
<td>18 (6.21%)</td>
<td>19 (7.79%)</td>
</tr>
<tr>
<td>Denounce</td>
<td>18 (6.21%)</td>
<td>34 (13.93%)</td>
</tr>
<tr>
<td>Neutrality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>18 (6.21%)</td>
<td>1 (0.41%)</td>
</tr>
<tr>
<td>Reflective</td>
<td>126 (43.45%)</td>
<td>89 (36.48%)</td>
</tr>
<tr>
<td>Total</td>
<td>290 (100%)</td>
<td>244 (100%)</td>
</tr>
</tbody>
</table>

**Figure 4. The trend of students’ attitude. Diagram by the authors (2021). Diagram by the authors.**

5.2.3 Chi-square test and Z-tests of proportion

The current study conducted a Chi-square test of independence and Z-tests of proportion to compare the frequencies of the themes of postcards statistically and to determine the congruity between the 2016 and 2020 years. As a result, statistical differences were found for four out of seven categories. As shown in Table 3, the Environmental theme displays the highest percentage in 2016 and 2020. The Environmental (2016 16.47%, 2020 19.47%) and Integrative (2016 11.42%, 2020 10.48%) themes had
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statistically significantly difference compared to other themes (Environmental $z = 7.111$, Integrative $z = 4.333$, $p < 0.001$). They also showed statistically different interests between students’ descriptions in 2016 and 2020.

Table 3. Chi-square test and Z-tests of proportion results

<table>
<thead>
<tr>
<th>Themes</th>
<th>2016yr</th>
<th>Prop. (%)</th>
<th>2020yr</th>
<th>Prop. (%)</th>
<th>Total (N,%)</th>
<th>Z-score</th>
<th>p-value $^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>16.47</td>
<td>19.47</td>
<td></td>
<td></td>
<td>192 (36.0%)</td>
<td>7.111</td>
<td>12$^*$</td>
</tr>
<tr>
<td>Economic</td>
<td>10.48</td>
<td>5.43</td>
<td>15.9%</td>
<td></td>
<td>85 (15.9%)</td>
<td>3.148</td>
<td>0.002$^{**}$</td>
</tr>
<tr>
<td>Social</td>
<td>7.11</td>
<td>6.55</td>
<td>13.7%</td>
<td></td>
<td>73 (13.7%)</td>
<td>2.704</td>
<td>0.007$^{**}$</td>
</tr>
<tr>
<td>Socio-environmental</td>
<td>4.86</td>
<td>2.24</td>
<td>7.1%</td>
<td></td>
<td>38 (7.1%)</td>
<td>1.407</td>
<td>0.159</td>
</tr>
<tr>
<td>Socio-economic</td>
<td>0.93</td>
<td>0.18</td>
<td>1.1%</td>
<td></td>
<td>6 (1.1%)</td>
<td>0.222</td>
<td>0.824</td>
</tr>
<tr>
<td>Enviro-economic</td>
<td>2.99</td>
<td>1.31</td>
<td>4.3%</td>
<td></td>
<td>23 (4.3%)</td>
<td>0.851</td>
<td>0.394</td>
</tr>
<tr>
<td>Integrative</td>
<td>11.42</td>
<td>10.48</td>
<td>21.9%</td>
<td></td>
<td>117 (21.9%)</td>
<td>4.333</td>
<td>05$^*$</td>
</tr>
</tbody>
</table>

Note

$^a$ A proportion of the theme among all themes (margin = null)

$^b$ All $p$-value are shown, $^* p < .001$, $^{**} p < .01$

A chi-square test of independence was performed to examine the relationship between sustainability themes and different years. The relation between these variables was significant, $X^2 (6, N = 534) = 17.762$, $p < .01$. Based on the results, we can tell students’ concentrated thoughts of sustainability are more likely to be changed based on different years.

To interpret the association between sustainability themes and different years, this study conducted the residual analysis from the chi-square test. Environmental (2016 $z=-1.539$, 2020 $z=1.737$) and Economic (2016 $z=1.448$, 2020 $z=-1.579$) presented a significant difference between the observed and predicted values (See Table 4 and Figure 5).

Table 4. Residual analysis results

<table>
<thead>
<tr>
<th>Years</th>
<th>Environmental</th>
<th>Economic</th>
<th>Social</th>
<th>Socio-environmental</th>
<th>Socio-economic</th>
<th>Enviro-economic</th>
<th>Integrative</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>-1.593</td>
<td>1.448</td>
<td>-0.261</td>
<td>1.181</td>
<td>0.965</td>
<td>0.993</td>
<td>-0.319</td>
</tr>
<tr>
<td>2020</td>
<td>1.737</td>
<td>-1.579</td>
<td>0.285</td>
<td>-1.287</td>
<td>-1.052</td>
<td>-1.083</td>
<td>0.347</td>
</tr>
</tbody>
</table>

Figure 5 also shows positive and negative residuals. Blue shows a positive association that specifies an attraction between the corresponding row and column variables. While red displays negative residuals, it’s evident that there is an association between the years and the themes. Specifically, there are strong positive associations between 2016 and the Economy theme and between 2020 and the Environmental theme. This research revealed that the 2020 postcards tended to have more interest in Environmental themes like climate changes, recycling, and natural resources. However, the 2016 postcards are not associated with the row Environment. Combined themes like Socio-Environmental are more likely to show negative association in 2020 than in 2016. In conclusion, the distribution of sustainability themes and years is not independent, and there are significant changes between sustainability themes and different years.
DISCUSSION

This study aimed to identify and analyze students' understanding of the most important aspects of sustainability and how these thoughts have changed over the recent years. The current study analyzed 90 postcards created in 2016 and 2020 through qualitative and quantitative approaches. As an answer to RQ1 and RQ2, an examination of the study represented that the foremost aspects of sustainability for students were environmental topics and integrative themes, revealing that most students showed neutral and reflective attitudes. Interestingly, students wanted to create suggestions but had minimal questions. Why were students not asking questions? Since asking questions can be a teaching tool to assess students' knowledge and stimulate critical thinking (Tofade et al., 2013), we can consider improving these parts in future research or teaching.

The results of this thematic analysis clearly show that there are no universal ideas and attitudes on sustainability, supporting the argument of Lambrechts et al. (2018). A more detailed examination of individual students' ideas showed that their thoughts regarding sustainability are more likely to be changed over time (RQ 3). Their ideas in 2016 emphasized on human interactions with nature. However, 2020's postcards highlighted environmental resources and an existential mindset as vital ideas about sustainability. Our results provide evidence of an association between the two years included in the study and students' perspectives regarding sustainability. In other words, the primary ideas on sustainability are different at different times.

We concede that the results of this thematic analysis study are insufficient in terms of providing substantial sample sizes. However, this study believes that the study's sample sizes are robust enough to be used because sample sizes are various depending on the topic and the scope while conducting the thematic analysis (Morse, 2015). This argument is consistent with the statement by Braun & Clarke (2016) that thematic analysis emphasizes "a clear conceptualization of what those themes represent and why we treat them as significant, rather than chasing the relatively large sample sizes."

This study demonstrates that the postcard assignment was effective in teaching content of ESD in LA. This result can be supported by Çifçi & Kobyası (2017) who stated that teaching sustainability requires the support of positive images of the future and skills to explore important sustainability topics. This study believes that this open-ended teaching strategy can help students prioritize issues in sustainability and
acquire the knowledge needed to understand sustainability, including environmental resources, global stewardships, social involvement, technical and economic efficiency, etc.

Understanding and identifying students' thinking is critical in moving forward with a comprehensive vision to achieve a successful sustainability-focused curriculum (Ferreira & Tilbury, 2012; Howlett et al., 2016; Rogers, 2001). Therefore, the current study intended to reveal that ESD content needs to be developed further in alignment with students' perspectives on sustainability change. For instance, the postcard approach proposed in this study benefits students by organizing and considering important ideas on sustainability. Accordingly, it can be supportive content for current curricula development when teaching sustainability. It is also applicable in various disciplines and with different types of data such as (surveys, interviews, mind maps, and other text and image data). Therefore, innovative and appropriate content should accompany students' perspectives on teaching sustainability. The ESD content should combine open-ended teaching strategies with student reflections to improve the LA curricula.

7 CONCLUSIONS

The study results reveal that students' ideas and attitudes on sustainability are changing in integrative and reflective way. It seems apparent that in order to teach sustainability, current teaching methods need to evolve and change, not maintain traditional methods or a one-fit-for-all approach (Lambrechts et al., 2018) to draw students' attention and engage them.

What this study has demonstrated in students' thoughts and interests shows that there are changes in students' thinking in different years. Therefore, it can be concluded that ESD contents need revision for future courses, accompanying students' changing perspectives, attitudes, or understandings of sustainability because identifying students' positions and thoughts will allow design and planning programs to improve their curricula. This will also help educators advance the awareness and contributions to fully and explicitly integrate sustainability into their education offerings. This study can initiate developing course content for student-driven sustainability education in which the education is based on the learners' perspectives (Herranen et al., 2018). We conclude that developing courses based on students' thinking and attitude toward sustainability can yield quality curricula. Above all, evolving learning and curriculum needs in teaching sustainability to educate future landscape architects. Lastly, the authors recommend that further research could be oriented toward surveys or students' targeted interviews to incorporate a triangulation to improve the validity and reduce bias (Jonsen & Jehn, 2009).

8 REFERENCES


GEO-SPATIAL AND DIGITAL ANALYTICS

Edited by Hong Wu, & Travis Flohr
GEODESIGN FOR MULTI-SCALAR CONSENSUS: LESSONS FROM FLOOD ADAPTATION PATHWAYS PLANNING

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1 ABSTRACT
Geodesign is an iterative process for cycling through representation, evaluation, change, impact, and decision models to forge consensus typically across disciplinary more so than geographic boundaries. Multi-scalar integration of blue, green, and human infrastructure is necessary for adapting communities to large-scale extreme flooding scenarios timely and effectively. This project explored the feasibility of using multi-scalar geodesign to converge geographic perspectives from smaller-scale units of analysis (networks of water resources regions (WRRs)) into a higher-order consensus at the continental level to facilitate adaptation pathways planning for instantaneous flooding events, including flash flooding from dam breaks, tidal surges from polar reversal, and rapid sea level rise due to extreme solar events. Participants were initially organized based on their disciplines and geographical familiarity with a particular network of WRRs. Each team helped inventory priority intervention types and sites for blue, green, and human infrastructure components within its respective network of WRRs. Participants were then reorganized into continental teams with an equal number of representatives from each of the four network teams to integrate regional inventories of priority intervention sites and types into continental framework alternatives. Interrater reliability test indicated high reliability (ICC>0.9) in the response patterns of two independent raters (non-participants) that compared convergeability of each pair of alternatives into one: The pairs with the alternative generated without all representatives led to less converge-ability than those pairs containing alternatives generated with all representatives. The finding suggests the importance of integrated teaming in generating consensus-based, multi-scalar adaptation plans for disruptive flooding scenarios more rapidly.

1.1 Keywords
Flood adaptation, Adaptation pathways planning, Geodesign, Scenario planning, Infrastructure

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2 INTRODUCTION

2.1 Problem Statement

To account for climate science uncertainties and different adaptation attitudes in climate action plans, scenarios based on different climate predictions have been largely used to help develop adaptation pathways for long-term incremental risks, such as sea level rise (Butler et al., 2016). As climate change impacts have unfolded beyond the tipping points of many worst-case predictions to necessitate an ongoing shift in the de facto adaptation pathways, new climate adaptation strategies must be chosen and implemented for each shift before the full forecasted climate change impacts take hold. Many of these strategies will take decades to plan, design, and construct, while consensus-based decision-making for multi-scalar, interdisciplinary, and multi-jurisdictional climate adaptation can also take as long as decades. Meanwhile, many instantaneous threats of climate change, such as the impacts of solar storms on sea level rise, have been underestimated (Dorman, 2009). These threats tend to be addressed primarily through reactive and inadequate emergency evacuation (McEntire, 2015). The sustainability of regional systems hinges upon their adaptive capacities to respond to these disruptive changes timely and effectively. However, it is challenging to generate consensus-based strategies due to the complex nature of engaging different scales, timeframes, disciplines, organizations, stakeholder groups, climate projections, and adaptation attitudes (with respect to emergency evacuation, adaptation in situ, and proactive relocation). There is, therefore, a need to develop a larger-scale decision-making network composed of smaller-scale networks to facilitate consensus in order to address the complex nature of multi-scalar climate adaptation timely and effectively to better adapt communities to the impacts of instantaneous climate extreme events.

Adaptation pathways planning has been used to develop sequences of alternative actions that can be implemented over phases and adjusted depending on how alternative futures unfold as scenarios (Werners et al., 2021; Burnham & Ma, 2018). While adaptation pathways planning has gained traction in addressing the complexity and uncertainties in adapting communities to climate extreme events, it remains challenging for the decision-making framework to 1) detect instantaneous extreme events as unpredictable tipping points that could prompt a switch to another adaptation pathway (Bloemen et al., 2018); 2) engender transformative actions that shift current patterns at various scales onto more coordinated resilient long-term adaptation pathways (Scoones et al., 2020; Bloemen et al., 2018); 3) motivate regional and local authorities, non-government organizations, and the private sector to commit (Werners et al., 2021); 4) integrate reflexive learning in pathways approaches to represent diverse disciplinary perspectives, governance regimes, and decision hierarchies (Bosomworth & Gaillard, 2019); and 5) translate national policies into regional planning frameworks and local adaptation plans while accounting for complex dynamics across scales (Bloemen et al., 2018; Bassett & Fogelman, 2013; Fazey et al., 2010).

2.2 Backgrounds

Geodesign has the potential to address the aforementioned challenges through adopting three main approaches to adaptation pathways planning (Butler et al., 2016): 1) the use of performance thresholds to meet short- and long-term adaptation needs; 2) the engagement of diverse stakeholders in collaborative learning to enhance adaptive capacity; 3) the focus on transformative strategies that account for complexity and long-term change. A geodesign framework is often conceptualized as an iterative process of cycling through representation, evaluation, change, impact, and decision models until divergent perspectives have converged into a consensus-based decision (Gohd, 2020). This non-linear process engages participants from different disciplines and levels of expertise in systems thinking across space and time to generate complex solutions that are more adaptive to the complex problems associated with climate change (Steinitz, 2012). Geodesign has the potential to integrate multiple geographic information systems (GIS) to facilitate multi-scalar consensus-based decision-making for participatory climate adaptation. Geodesign is a data-driven process of collective creativity that enables multiple participants to design collaboratively online at varying scales and measures the impacts of each proposed design move as the collaboration proceeds (Rivero et al., 2015). The geodesign framework has been used in visualizing and comparing the performances of different models to 1) assess the influence of various combinations of systems (e.g., transportation, surface water, land use, etc.) on watershed sustainability; and 2) investigate
the interactions among multiple, interdisciplinary teams in arriving at consensus-based solutions (Debnath, Pettit, & Leao, 2022). The framework has been found to support high-performance collaboration when multi-disciplinary teams negotiate their design moves into a consensus-based plan by focusing on meeting common targets as performance-based objectives (Debnath, Pettit, & Leao, 2022).

A systematic review of geodesign approaches to city resilience planning in the literature identified a need to explicitly integrate collaborative multi-scalar scenario planning with performance evaluation to increase community engagement in resilience decision-making (Wu & Chiang, 2018). Flood-resilient urban design has been facilitated using a geodesign framework that helps the general public understand site-specific flood risk mapping and microscale three-dimensional (3D) design optimization for both sea level rise and extreme rainfalls in order to better evaluate a proposed design (ten Voorde, 2018). Microscale experience is critical for understanding the effectiveness of evacuation strategies for extreme flooding events, while examination of these scenarios across scales is essential for investigating relocation as an adaptive response to extreme flood risks (Terribile, 2020). Geo-spatial decision support systems (S-DSSs) for multi-scalar land planning and management provide operational tools to enable decision-makers to evaluate the tradeoffs between policies based on their ecological, social, and economic performances under current and future climate scenarios (Chen & Lee, 2015). However, no cases in the literature systematized the ways in which multi-scalar alternatives 1) emerge from stakeholders’ microscale experience and 2) converge into a large-scale consensus as a guiding framework for smaller-scale site-specific actions. Instead, the proposed site-specific designs and the multi-scalar frameworks were predetermined for evaluation (rather than generated) by participants using the aforementioned interactive platforms. While GIS was used to display and simulate multi-scalar spatial data to solicit public input in a workshop, the ways in which the public input converged into a multi-scalar consensus were not structured systematically for replication and validation.

2.3 Theoretical Framework

Landscapes are complex systems with non-linear feedback loops, which cut across multiple scales and diverse subsystems of components to self-organize into a coherent state as an emergent system-level attribute. The planning and design processes for landscapes as complex systems require “scaled system thinking,” which is a tripartite concept of complexity, system thinking, and scaled thinking (Chen & Lee, 2015). Scaled system thinking characterizes the design aspect of geodesign, which uses macroscale contextual forces as constraints to converge alternatives into mesoscale regional frameworks and microscale site-specific resolutions (Foster, 2016). The science aspect of geodesign has not been explored in its potential to generate non-site-specific universal knowledge from phenomenon that can be replicated for validation. To explore the potential of geodesign in integrating microscale perspectives into macroscale consensus as a coherent whole, this study proposed complex adaptive system (CAS) as a potential scientific framework for operationalizing adaptation pathways planning for disasters across scales and disciplines as three interacting systems (Burger, Kennedy, & Crooks, 2021): 1) the physical system of blue, green, and human infrastructure; 2) the social system of collective behaviors; and 3) the individual actor system.

CASs tend to have highly interconnected yet modular and resilient subsystems that are interchangeable enough to provide system redundancy (Nyerges et al., 2016). In other words, complex adaptive systems are likely to be made of similar subsystems that are open to change and thus better fitted into a coherent whole. Yet, each subsystem, as a decision-making micro-network, requires resilience to adapt to unexpected change. Such resilience is grounded in the subsystem’s structural complexity, which can be measured by the number of “bridging” links to diverse perspectives as opposed to “bonding” links (Newman & Dale, 2005). “Bridging” links help optimize collective decision-making to adapt to change, whereas “bonding” links homogenize the micro-network with constraining social norms (McPhearson et al., 2016). Based on this theory of CAS as a network of networks, an integrated geodesign team can be considered a high-complexity micro-network composed of a diverse collective of stakeholder agendas, disciplines, expertise levels, geographic interests, and organizations. This integrated teaming approach is likely to help reconcile conflicting perspectives more effectively, thus creating more resilient solutions better adapted to complex problems around climate adaptation. Bridging strategies have been found to increase
the organizational resilience of hierarchical/vertical emergency management networks (Jung & Song, 2015). When high-complexity micro-networks are created from bridging links as interdisciplinary teams for generating microscale alternatives, these teams, collectively, are more likely to form a high-coherence macro-network to generate macroscale consensus across both horizontal and vertical teams and geographic scales. In other words, compared to the silo teaming approach, this integrated teaming approach for geodesign is expected to generate outcomes that are more similar and thus convergeable across teams into a consensus-based action plan. The integrated team outcomes are more likely to be more interchangeable because these outcomes have been synthesized from similar integrated sets of diverse perspectives through “bridging” links. Moreover, because of their inherent diversity of perspectives, the integrated teams are more resilient and thus more likely to adapt to the changes required to strengthen the connections across team results.

3 RESEARCH OBJECTIVES

The overall goal of this project is to demonstrate the potential of a multi-scalar geodesign framework for adaptation pathways planning as a CAS of decision-making networks to facilitate timelier and more effective adaptive responses to extreme flooding scenarios. To achieve this goal, the first objective is to explore the feasibility of using the framework to converge geographic perspectives from smaller-scale units of analysis, such as networks of water resources regions (WRRs), into a higher-order consensus for transformative actions at the continental level. The second objective is to illustrate the use of the framework to translate the higher-order consensus for adaptation pathways for multiple flooding scenarios at the continental level into regional planning frameworks and local adaptation plans while accounting for complex dynamics across scales.

4 METHODS

4.1 Scenario-based strengths-weaknesses-opportunities-threats (SWOT) analysis

This study benchmarked three disruptive extreme flooding scenarios that require instantaneous transformative actions across geographic boundaries (Figure 1, Right of Image): 1) flash flooding due to more extreme storms that could lead to more frequent and catastrophic dam breaks; 2) tidal wave flooding (over the eastern half of the United States) caused by an overdue polar reversal (indicated by the rapidly weakening magnetic field) (Tarduno, 2018; Dikpati et al., 2017; Raup, 1985), and 3) flooding from rapid sea level rise due to the melting of all ice on Earth by extreme solar storms (that are likely to increase from now until 2025) (McEntire, 2015).

Figure 1. SWOT analysis of blue, green, and human infrastructure for flooding scenarios.

For each flooding scenario, a strengths-weaknesses-opportunities-threats (SWOT) analysis of blue, green, and human infrastructure was conducted through compositing GIS maps of existing and future...
conditions (Figure 1, Left of Image): strengths (S) and weaknesses (W) versus opportunities (O) and threats (T) referred to the aspects of the existing versus future conditions that were expected to facilitate or deter adaptation to the impacts of each flooding scenario. The suitability of an intervention was then determined by the extent to which the intervention helped transform Ws and Ts into Ss and Os.

4.2 Operationalizing physical, social, and individual actor systems

The continental scale was used to measure the coherence of the physical system containing the proposed blue, green, and human infrastructure components as CAS. The physical system was operationalized into four subsystems based on four networks of United States Geological Survey (USGS) water resources regions (WRRs) as the scale for which regional frameworks were proposed. The four networks were delineated to match the geographic domains of the four regions for the Climate Adaptation Science Centers (CASC). These four CASC regions or networks, North Central (NC), South Central (SC), Northeast (NE), and Southeast (SE), are indicated in green, orange, purple, and blue in the center of the network plan inventory and consensus graphics in the lower right corner of Figure 2. Each WRR is composed of several watersheds as the scale for proposing focus area plans. At each scale, potential design interventions proposed and selected by participants were categorized as blue, green, and human infrastructure components to operationalize the physical system based on the CAS framework.

To couple the physical and individual actor systems, an online mobile geo-survey was used to enable any local stakeholders to propose blue, green, and human infrastructure components through delineating their geographic extents on an interactive online map shared by respondents. To couple the physical and social systems, CASC recruited (from its networks of academic, government, and community contacts) four federal agency representatives originally from each of the four regions (NC, SC, NE, and SE) and 12 participants with three located within each of the four regions or networks. For each network team, four participants were recruited to represent expertise in hydrological, ecological, social, and economic sciences equally. To couple the social and individual actor systems, each of the four teams was initially composed of participants from its respective region or WRR network. The participants of each network team took turns selecting proposed infrastructure components from the mobile geo-survey results and proposing additional components based on their microscale experience. The consensus from each network team provided a regional inventory of the physical system for each WRR network based on the perspectives of the social and individual actor systems.
As shown in the concentric ring graphics in the lower left corner of Figure 2 and the teaming diagram on the left side of Figure 3, each participant of a network team was reassigned to a continental team. This teaming strategy ensured that each of the four continental teams had one representative from each network team. To resolve conflicts among the four consensus-based network inventories generated by the four network teams, each continental team took turns selecting components from the four network inventories to generate a continental framework alternative. Participants returned to their original network teams to take turns resolving conflicts among four continental framework alternatives to generate a consensus-based continental framework alternative. Two independent raters (that did not participate in the workshops) compared each pair of the consensus-based continental framework alternatives to determine if they were similar enough to be combined into a consensus-based continental framework that would remain similar to the original alternatives. The consensus-based continental framework was then used by each network team to revise their initial regional inventory for each WRR network into a regional framework based on multi-scalar consensus (Figure 3, Right of Image).

Figure 3. Geodesign framework for multi-scalar adaptation pathways planning.

4.3 Integrating CAS with geodesign for consensus-based decision-making

Three three-hour geodesign workshops were conducted based on the geodesign framework as an iterative process of cycling (across and within workshops) through representation, evaluation, change, impact, and decision models until divergent perspectives converged into a consensus-based decision. During the representation phase, geodesign participants first completed a pre-workshop mobile geo-survey before forming teams based on their disciplines and geographical familiarity with a particular network of WRRs (Figure 4, Bottom of Image). The mobile geo-survey enabled all participants to inventory priority intervention types and sites for blue, green, and human infrastructure components within their respective networks of WRRs they were familiar with. The shared inventory was made available to each geodesign team for further prioritization of intervention types and sites. During the evaluation phase, the participants reorganized themselves into continental teams to coordinate the regional inventories of priority intervention sites and types for blue, green and human infrastructure components. During the change phase, the participants returned to the original network teams to realign their previous network-level frameworks with the continental framework and to identify priority focus areas for site-specific interventions within each
network. The impacts of the intervention types for the priority focus areas were assessed based on their hydrological, ecological, social, and economic performances and the relative importance of these four categories of performances through post-workshop surveys to help select the final focus area and intervention types for the decision model (Figure 4, Top of Image). The six phases of geodesign formed iterative loops at each scale of analysis to facilitate the convergence of decisions at varying scales through the use of a pre-workshop mobile geo-survey and three three-hour long geodesign workshops.

![Network plan consensus](image)

**Figure 4.** Network plan consensus (top) with proposed interventions and suitable locations (bottom) based on geodesign outcomes and survey results.

### 4.4 Pre-workshop mobile geo-survey

Before the first geodesign workshop, participants were invited to delineate specific areas as possible intervention sites using an online interactive mapping interface. The interface allowed participants...
to submit interventions to Google Earth while turning on and off maps of existing conditions. The interface enabled respondents to exercise individual agency from the individual actor system through proposing locations and types of infrastructure interventions for minimizing the vulnerabilities of the physical and social systems. The following data for the physical system were obtained from Commission for Environmental Cooperation, Army Corps of Engineers, USGS, and CASC to determine physical vulnerability: Climate-related maps included historic and projected data for drought, precipitation, temperature, flood, hurricane, and sea level rise. Maps for terrestrial conditions included habitats and migration routes for monarch butterflies, elevation, watershed hierarchies, wetlands, protected areas, irrigated areas, land covers, impervious surfaces, and soils and geological surveys. Development-related maps included population density, existing and proposed transportation systems, urbanized areas, building footprints in addition to locations of high-risk dams and facilities that could explode due to flooding. The data collected for the social system used to determine social vulnerability included the census data and American Community Survey data from Social Explorer, indigenous land parcels from GitHub, and environmental justice indicators from the Environmental Protection Agency.

The first step of the mobile geo-survey asked participants to select one regional network they were familiar with to provide their input. The second step of the mobile geo-survey asked participants to select one infrastructure type they were the most familiar with, from green, blue, or human infrastructure. For those participants that chose to work with green infrastructure, they were asked to inventory priority sites to help monarch butterflies adapt to climate extremes, thus enhancing their migratory connectivity. These sites were prioritized because 1) their sizes were important for creating effective core zones for monarch conservation areas; 2) their locations were within a critical gap along the migration route without stopover sites within monarch butterfly’s daily migration distance; and 3) their landscape and terrains offered refuges and microclimatic advantages for protecting monarch butterflies from lethal conditions caused by more climate extreme events. Based on the aforementioned selection criteria, the participants delineated the five most suitable sites for 1) protecting existing monarch butterfly habitats, 2) restoring fragmented or lost monarch butterfly habitats, and 3) creating new monarch habitats.

For those that elected to work with blue infrastructure, the mobile geo-survey asked them to help identify important intervention sites for implementing distributed networks of decentralized water detention and retention areas upstream of high-risk dams that could lead to flash flooding due to dam breaks. These upstream water bodies were intended to capture enough runoff to eliminate the need to have high-risk dams downstream for flood control. In the event there was not enough open space upstream to capture enough volume of runoff, they were asked to identify possible sites for room-for-the-river projects downstream of a dam to minimize riverine flooding in general in addition to flash flooding caused by dam breaks. Based on these site selection criteria, they also delineated five most dangerous dams upstream of major population centers to be decommissioned and five most suitable sites for water detention/retention upstream of each dam selected, and the five most suitable sites for room-for-the-river projects downstream of each dam selected.

If participants selected human infrastructure, they were prompted to delineate potential relocation destination sites for individuals and businesses that had been displaced or would likely be impacted by climate extremes. As there was a need to create job training and opportunities in town-gown districts with Civilian Climate Corps/employment zones as job-based proactive relocation destinations, participants were asked to locate these districts within commute distances from climate-vulnerable population centers along planned high-speed rail lines, highways for self-driving vehicles using fuel cells, and flying taxi routes, or propose new transportation routes to facilitate the commute. Based on these site selection considerations, the mobile geo-survey asked them to delineate the five most suitable sites for relocation destinations within a commutable distance by 1) high-speed rails; 2) highways; and 3) landing and launching sites for flying modes of transportation. Participants were allowed to propose transportation routes and components that had not been planned or constructed. Some of the flying modes of transportation were intended to double as space transit habitats to facilitate emergency evacuation in the event of permanent inundation due to sea level rise or polar reversal and eventually proactive relocation to outer space.
4.5 Geodesign workshops

During the first part of the first geodesign workshop, participants formed teams based on the network of WRRs they were the most familiar with. Each network team followed the geodesign process to generate a draft consensus-based network plan of intervention types and locations. During the second part of the first workshop, participants formed continental teams composed of one representative from each of the four networks. Each continental team followed the geodesign process to cocreate continental plan alternatives that integrated intervention types and locations previously proposed for each of the four draft network plans. During the last part of the first workshop, each continental team presented their continental plan alternative while other participants evaluated the alternative through completing a survey. The survey contained three questions for each intervention proposed at the continental scale by each team: The first question asked the participants to use a four-point Likert scale to evaluate the hydrological, ecological, social, and economic performance of the intervention based on the following response categories: very low, somewhat low, somewhat high, and very high. The second question asked the participants to use a five-point Likert scale to evaluate the importance of each of the aforementioned performances from extremely, very, moderately, slightly, to not at all. The third question asked participants to provide open-ended comments on how to improve the proposed intervention and location. The survey results (Figure 4, Bottom Left of the Image) were used to identify final intervention types and suitable locations for the final continental plan.

During the first part of the second geodesign workshop, participants went back to their initial network team to revise the draft network plans created from the first part of the first workshop to make the network plan align with the final continental plan based on the survey results from geodesign workshop one (Figure 4, Bottom Left of the Image). During the second part of the second workshop, participants used the revised network plan to inform smaller-scale intervention types and locations for each of the WRRs within each network to create a regional plan for each WRR. During the last part of the second workshop, each network team presented each regional plan for each of the WRRs within their network, while other participants evaluated the regional plans through completing a survey with the same three questions for evaluating each intervention proposed at the regional scale. The survey results (Figure 4, Top Right of the Image) were used to identify, from each regional plan, at least two focus areas, each of which contained five priority intervention types and locations for use by the third geodesign workshop.

The third geodesign workshop focused on the South Central (SC) CASC network of WRRs for multi-scalar testing: Rio Grande, Texas-Gulf, and Arkansas-White-Red. During the first part of the third workshop, participants regrouped themselves into three teams corresponding to the three WRRs. Using the same geodesign process, participants began by reviewing all the WRR plans from the second geodesign workshop to resolve conflicts among the alternative WRR plans for the respective WRR for their team. This was accomplished through choosing intervention prototypes and sites that had received the highest scores from the analyses used by the Representation, Integration, Change, Impact, and Decision Models (Figure 2, Top of Image) described as follows: During the representation model, participants were asked to identify five priority intervention types and sites with suitability analysis that aimed to minimize physical and social vulnerability. During the integration model, participants were asked to resolve conflicts through multi-systems reconciliations, which involve choosing 1) monarch habitats over water management areas, 2) water management areas over developments, and 3) monarch habitats over water management areas and developments. During the evaluation model, participants took turns prioritizing intervention types and sites with the highest potential using SWOT analysis for each of the three infrastructure subsystems of the physical system. The potential was determined by the degree to which each intervention type and site helped transform Ws and Ts into Ss and Os from the SWOT analysis. The SWOT analysis classified GIS layers into Ss and Ws as favorable and unfavorable existing conditions versus Os and Ts as favorable and unfavorable future conditions for siting each of the blue, green, and human infrastructure components. The change model reconciled intervention types and sites with budgets using cost-benefit analysis.

During the second part of the third geodesign workshop, participants were assigned to one of the WWR teams to work on one of the top two relocation destinations within each WWR. Participants took turns to propose intervention prototypes and sites to be experienced from the eye level for each of the
green, blue, and human infrastructure subsystems of the physical system. During the change phase, the participants returned to the original network teams to realign their previous network-level frameworks with the consensus-based continental framework and to identify priority focus areas for site-specific interventions within each network. The impacts of the intervention types for the priority focus areas were assessed through the same performance-based post-workshop surveys (Figure 4, Top Right of Image) to help select the final focus area and intervention types for the decision phase, as shown in Figure 5.

Figure 5. Focus area phasing plans (left) based on continental consensus (bottom right of image) and regional framework (top right of image) as outcomes of three workshops.

5 RESULTS

Two independent raters who did not attend the workshops were recruited to evaluate the convergeability of every pair of continental framework alternatives. Four alternatives (A1, A2, A3, and A4) were combined into six comparison pairs (A1A2, A1A3, A1A4, A2A3, A2A4, & A3A4). The original six comparison pairs were duplicated ten times to generate 60 comparison pairs that were then randomly sequenced for presentation in Qualtrics. For each pair of alternatives for comparison, each independent rater was asked to determine whether the two alternatives were similar enough to be combined into one composite framework that would remain similar to the original framework alternatives. The Intraclass Correlation (ICC>0.9) of the Interrater Reliability in SPSS 27 showed that the following response patterns from both raters had excellent reliability (Koo & Li, 2016): The 30 non-convergeable pairs that are duplicates of A1A2, A1A3, and A1A4 always had the continental framework alternative from a team with some representatives missing for parts of the geodesign process (A1). A1 refers to the bottom map of the continental consensus graphics from the bottom right of Figure 1. The other duplicates of convergable pairs (A2A3, A2A4, and A3A4) had the other three continental framework alternatives (A2, A3, and A4) from teams with all representatives actively participating throughout the geodesign process. A2, A3, and A4 refer to the top three maps of the continental consensus graphics from the bottom right of Figure 1. The findings suggest that maximizing the diversity of geographic and disciplinary perspectives within each team was essential for multi-scalar consensus-based decision-making using the six phases of geodesign in three three-hour-long online workshops. Without the diverse geographic and disciplinary representations in the other three teams, the convergence of continental framework alternatives into a consensus-based continental framework would have required more workshops to be conducted. The results demonstrated preliminary feasibility of using CAS as a framework to structure geodesign workshops across scales with
geographically and interdisciplinarily representative teams. This integrated teaming approach has the potential to help facilitate more effective and timely decision-making around infrastructure intervention types and locations for flood adaptation pathways planning based on ongoing monitoring of disruptive extreme flooding events.

6 CONCLUSIONS

The proposed multi-scalar geodesign framework demonstrated preliminary feasibility for 1) converging geographic perspectives from smaller-scale units of analysis, such as networks of WRRs, into a higher-order consensus for transformative actions at the continental level and; 2) illustrating the use of the framework to translate the higher-order consensus at the continental level into regional planning frameworks and local adaptation plans while accounting for complex dynamics across scales. This study served as an initial step to demonstrate the potential of geodesign to enhance regional systems’ adaptive capacity to respond to the changing nature of climate adaptation pathways when optimized as a high-coherence macro-network of decision-making composed of high-complexity micro-networks of diverse geographic and disciplinary perspectives.

However, the potential of geodesign identified here as a mechanism for developing CASs of decision-making has not been systematically examined. This should occur through testing random, integrated, and silo teaming approaches using a larger number of geodesign teams and workshops. The silo teaming approach is more likely to create homogenous teams through “bonding” links that encourage conformance to cultural norms. The silo teams are low-complexity micro-networks around the cultures of distinct disciplines, organizations, geographies, or interest group agendas. These low-complexity micro-networks are postulated to result in polarized team outcomes that are less adaptable to the change necessary for creating higher-level consensus and for addressing complex problems around climate adaptation. In summary, these low-complexity micro-networks tend to lead to a low-coherence macro-network, necessitating more iterations of geodesign workshops to reconcile conflicting perspectives to generate consensus across teams. Future workshops can benefit from creating a baseline group of geodesign teams by randomly assigning participants into 1) silo teams, 2) a group of silo teams with participants from similar perspectives, and 3) a group of integrated teams with participants from diverse perspectives. The diversity of perspectives can be tested as disciplinary and geographic in different geodesign teams without overlaps to better parse out their effects versus combining them within the same team to study their interactive effects.

This study demonstrated the potential of an enhanced geodesign framework for multi-scalar consensus-building in addressing the aforementioned challenges and limitations associated with adaptation pathways planning in Section 2.1 through 1) synergizing multi-flood scenarios with geodesign to increase community resilience for instantaneous extreme events with unpredictable tipping points; 2) facilitating the convergence of microscale and mesoscale actions into more coordinated resilient long-term adaptation pathways as macroscale transformative actions; 3) incorporating regional and local authorities, non-government organizations, and the private sector into microscale, mesoscale, and macroscale decision-making networks to motivate their long-term commitment to transformative actions; 4) integrating reflexive learning in pathways approaches through interdisciplinary teaming across scales and multidimensional performance evaluations to represent diverse disciplinary perspectives, governance regimes, and decision hierarchies; and 5) translating national/continental consensus into regional planning frameworks and local adaptation plans while accounting for complex dynamics across scales.

7 REFERENCES


PLANNING FOR PRESERVATION: A CONCEPTUAL MODEL FOR PROTECTING TIGER HABITAT AND INDIGENOUS PEOPLE

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1 ABSTRACT

In 1973, the Indian government established ‘Project Tiger,’ a conservation initiative that created 50 tiger reserves throughout the country. The Amrabad Tiger Reserve (ATR) is the second largest of these reserves and has only 13 tigers, far below its potential capacity (Abhinay, 2017). The reasons for this low tiger count are inconclusive. Regardless, current government initiatives perceive any human interaction as having a negative impact on protecting the endangered tiger species (National Tiger Conservation Authority, 2019). This government approach directly impacts the Chenchu people, an indigenous culture that has lived alongside the Bengal tiger in the ATR for millennia. This conflict may result in the eviction of the Chenchu people from the ATR.

The purpose of this paper is to document a regional framework in GIS that seeks to define and preserve prime Bengal tiger habitat while still protecting the cultural heritage of the Chenchu people within the ATR. This is executed through research into the preferred habitat characteristics of the Bengal tiger and its prey. Based on this data, a suitability model for the tiger was created that defines prime Bengal tiger habitat. The framework then analyzes Chenchu settlement locations and characteristics as a subsequent overlay to weave the settlement zones around prime Bengal Tiger habitat to abate the perceived human-wildlife conflict in the preserve. The application of this methodology in the ATR provides a case study for similar scenarios where two inhabitants are in conflict, whether that conflict is real or perceived.

1.1 Keywords
Geographic Information Systems; Suitability mapping; Human-wildlife conflict; Bengal tiger; Chenchu people
2 INTRODUCTION

Human-wildlife conflicts exist throughout the developed world and are largely a product of modern civilization. These conflicts are most acute when they threaten keystone species on which entire ecosystems depend. Moreover, they become difficult to define when the human settlements that are identified as being in conflict are indigenous people that are part of the overall ecosystem and have evolved alongside the keystone species. Indigenous peoples are more likely to see their culture as a part of nature rather than apart from it (Colchester, 1994). This perspective holds true for the Chenchu People of the Nallamala Forest Preserve in Central India and their relationship to the Bengal Tiger. Most indigenous people of this region hold a positive attitude toward big cats even though they clearly acknowledge the risks they create (Sekhar, 2003; Bhattarai, 2014). When asked about their willingness to live alongside the Bengal Tiger, a Chenchu leader answered, “If a tiger or a leopard kills our cattle, we feel as if our brothers have visited our homes and they have eaten what they wanted.” (Survival International, 2018).

Even though the Chenchu people have coexisted alongside the Bengal Tiger for millennia, their way of life is being threatened. Current Indian government initiatives see any human interaction as having a negative impact on protecting endangered tiger species (National Tiger Conservation Authority, 2019). Within the Nallamala Forest Preserve, and in the Amrabad Tiger Reserve (ATR) specifically, these policies create a conflict where protection of the Bengal Tiger may result in losing the cultural heritage of the Chenchu people, whose ancestral lands most often intersect with pristine tiger habitat. Not all governments view indigenous cultures as disruptive to sensitive environmental systems. Some governments have acknowledged indigenous people’s role in protecting the environment and have begun enrolling them in the management of protected areas and species (Sekhar, 2003). It is the belief of the authors of this paper that the Chenchu people have a supportive relationship with the Bengal tiger in the Amrabad Tiger Reserve and that the government initiatives to remove them from their ancestral lands are misguided. Thus, there are two emerging crises: the impending removal of the Chenchu from the ATR and the identification of the actual threats of the current tiger populations in the ATR.

This non-funded research investigation seeks to address the first concern by proposing a regional framework for the future of the ATR that preserves prime tiger habitat while still allowing for Chenchu settlements. The background will provide context for this framework, and the methods will describe the research, criteria, and strategies used to execute the regional conservation framework. While the creation of remote sensing, GIS, and advanced modeling tools have been successfully implemented to identify and protect wildlife (Imama et al., 2009; Steinitz, 2012), these models typically focus on a specific species or ecosystem and view human development as another modeling criteria like topography or vegetative cover. The framework presented in this paper aspires to balance two keystone species (the Bengal tiger and the Chenchu people) through a series of models and overlays. The first model investigates the preferred habitat requirements of both the Bengal tiger and its prey. The study additionally analyzes Chenchu settlement locations and characteristics as a subsequent overlay in an effort to weave the settlement zones around prime Bengal Tiger habitat to abate the perceived human-wildlife conflict in the preserve. The canvas for this work is the ATR, but the framework itself serves as a model for addressing and potentially reconciling spatial conflicts between two keystone species.

3 BACKGROUND

The role of biodiversity in maintaining ecological balance and environmental stability is well documented (Singh et al., 2009). However, recent reports have indicated that biodiversity is declining globally at rates unprecedented in human history due to climate change, which interferes with species behavior, causes habitat loss, and reduces overall patch size and overall species carrying capacity (Malcolm et al., 2000). While reversing the decline in biodiversity can be addressed in multiple ways, the concepts of national and conservation parks put forward in the late 19th century are prominent means of conservation that promote biodiversity. Developed in the United States in the early 1800s, the idea of national parks or preserves has been widely adopted around the world as a tool for protecting the
most endangered species and the habitats on which they depend (Zube, 1989). By preserving ecological features, restoring historical and cultural sites, and inspiring the engagement of people inside or outside the park, the national park system helps to create biodiversity protection and development.

There were approximately 100,000 Bengal Tigers in the world at the turn of the 20th century, yet only 3,900 live in the wild today (Hauser, 2016), leaving them listed as endangered species on The International Union for Conservation of Nature Red List (Breitenmoser, 2008). India, home to 70-80% of the world’s wild tiger population, is at the center of this ongoing catastrophe. According to the 2018 Tiger Census Report, less than 3,000 Bengal Tigers exist in India (Patel, 2020). The Bengal Tiger’s habitat loss and resulting population decline have been caused by illegal poaching, urban development, large-scale agricultural expansion, and road construction. (Srinivasulu et al., 2002; Velho et al., 2012).

The Bengal Tiger, which has a disproportionately large effect on its environment relative to its abundance, serves as a keystone species in its ecosystem (Paine, 1995). Described by Davic (2003), the Bengal tiger is "a strongly interacting species whose top-down effect on species diversity and competition is largely relative to its biomass dominance within a functional group." The significant value of the tiger and its dramatic decline in India led to the establishment of a national protection project. In 1973, the government created ‘Project Tiger,’ a conservation program consisting of 50 tiger reserves today (NTCA, 2019). The program has yielded extraordinary results, with the population of Bengal Tigers in India growing from 1,411 in 2006 to 2,967 in 2018 (Breitenmoser, 2018).

3.1 Indigenous People and Perceived Conflicts with the Bengal Tiger

Formal labels for indigenous people were not recognized until the late 20th century, when biodiversity protection was already widely acknowledged (Tran et al., 2020; Stevens, 2014). However, the territories of indigenous people, who comprise 5% of the worldwide population, typically coincide with critical habitats for endangered species (Stevens, 2014). Research indicates that indigenous peoples can establish protected and conservation areas independently and through multi-scaled partnerships worldwide. The socio-cultural, political, and ecological benefits of these protected areas for indigenous cultures are abundant. They include the improvement of indigenous livelihoods, increased governance and management capacities, and improving species populations and habitat protection within their own communities (Tran et al., 2020).

While current research points to the benefits of indigenous cultures with endangered species, not all governing bodies share this view. In the case of the Indian government, there is a perception that the Chenchu people pose a threat to the Bengal tiger and that their presence in the ATR creates a negative impact on tiger populations (Sunarto et al., 2012). This has led policymakers to displace human inhabitants in reserves, believing it was necessary to achieve tiger conservation objectives. According to the National Tiger Conservation Authority (NTCA), ‘Once an optimum tiger carrying capacity is arrived at, habitat interventions should be planned in order to minimize conflict outside as well as reduce artificially induced internecine interactions amongst tigers’ (NTCA, 2019). Thus, even tribal peoples, who have occupied the same lands for millennia, are being forced to relocate to minimize human-tiger intersections, even if these interactions are not harmful to the tiger.

3.2 Habitat Conservation Planning Models

Shafer (1999) described formulating goals, selecting management categories, taking inventory, identifying gaps, designing reserves, measuring reserve condition and vulnerability, and recognizing the relationship between research and management as the basic elements of planning for the protection of biological diversity. Monitoring or predicting the likelihood of certain species is the first step in determining priority areas for conservation. According to the multi-Attribute Utility Theory, a habitat suitability model, based on GIS along with data processing, spatial analysis, and multi-criteria analysis, can be applied to indicate the landscape properties of preferred habitats (Johnson and Temple, 1986; Store and Kangas, 2001). With the maturation of computing power and empirical theory, remote sensing and GIS as tools in habitat suitability modeling for various wildlife species have become widely utilized and applied in conservation and wildlife management (Imama et al., 2009).
Several studies have explored suitability mapping of tigers with GIS as a powerful tool in addressing resource decisions (McDermid, 2005). While exploring the approach for forest conservation planning at a landscape scale, Phua et al. (2005) determined that a multi-criteria decision-making approach is valuable when handling complicated indexing in a GIS-based model. Singh et al. (2009) showed the successful integration of remote sensing, ground, and other ancillary sources in GIS to evaluate tiger habitat in the Corbett Tiger reserve. Similarly, Imama et al. (2009) aggregated different layers of land use, land cover, forest density, measures of proximity to disturbances, water resources, and other related criteria in a GIS environment to successfully model a habitat suitability index. While there are considerable studies on habitat suitability, few studies have attempted to model the lifespans of a keystone species and indigenous people to explore spatial coexistence and negotiate planning futures within the same ecosystem.

3.3 The Amrabad Tiger Reserve

The Amrabad Tiger Reserve, located within the State of Telangana in India, is the second largest tiger reserve in India. It sits within the Nallamala National Forest, where the landscape is primarily a series of parallel hills whose ranges are North-south oriented towards the eastern portion of peninsular India (Venkata et al., 2010). A southern tropical dry mixed deciduous forest is the dominant vegetation type in the reserve (Champion HG, 1968). The climate in this region is monsoonal, with monsoon rains typically occurring from June to September (Sudeesh et al., 2011). Average annual rainfall in the whole Nallamala forest is about 74cm. The hot season starts in March and typically lasts for three months, during which the temperature can reach up to 45°C (Reddy et al., 2008)

A report conducted in 2017 indicated the presence of only 13 Bengal tigers (Panthera tigris tigris) in the ATR (Abhinay, 2017), while the maximum biological carrying capacity has been estimated to be between 26 to 40 tigers. In 2010, political leaders had a stated goal of ‘double(ing) the number of wild tigers across their range by 2022’ (Hebblewhite et al., 2014). Both politically and environmentally, the ATR has a great responsibility to help protect the tiger and promote its tiger habitat.

Within the ATR, there are approximately 1,000 Chenchu households (Jinka Ramamurthy, 2020), with 87% of the households against the displacement of their settlements outside of the ATR, according to Jinka Ramamurthy’s (2020) fieldwork. For hunting purposes, the Chenchu have temporary, seasonal settlements in addition to their permanent settlements. Their diets consist of jungle products like roots, fruits, tubers, beedi leaves, mohua flowers, honey, gum, tamarind, and green leaves. For protein, they hunt wild animals like boar and deer, but with the increasing interest in wildlife conservation, they are also adjusting to hunting small animals like lizards, rabbits, and wild birds (Rao et al., 2007).

3.4 The Challenge of the Amrabad Tiger Reserve

Having thrived alongside Bengal Tigers, the Chenchu people’s ancestral lands have significant overlap with the relatively new Amrabad Tiger Reserve (ATR) (Reddy, 2006). While some of their settlements have already been relocated, a debate is ongoing as to if and where the remaining settlements should be moved. While some argue that all humans must be removed, others, who have worked closely with the Chenchu, think that they serve the overall conservation goals. “They [the Chenchu] don’t harm the tigers. In fact, the tigers are protected because of the Chenchu. The poaching and smuggling are controlled by the Chenchu presence” (Jinka Ramamurthy, 2020).

The extraordinary efforts made by India’s government have played a vital role in increasing the number of Bengal tigers, ultimately saving them from extinction. Still, Bengal tiger populations in the ATR are far short of the populations first recorded in 2010 (Jhala, 2011). The need for protecting Bengal tigers, the keystone species, is urgent. Could the goals of protecting the Bengal tiger be achieved while also preserving the way of life of the Chenchu people by modeling and negotiating the habitat and settlement criteria of both groups?
METHODOLOGY

As described in the introduction, the purpose of this paper is to present a regional framework for systematically thinking about the biological requirements for the Bengal tiger and preserving human habitation requirements for the indigenous Chenchu people. While the creation of remote sensing, GIS, and advanced modeling tools have been successfully implemented to identify and protect wildlife (Imama et al., 2009; Steinitz, 2012), these models often focus on a specific species or ecosystem. The methodology presented in this paper, however, generates models for two species (one for the Bengal tiger and one for the Chenchu people) and then overlays and negotiates the two models in an effort to weave Chenchu settlement zones around Bengal tiger habitat. The primary goal of the results is to abate the Indian government's perception of a human-wildlife conflict in the ATR.

4.1 General Outline of Methods

Accurate and relevant data are essential to the suitability modeling process. In this work, some of the data were already captured. Records of existing Chenchu settlement locations were collected through aerial photograph investigation for an appraisal report (Reddy, 2006). This data played an essential role in constructing the model for indigenous people, though it must be verified and updated as needed should the model results be presented to the government and Chenchu people themselves. Empirical data for the Bengal tiger, however, was unavailable due to the high cost of tracking the tiger over an extended period. As a substitute, Store et al. (2001) suggests the application of expert knowledge to help construct the model on the basis of relative research. For our purposes, this meant that, in place of tracking data of the Bengal tiger, it is appropriate to document the landscape characteristics associated with tiger behavior (e.g., shelter, prey, etc.) to determine the likely habitat areas for the species. This approach was utilized for this project through Geographic Information System (GIS), which has been widely acknowledged as effective in producing suitability models (Store, 2001). More specifically, it is appropriate for determining the habitat occupied by wildlife species or a population of such species (Singh et al., 2009).

The following two subsections discuss two suitability models, one identifying preferred habitat for the Bengal Tiger within the ATR and another identifying optimal settlement locations of the Chenchu People. Both suitability maps employ a Multi-Criteria evaluation (MCE), an additive technique designed to
facilitate decision-making in site selection, land suitability analysis, resource evaluation, and land allocation (Malczewski, 1999). Using this MCE approach, data is reclassified to a numeric value that corresponds with a value for determining suitability. For example, research indicates that the Bengal tiger prefers higher elevations in the ATR. Subsequently, the MCE approach reclassifies elevation data so that the higher, more desirable elevations are represented with a higher numeric value, and the lower, less desirable elevations are represented with a lower value. Additionally, each criterion is given a weight. For example, the optimal slope for Bengal tiger habitat is weighted less than the presence of tiger prey because the presence of tiger prey is more important in determining optimal tiger habitat than a preferred slope. The final suitability map is a composite of all reclassified and weighted data. The same method (but with unique data, reclassifications, and weights) was used in the suitability map for proposed Chenchu settlements.

Figure 2: Model Process Diagram. Diagram by authors.

The final subsection of the methodology describes the negotiation of the two suitability maps. With the political emphasis on tiger habitat through ‘Project Tiger,’ core tiger habitat is prioritized. The expected number of tigers (as determined by policymakers) was referenced to determine the minimum area needed. This minimum area was then located in accordance with the optimal tiger habitat as determined by the
suitability map. Boolean logic was applied to the Chenchu settlement suitability map to remove those core tiger habitat results. From this point, three unique alternatives are presented. Each alternative is a viable plan that supports a different level of tiger habitat, human settlement, and overall ecological balance. The planning process ends with these alternative futures, as the final decision would require stakeholder input and those needed to ultimately implement the plan.

4.2 Bengal Tiger Suitability Model

The framework for the Bengal tiger suitability model was grounded in an understanding of the characteristics of preferred tiger habitat. Initial stages of the research investigated environmental characteristics most essential for pristine tiger habitat. This included a preference for sites with high altitudes, steep slopes, a low level of disturbance, abundant soil carbon content, forest cover, and proximity to water bodies (Hewlett and Hewlett, 1995; Sunarto et al., 2012). While forest cover was the preferred land cover, other suitable land cover typologies were also integrated and reclassified accordingly.

Proximity to undesirable infrastructure and land cover was also considered, as was the availability of prey. According to research, chital, sambar, and wild pig (*Sus scrofa*) constituted a major part of the tiger’s diet (Biswas and Sankar, 2002; Bagchi et al., 2003). The proportion was 47.3%, 14.5%, and 10.9% respectively. Habitat density data for each prey was not available; therefore, habitat models for each prey were developed to identify prey density maps that were then integrated into the overall Bengal Tiger suitability map.

Much of the data was a direct reclassification of the raster data. For example, land cover pixels were reclassified to represent a higher value for preferred habitats like forests, a mid-value for land cover like grasslands, and a low value for undesirable land cover like croplands. In some instances, like in the case of the slope, DEMs were processed using ArcToolbox commands to produce slope percentages that were then reclassified. Buffer and Euclidean distance were also leveraged in the process to designate buffers from infrastructure like roads and proximity from resources like water. Additionally, weights for each parameter were assigned by considering the significance of each element in deciding tiger habitat as well as its ecological value derived from literature survey and expert knowledge (Singh et al., 2009). Characteristics like forest cover, prey availability, and proximity to water were weighted more heavily than other criteria.

The data reclassification characteristics are outlined in Table 1. Each reclassification included four output values assigned from least suitable (1) to less suitable (2), suitable (3), and most suitable (4). The final suitability map was accomplished by one additional calculation $P = \sum i_{qixmi}$, where $P$ is the suitability value assembled, $i$ is the suitability index, $q$ is the score of factor $i$, and $m$ is the classified value of each factor. Figure 3 shows the overall model flow for the preferred Bengal tiger habitat suitability map.
Figure 3: Bengal Tiger Suitability Model: A Suitability maps provide optimal locations for both permanent and temporary locations for the Chenchu people settlements. Image by authors.
Table 1. Bengal Tiger Multi-Criteria Evaluation: Relevant data that corresponds with tiger habitat preference was reclassified and weighted to determine optimal tiger habitat within the ATR.

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<th>Most suitable</th>
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<tr>
<td><strong>Chital Prey Modeling Criteria</strong></td>
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<td>(1)</td>
<td>(2)</td>
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<tr>
<td>Tree canopy / NDVI</td>
<td>20%</td>
<td>0-0.1</td>
<td>&gt; 0.3</td>
<td>0.2-0.3</td>
<td>0.1-0.2</td>
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<td>Slope (deg)</td>
<td>20%</td>
<td>&gt;30</td>
<td>20-30</td>
<td>5 ~ 20</td>
<td>&lt; 5</td>
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<tr>
<td>Distance to road (m)</td>
<td>20%</td>
<td>&lt;250</td>
<td>250-500</td>
<td>500-1000</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>Distance to cropland (m)</td>
<td>20%</td>
<td>&lt;250</td>
<td>250-500</td>
<td>500-1000</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>Distance to water (m)</td>
<td>20%</td>
<td>&gt;3000</td>
<td>2000-3000</td>
<td>1000-2000</td>
<td>0-1000</td>
</tr>
</tbody>
</table>

| **Sambar Prey Modeling Criteria** |       | (1)            | (2)           | (3)      | (4)           |
| Tree canopy / ND      | 20%   | 0-0.1          | > 0.3         | 0.1-0.2  | 0.2-0.3       |
| Slope (deg)           | 20%   | >30            | <5            | 20-30    | 5~20          |
| Distance to road (m)  | 20%   | <250           | 250-500       | 500-1000 | >1000         |
| Distance to cropland (m) | 20% | <250           | 250-500       | 500-1000 | >1000         |
| Distance to water (m) | 20%   | >3000          | 2000-3000     | 1000-2000| 0-1000        |

| **Wild Pig Prey Modeling Criteria** |       | (1)            | (2)           | (3)      | (4)           |
| Tree canopy / NDVI    | 25%   | 0-0.1          | > 0.3         | 0.2-0.3  | 0.1-0.2       |
| Distance to road (m)  | 25%   | <250           | 250-500       | 500-1000 | >1000         |
| Distance to cropland (m) | 25% | <250           | 250-500       | 500-1000 | >1000         |
| Distance to water (m) | 25%   | >3000          | 2000-3000     | 1000-2000| 0-1000        |

| **Overall Prey Habitat Suitability Assessment** |       | (1)            | (2)           | (3)      | (4)           |
| Chital                | 65%   | 1              | 2             | 3        | 4             |
| Sambar                | 20%   | 1              | 2             | 3        | 4             |
| Wild pig              | 15%   | 1              | 2             | 3        | 4             |

| **Tiger Habitat Suitability Assessment** |       | (1)            | (2)           | (3)      | (4)           |
| Tree canopy / NDVI    | 12.5% | 0-0.1          | 0.1-0.2       | 0.2-0.3  | >0.3          |
| Slope (deg)           | 12.5% | 30-60°         | 0-5°          | 20-30°   | 5-20°         |
| Elevation (m)         | 12.5% | <300           | 300-500       | 500-800  | >800          |
| Distance to road (m)  | 12.5% | <250           | 250-500       | 500-1000 | >1000         |
| Distance to cropland (m) | 12.5% | <250           | 250-500       | 500-1000 | >1000         |
| Distance to water (m) | 12.5% | >2000          | 1500-2000     | 1000-1500| 0-1000        |
| Soil carbon content   | 12.5% | Minimum        | Less          | More     | Maximum       |
| Prey availability     | 25.0% | Unavailable    | Moderate      | Sufficient| High          |

4.3 Chenchu People Suitability Model

The Chenchu people lead a seasonally nomadic lifestyle. As a result, they maintain both permanent and temporary settlements. Permanent settlements are typically 3 to 10 households and are most prominently associated with deciduous forests and proximity to water (Reddy, 2010; Dev, 2016). Proximity to water is not a linear reclassification, however. Settlements are established where there is access to water but a suitable buffer protecting them from wildlife commonly associated with water. According to the
Chenchu people, a buffer distance of 3-4 km is ideal. This means that being both near and far from water are undesirable (rated lower in the reclassification) with gradients of preference in between. Additional conditions for identifying optimal sites for permanent settlements include elevation, tree canopy, soil, and slope.

During the summer months, the Chenchu people will migrate to shaded areas and establish temporary settlements where sufficient food is available. Their culture depends on hunting and gathering of wild plants along with seasonal fishing (Reddy, 2010). For these settlements, tree canopy coverage and prey (rabbits and lizards) availability are critical factors in identifying preferred temporary settlements. Similar to the Bengal tiger suitability model, the prey availability data was determined by modeling the habitat preference of animals that the Chenchu people hunt within the ATR.

Altogether, relevant data, as shown in Table 2, was reclassified to include four output values assigned from least suitable (1) to less suitable (2), suitable (3), and most suitable (4). There wasn’t sufficient research available to determine the hierarchy of the data being reclassified, and all data were weighted equally in the final Chechu settlements suitability model. Future work on this topic must engage the Chenchu people to better understand that hierarchy to refine the settlement suitability map. The final suitability map was accomplished by one more step of accumulation: $P = \sum_i q_i \times m_i$, where $P$ is the suitability value assembled, $i$ is the suitability index, $q$ is the score of factor $i$, and $m$ is the classified value of each factor. Figure 4 shows the overall model flow for the optimal settlement locations for the Chenchu people.

![Figure 4: Chenchu People Suitability Model](image-url)
Table 2. Chenchu People Multi-Criteria Evaluation: Seasonal behaviors and settlement patterns were studied and relevant data that corresponds with these conditions was reclassified and weighted to determine optimal Chenchu settlement locations within the ATR.

<table>
<thead>
<tr>
<th>Rabbit Wildlife Modeling Criteria</th>
<th>Weight (1)</th>
<th>Least Suitable (2)</th>
<th>Less Suitable (3)</th>
<th>Suitable (4)</th>
<th>Most suitable (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree canopy / NDVI</td>
<td>33.3%</td>
<td>0-0.1</td>
<td>&gt;0.3</td>
<td>0.2-0.3</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td>Slope (deg)</td>
<td>33.3%</td>
<td>Minimum</td>
<td>Middle down</td>
<td>Upper middle</td>
<td>Maximum</td>
</tr>
<tr>
<td>Clay</td>
<td>33.3%</td>
<td>Maximum</td>
<td>Upper middle</td>
<td>Middle down</td>
<td>Minimum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lizard Wildlife Modeling Criteria</th>
<th>Elevation (m)</th>
<th>Distance to cropland (m)</th>
<th>Permanent Settlement Suitability Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
<td>Maximum</td>
<td>Elevation (m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;700</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt;700</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>500-700</td>
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<td></td>
<td></td>
<td></td>
<td>300-500</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum</td>
<td>Distance to water (m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper middle</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Middle down</td>
<td>&lt;1000, &gt;5000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper middle</td>
<td>1000-3000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Middle down</td>
<td>4000-5000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
<td>3000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
<td>3000-4000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temporary Settlement Suitability Assessment</th>
<th>Tree canopy / NDVI</th>
<th>Prey availability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
<td>Minimum</td>
</tr>
<tr>
<td></td>
<td>0-0.1</td>
<td>Less</td>
</tr>
<tr>
<td></td>
<td>&gt;0.1</td>
<td>More</td>
</tr>
<tr>
<td></td>
<td>&gt;0.2</td>
<td>Maximum</td>
</tr>
</tbody>
</table>

4.4 Overlaying and Negotiating Two Suitability Models

Both the Bengal tiger and Chenchu suitability models represent isolated suitability maps. They use objective data and research to provide insight into the settlement and roaming preferences of each user. The heart of this process, however, is the overlay of both models to propose a future for both users within the ATR. While there is no evidence that the Chenchu people are threatening the health of the Bengal Tiger population in the ATR, current government policies in India are still pressuring the relocation of Chenchu settlements. To address those concerns, the government's goals for preserving tiger habitat must be met to justify the preservation of the Chenchu people. With this in mind, the overlay and negotiations of both models had these two primary goals:

Goal 1: Protect and Expand Bengal Tiger Habitat
Using government goals for tiger population in the ATR, create a core habitat area that meets this goal and then expand the area and connect disparate parts of the core by identifying areas for habitat expansion.

Goal 2: Identify Areas for the Chenchu People to Thrive in the Reserve
After protecting core and expanded tiger habitat, create a plan for maintaining existing households and identify possible resettlement locations within the ATR for households that are within the core tiger area defined in Goal 1.

The state forest department established the goal of 32 to 40 Bengal tigers within the ATR, an increase from the estimated 13 Bengal tigers in 2017 (Abhinay, 2017). To determine the appropriate spatial requirements to meet that goal, the following formula was introduced:

\[ A = M \times (K_m \times T_m \times K_f \times T_f) \]

where

- \( A \) is the expected core area needed,
- \( M \) the estimated tiger population \( K_m \), the male tiger ratio, \( T_m \) the territory required by a male tiger, \( K_f \) the female tiger ratio, and \( T_f \) the territory required by a female tiger. According to research produced by Sadhu et al. (2017), \( K_m \) is given the value 0.43 and \( K_f \) 0.57. \( T_m \) (60 square kilometers) and \( T_f \) (20 square kilometers) were based on the data provided by Lions.org (Tigers’ habitat,
n.d.). $M$ represents the minimum goal of 32 Bengal tigers in the ATR. The maximum goal of 40 will be accounted for in the expanded core tiger area introduced in each of the three planning alternatives.

When executed, the formula indicates that 1190 sq.km. of core tiger habitat is required to address the Indian government’s goals for preserving tiger habitat. With the knowledge of this required area, the Bengal tiger suitability map was examined to extract the most pristine habitat within the ATR to designate it as core tiger habitat. The top percentile was extracted, and its total area calculated. If the total area was less than the required 1190 sq.km., an additional percentile was added. This process was repeated until the required minimum areas for Bengal tiger habitat were met. The resulting pixels represent the core tiger habitat. These pixels of high value were often consolidated, but the entirety of the 1190 square kilometers was not contiguous. The Bengal tiger, however, would need the ability to roam between all core tiger area (Turpentine Creek Wildlife Refuge, 2020). For this reason, an expanded tiger habitat area was established to, at minimum, connect all core tiger habitats. The tiger suitability map was referenced in these connections in order to expand the core tiger habitat in the most advantageous areas. The three planning alternatives (presented in the results) take unique approaches to these connections, having different motivations for where and how much expanded tiger habitat is allocated.

With the core tiger habitat established, certain permanent Chenchu settlements are impacted. These permanent settlements within the core tiger habitat would need to be relocated to other parts of the ATR in order to address the perceived impact they would have on the Bengal tiger population. Potential settlement locations would be determined using the Chechu suitability model results, with all results overlapping the newly established core tiger habitat removed. The remaining data reveals a hierarchy of spaces that most closely match the settlement characteristics of the Chenchu people. Optimal results were extracted to account for all displaced settlements. To ensure a minimum of 3 kilometers between settlements, a triangular fish net was established to appropriately distribute the potential new settlement locations. While these potential new settlement locations respond to the preferred characteristics of the Chenchu people, it would be imperative for the Chenchu themselves to assess the model logic and investigate any proposed settlements to ensure it meets the needs of each community.

Traditional habitat conservation planning models introduce buffer zones beyond the core habitat zone. As they indicate, these zones provide more spatial separation to reduce potential conflict. In the case of the Chenchu and core tiger habitat, however, no specific buffer was established. For one, the Chenchu settlements are light on the land, and they themselves do not pose a threat to the Bengal tiger. Additionally, this project sees the Chenchu in harmony with both the land and the Bengal tiger. In time, as stewards of the land, they can prove to foster the safety and expansion of Bengal tiger habitat.

5 RESULTS

Based on Tiger and Chenchu analysis, three alternative futures were presented. All meet tiger habitat needs by first integrating the core tiger habitat. This portion of each proposal was non-negotiable, and all alternatives share the same core tiger habitat. From there, each alternative expands the core tiger area through a different approach: Alternative 1 is Bengal Tiger Focused, Alternative 2 is Balanced, and Alternative 3 is Chenchu People focused. Each of the alternatives provides a viable plan that supports a different level of tiger habitat, human settlement, and overall ecological balance.

Alternative one offers the greatest expansion of tiger habitat, connecting all core tiger habitats with large swaths of the expanded habitat zone. This approach meets the top-end goal (39) for Bengal tiger population as established by the Indian government. While optimal for tiger habitat, this approach displaces 29 Chenchu settlements that will need to be relocated in the ATR. Those potential settlement locations, as indicated in Figure 5, are strategically located in the remaining areas of the ATR based on the modeling and fishnet strategies discussed in the methods portion of this paper.

Alternative two seeks to balance the tradeoffs for both the Bengal tiger habitat and the existing Chenchu settlements. In this proposal, the carrying capacity of the core and expanded tiger habitat is 34 tigers and limits the displaced Chenchu settlements to only 22 settlements. In limiting the number of displaced settlements and reducing the expanded tiger habitat by 35% (from 501 sq. km. to 325 sq. km.), the carrying capacity of the Chenchu people is increased.
Alternative three still maintains the core tiger habitat and only expands the tiger habitat to connect all core fragments and promote uninterrupted roaming of the Bengal tiger. The carrying capacity of the tiger still meets the project goals but limits the amount of land strictly designated for the tiger at the expense of the Chenchu people. As a result, this limits the disruption of Chenchu settlements, and retains a significant portion of the ATR for future settlements of the Chenchu people.

In each alternative, the lines of delineation between the core tiger habitat, expanded habitat, and Chenchu settlement are drawn precisely, but their application is a gradient at best. They provide an initial framework for the relocation of Chenchu settlements within the ATR. Given that there is no clear evidence that the Chenchu people pose a threat to the Bengal tiger population in the ATR, the lines could be described as merely a compromise between parties that currently disagree on the perceived conflict between these two signature inhabitants of the ATR.

Figure 5: Planning Alternative Comparison: Three alternatives are proposed that address the project goals but vary in the extent that they address each component. Image by authors.

6 DISCUSSION AND CONCLUSION

As a process, multi-criteria evaluation and suitability mapping have proven benefits, though most of their applications are for a single criteria or species. This paper argues that the same processes can also be instrumental in reconciling competing interests in the same territory. The objective, independent analysis of each user group, combined with specific goals and strict metrics, provides a framework for a future for both inhabitants. In the case of the ATR, the Indian government believes there are competing interests between the Bengal Tiger population vs. the Chenchu people’s settlement in the ATR. They see the sharing of the ATR as detrimental to the Bengal tiger population and, in turn, favor the removal of the Chenchu from the reserve altogether. This framework pushes back on this view, presenting an amicable solution for both interests: boosting tiger populations and keeping the Chenchu in the ATR. As indicated in the background section, though, it is the authors’ position that any conflict between the Bengal Tiger and Chenchu people is unfounded. The use of this framework is to abate a perceived human-wildlife conflict in order to prevent the Chenchu from being evicted from their ancestral lands.

It is important to note that the effectiveness of the framework is tied to the accuracy of the data. Data, even in this effort, must be scrutinized by the impacted communities and verified in the field. Additionally, many of the reclassifications of data and weights applied in the GIS model can be refined
through surveys, workshops, and input from the users or other researchers. The weights and criteria can also adapt to environmental changes related to climate change as new data emerges. While all parts of the GIS modeling were based on research into the tiger and indigenous culture, this process would be more comprehensive with direct input from stakeholders. Moreover, the planning alternatives must be a transparent process to gain the support and trust needed for its implementation.

Success, as defined by the Indian government policies, will be the increase of the Bengal tiger population in the ATR to meet the government goals of 32 to 40 tigers. The relocation of Chenchu settlements within the ATR can ease political pressure but what might be the actual threats to the Bengal tiger population are still at large. The success of this proposal must also partner with other ventures to address the threats that have harmed the Bengal tiger in the ATR up to this point. Threats might include the dwindling presence of tiger prey or the effects of climate change on existing tiger habitats (World Wildlife Fund, 2021). The most pressing and disturbing threat, however, is the illegal poaching of tigers. As an endangered population, tigers have a high value on the black market (YPTE, 2014). Without addressing the current threats to the Bengal tiger, specifically in and around the ATR, it is likely that indigenous cultures like the Chenchu will continue to receive blame for the decline of Bengal tiger populations.

7 REFERENCES


THE COLORADO BRIGHTFIELDS PROJECT: 
A LAND USE INITIATIVE AT THE INTERSECTION OF RENEWABLE 
ENERGY AND CONTAMINATED SITES

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1 ABSTRACT
Colorado’s proposed transition to 100% clean, renewable energy by the year 2040 presents serious land use challenges, given the massive land areas required for wind and solar power generation as compared to traditional fossil fuels. One potential solution is to site some of these projects on ‘brightfields,’ contaminated properties that can be repurposed for renewable energy development. The Colorado Brightfields Project is a geodatabase and web mapping application aimed at providing actionable data on brightfield sites in Colorado, streamlining the process of reaching statewide renewable energy development goals. Developed in collaboration with government agencies and energy industry consultants, contaminated properties were identified using a wide variety of state and federal datasets and populated with essential attribute data covering legal and regulatory information, physical site characteristics, and renewable energy potential. This dataset was then made available to the public through the web mapping application, which provides tools for finding, filtering, measuring, and assessing brightfield properties. Compared to similar mapping initiatives by the Environmental Protection Agency and state-level efforts in Massachusetts and Hawai’i, Colorado Brightfields provides several important advances over earlier precedents. These include the use of a much wider variety of contamination types than other databases to identify brightfields, presentation of the data as polygonal parcel boundaries rather than simply as points, and provision of contextual data overlays such as topographic contours and electrical infrastructure that can be critical in renewable energy siting decisions. These innovations can provide a template for future brightfield mapping efforts in other states as they seek to reach their own clean energy goals.

1.1 Keywords
Contaminated sites, Renewable energy, Brownfields, Geospatial analysis, Web mapping application
2 INTRODUCTION

Like many states, Colorado has embraced ambitious new goals for reduction of carbon emissions in recent years. In the spring of 2019, the newly-elected governor of Colorado, Jared Polis, set a goal of transitioning the state's electricity generation to 100% clean, renewable sources (such as solar, wind, geothermal, and biomass) by the year 2040, for the purposes of reduction in the rate of climate change, creation a more resilient electrical grid, improved air quality and health for Coloradans, and preservation Colorado's natural environment (Colorado Energy Office, n.d.). To achieve this goal, development of renewable energy projects will need to be accelerated dramatically. Even though Colorado's renewable energy generation has more than tripled in the last decade, only 35% of the state's current energy comes from renewables (U.S. Energy Information Administration, n.d.), leaving a large gap yet to be filled with less than two decades to go until the target date is reached. Unfortunately, energy sources such as wind and solar require up to 370 times more land area to generate the same energy as carbon-releasing sources like coal and natural gas (Merrill, 2021). As the pressure to develop renewable energy on large, open tracts of land intensifies, conflicts with other land uses, particularly agriculture, will become more common and problematic (Rule, 2014). As a result, energy developers will eventually need to shift to smaller projects sited in closer proximity to electricity demand.

One model that seeks to avoid these conflicts is the Brightfields Initiative, developed by the US Department of Energy in 1999, which advocates for the development of renewable energy projects on brownfields or other contaminated sites (The White House, n.d.). These compromised properties are often attractive for renewable energy development due to proximity to utility infrastructure, the potential to make productive use of property that may otherwise remain abandoned, and physical configurations that are conducive to wind and solar energy projects (Marcacci, 2017). A key roadblock in the promulgation of such initiatives is that many energy developers, communities, and electrical utilities lack the technical sophistication to identify, map, and assess potential brightfield sites. The Colorado Brightfields project seeks to address this challenge through the compilation of a publicly accessible geodatabase and web mapping application to inventory and analyze the suitability of various brightfield sites across the state for renewable energy development. As a proof of concept, an initial set of brightfields selected from ten Colorado counties was used to populate a geodatabase and provide the data backbone for the web mapping application, which launched publicly at https://brightfields.colorado.gov in mid-2021.

2.1 Advisory Committee

An advisory committee was formed at the outset of this project to help steer the development of the geodatabase and web mapping application to best meet the needs of potential users, as well as avoid potential pitfalls. Representations from energy developers, municipalities, state government, environmental organizations, and experts in land use and site contamination were included in the Committee to ensure that the resulting product would be broadly applicable for a range of potential uses. Participating organizations included the US Environmental Protection Agency, the National Renewable Energy Lab, the Colorado Office of the State Architect, Colorado Department of Public Health and Environment, The Nature Conservancy, Wilderness Society, the Colorado Governor's Office of Information Technology, renewable energy developers, Colorado electric utilities, and community solar advocacy groups.

The Committee met once in person at the outset of the project in January of 2020 for a brainstorming session to identify potential criteria for identifying the counties to be included, the types of parcels that would be identified as potential brightfield sites, and the types of site analysis data that would be helpful to users in assessing the suitability of individual parcels. A second meeting was held in the summer of 2020 to update the Committee on progress and solicit feedback on the development of the geodatabase and the web mapping application, and a final meeting was held in December of 2020 to unveil the completed products and solicit final feedback prior to the public launch. Between these meetings and throughout that year, various members of the Advisory Committee provided critical support in completing the project.
2.1 Literature and Precedent Review

Site suitability analysis, which is the process of assessing and overlaying multiple types of geospatial datasets to find preferred locations for a particular land use, has long been a staple use-case of geographic information systems (GIS) applications (Malczewski, 2004). In fact, this was the driving force behind the earliest conceptions of GIS and map overlay analysis in the 1960s during its nascent stages of development as a new technique for land planning (McHarg, 1969). Every land use has specific criteria that make each potential site more or less appropriate for that particular type of use or development, and renewable energy is no exception. A review of the literature on multicriteria GIS modeling for renewable energy development siting reveals a fairly consistent set of factors, including wind power potential (based on average wind speeds), solar power potential (measured as global horizontal irradiance, or GHI), distance to electrical transmission lines and substations, slopes, and land cover, among other factors (Janke, 2010). These criteria formed the basis for the attribute data to be included in the Colorado Brightfields project, along with critical additional criteria that were developed in coordination with the Advisory Committee, as described in (Section 4.4) below.

At the time of the database and web mapping application development, there were only three known relevant precedents for the type of mapping application that was being developed for this project: the EPA’s RE-Powering Mapper 2.0 (Environmental Protection Agency, 2011), the Hawaii Brightfields Initiative interactive map (Hawaii State Energy Office, n.d.), and the Massachusetts Brownfields to Brightfields (B2B) Site Mapper (Groundwork USA, n.d.). Each of these precedents was assessed for mapping functionality, accessibility, and data propriety for the purposes of siting renewable energy. The earliest precedent, which started development in 2012, was the EPA’s RE-Powering Mapper, a nationwide brightfields mapping utility that tracked four types of renewable energy sites: solar, wind, geothermal, and biofuel. It provided a fairly straightforward search and filter functionality that identified contaminated sites as simple points on a map and included attribute data on renewable energy potential for each of the four categories, the nature of the site contamination, and information on any remediation activities, along with some physical site characteristics, such as slopes and land cover (Environmental Protection Agency, 2011).

The mapping applications developed for Massachusetts and Hawaii shared many similarities with the RE-Powering Mapper, with some minor differences in the types of information presented. Of these, only the Hawaii mapper shows polygonal parcel data, but no other graphical information beyond the base map, and only the Massachusetts mapper offers a handful of contextual data layers that can be visualized. Despite providing some useful search features and site data, it was the opinion of the Advisory Committee that much of the information needed to make a decision regarding the feasibility of developing renewable energy on a particular site was lacking in these precedents. In particular, the Committee determined that more detailed physical site characteristics (such as parcel geometry, tree cover, presence of water bodies, proximity to roads, transmission line and substation locations, conservation easements, and topographic contours, among others), preferably presented in a graphic format, would significantly improve the practical usefulness of a brightfields mapping application. These shortcomings were specifically addressed and improved upon in the development of the Colorado Brightfields geodatabase and mapping application, as described in (Section 5) below.

3 PROJECT OBJECTIVES

The primary objective of this project was to create a powerful, comprehensive, and yet easy-to-use web mapping application that could find, display, and analyze potential brightfield sites across the state of Colorado to help facilitate development of renewable energy on compromised properties. In order to achieve this overarching goal, three sub-objectives needed to be met. First, given the reality of limited time and resources, a fair and representative methodology for the selection of counties had to be developed. Second, a consistent and replicable set of operations needed to be devised to identify brightfield parcels and populate attribute tables with analytical data. Finally, the compiled data needed to be presented to a user base that is not necessarily technically sophisticated in a simple, intuitive, and powerful format that would help facilitate the siting of renewable energy development on these sites. The ways in which these objectives were achieved are described in detail in (Section 4) below.
4 METHODS

The methods used to prioritize Colorado counties for inclusion in the project, identify parcels as brightfield sites, analyze those brightfield sites, assemble the geodatabase, and disseminate that information through the web mapping application are detailed below. All geospatial mapping, analysis and publishing tasks described herein were completed using ArcGIS Pro, version 2.6.

4.1 County Prioritization Methodology

Given the constraints of the Colorado Lab funding award in terms of time and budget, it became apparent at the start of the project that we would not be able to complete the geodatabase for the entire state. Since the most accurate parcel-level data is available in Colorado only at the county level, it became necessary to prioritize counties for inclusion. At the kickoff meeting with the Advisory Committee, a sub-committee was formed to explore the criteria that should be used to determine how to prioritize which of the 64 Colorado counties should be included in the initial geodatabase. In response to the general guidelines they provided, we devised a more comprehensive and detailed scoring mechanism that could fairly capture the most important criteria that would be positive indicators for the project. While the resulting prioritization guided the order of data collection and parcel analysis efforts, any counties found to be lacking sufficient data for parcel selection and data analysis were omitted from consideration, pending such data becoming available.

The criteria that were applied to the selection of counties for the first version of the geodatabase and web mapping application can be categorized as follows: Potential Demand for Renewable Energy Projects, County ‘Enthusiasm’ for Renewable Energy, Estimated Total Brightfield Acreage (based upon known contaminated sites from three sources), and Geographic Representation. These criteria, and the relative weighting of each of the metrics that went into the overall scoring, were based upon feedback from the Advisory Committee, which was tasked with developing a framework for ranking counties for the purposes of this study. There are, of course, many ways that one could choose to rank counties based upon these criteria, so the intent here was not to devise an unassailable ranking methodology, but rather to devise a methodology that is transparent and as fair and defensible as possible, given the economic and political interests that could become potential distractions from the main purpose of the project. In any event, it was an instructive exercise and useful in defending the selection of the ten-county area that was ultimately included in the database. The following describes the methodology used for ranking the counties.

The category of Potential Demand for Renewable Energy Projects was established by applying the metrics of county population, county growth rate over the past decade, recent and upcoming fossil fuel power plant closures, and designation as a state Opportunity Zone. The Colorado Opportunity Zone Program helps drive private investment and economic development in disadvantaged communities throughout the state by providing tax incentives for development projects in these communities (State of Colorado, n.d.), making them attractive locations for renewable energy development. The most current census data on the county population and growth rate available from the state of Colorado was adjusted to a 10-point scale. In addition, information about the closures of fossil fuel power plants that occurred over the past ten years, as well as those plants expected to cease operations over the next ten years, was considered. In order to quantify an environmentally conscientious transition from fossil fuel usage to renewables, the total generation capacity for each county was adjusted to a 20-point scale. Opportunity Zones were examined against the total area of the county and were adjusted to a 10-point scale. On this scale, 10 points equate to the opportunity zone covering 100% of the county. Calculations demonstrate that this category has the potential to reach a maximum score of 50 points, or 31.25% of the total score.

The category of County ‘Enthusiasm’ for Renewable Energy was established through a review of the metrics of county population, county growth rate over the past decade, recent and upcoming fossil fuel power plant closures, and designation as a state Opportunity Zone. The Colorado Opportunity Zone Program helps drive private investment and economic development in disadvantaged communities throughout the state by providing tax incentives for development projects in these communities (State of Colorado, n.d.), making them attractive locations for renewable energy development. The most current census data on the county population and growth rate available from the state of Colorado was adjusted to a 10-point scale. In addition, information about the closures of fossil fuel power plants that occurred over the past ten years, as well as those plants expected to cease operations over the next ten years, was considered. In order to quantify an environmentally conscientious transition from fossil fuel usage to renewables, the total generation capacity for each county was adjusted to a 20-point scale. Opportunity Zones were examined against the total area of the county and were adjusted to a 10-point scale. On this scale, 10 points equate to the opportunity zone covering 100% of the county. Calculations demonstrate that this category has the potential to reach a maximum score of 50 points, or 31.25% of the total score.

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rankings and awards from national RE advocacy groups. It was discovered upon initial calculations that these measures favored the more populated counties in the state. These counties, which are mostly located in the central and northern Front Range, typically have the greatest resources and means to actively seek RE grants and designations. In order to try to eliminate this bias, the scores were proportionally adjusted according to the county’s population. In other words, rather than simply tallying the number of renewable energy grants awarded to each county, the number of grants per 1,000 residents was calculated, resulting in a more balanced view of each county’s efforts to encourage RE development. This category had the potential to reach a maximum score of 50 points. This represents 31.25% of the total score.

The category of Estimated Total Brightfield Acreage was created by estimating the potential land available in each county for inclusion in the Brightfields Project geodatabase. Representative data sources were chosen to calculate these estimates, including the number of sites in each county designated by the EPA as federally-recognized brownfields, the number of sites designated by the CDPHE as state-recognized brownfields (eliminating those that were already captured in the federal data), and the number of closed landfills in each county. The project team feels that it’s likely that these sources, while not complete measures, can usefully predict the relative abundance of brightfield sites in each county. The total number of sites in each county was adjusted to a 50-point scale, representing 31.25% of the total score.

Finally, the category of Geographic Representation was created to improve the selection of sites from a wide variety of environments across the state, and not just the industrialized and densely populated Front Range. To combat this tendency, ten additional points were awarded to the top-ranking county in each of the state’s 14 Planning and Management Districts. The result was a more proportionate and representative geographic distribution across the state. This was particularly critical for the sparsely populated counties, which routinely ranked lower in all other categories. Ten possible points in this category represented 6.25% of the total score.

For complete results and visualizations, please see Table 1 and Figure 1. The order in which the counties are listed reflects their ranking, while the map reflects the same information geographically, with counties in brighter red ranking closer to the top of the list. After many iterations of possible ranking matrices, one fact emerged: all are imperfect, and none adequately represent the geographic diversity of the state. That said, we narrowed our preference down to the version described above after receiving input from members of the Advisory Committee and the Colorado Lab. Ultimately, the following ten counties were selected for inclusion based upon their ranking: Denver, Ouray, Adams, Jefferson, Pueblo, Lake, Weld, Arapahoe, El Paso, and Montezuma. Mineral, San Juan, and Hinsdale Counties were skipped due to unavailability of needed parcel data.

Table 1. Abridged ranking matrix used to determine county prioritization for inclusion in the Colorado Brightfields Project geodatabase and web mapping application.

<table>
<thead>
<tr>
<th>County Name</th>
<th>Total Land Area</th>
<th>Population 2019</th>
<th>Potential RE Demand Score</th>
<th>Population-Corrected RE Enthusiasm Score</th>
<th>Brightfield Total Acreage Score</th>
<th>Geographical Diversity Score</th>
<th>Total Score</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denver</td>
<td>156.089396</td>
<td>716492</td>
<td>25.25</td>
<td>0.48</td>
<td>50</td>
<td>10</td>
<td>85.73</td>
<td>1</td>
</tr>
<tr>
<td>Ouray</td>
<td>536.022777</td>
<td>4833</td>
<td>3.64</td>
<td>6.29</td>
<td>50</td>
<td>10</td>
<td>69.93</td>
<td>2</td>
</tr>
<tr>
<td>Mineral</td>
<td>862.599012</td>
<td>776</td>
<td>4.33</td>
<td>50</td>
<td>4</td>
<td>10</td>
<td>68.33</td>
<td>3</td>
</tr>
<tr>
<td>Adams</td>
<td>1198.69693</td>
<td>511868</td>
<td>33.62</td>
<td>0.22</td>
<td>33</td>
<td>0</td>
<td>66.84</td>
<td>4</td>
</tr>
<tr>
<td>San Juan</td>
<td>382.992844</td>
<td>762</td>
<td>13.23</td>
<td>39.91</td>
<td>3</td>
<td>10</td>
<td>66.14</td>
<td>5</td>
</tr>
<tr>
<td>Hinsdale</td>
<td>1105.92248</td>
<td>811</td>
<td>0.01</td>
<td>50</td>
<td>3</td>
<td>0</td>
<td>53.01</td>
<td>6</td>
</tr>
<tr>
<td>Jefferson</td>
<td>780.138773</td>
<td>580233</td>
<td>12.7</td>
<td>0.19</td>
<td>39</td>
<td>0</td>
<td>51.89</td>
<td>7</td>
</tr>
</tbody>
</table>
Figure 1. Color-coded map depicting prioritization of counties for inclusion in the Colorado Brightfields geodatabase and web mapping application (2020). Numbers in parenthesis indicate the rank of each of the 64 counties. Diagram by the author.

4.2 Brightfield Parcel Identification Methodology

One of the primary advantages of the geodatabase and web mapping application developed for this project is that it allows for the visualization and analysis of potential energy development sites at the parcel level, with county assessors’ property boundary data depicted as polygons. For a renewable energy developer, municipality, or designer seeking an appropriate site on which to build, this is a hugely important leap forward from other precedents, eliminating the time-consuming task of cross-referencing contaminated sites against other property records and researching or conducting a preliminary site analysis. Potential brightfield parcels were identified using GIS and tabular data (which was converted to a geospatial format) from dozens of datasets provided by numerous sources, such as state and federal agencies, as well
as non-governmental organizations. The four primary sources providing most of the data used, and the abbreviations used to identify each source, are as follows:

- U. S. Environmental Protection Agency (EPA)
- Colorado Department of Public Health and Environment (CDPHE)
- Division of Oil and Public Safety (OPS) at the Colorado Department of Labor and Employment
- Colorado Division of Reclamation, Mining, and Safety (DRMS)

The datasets provided by these sources cover various forms of land and water contamination, as well as indicators of vacant or abandoned land. Specifically, the following types of data were used to identify brightfields (with the data source indicated in parenthesis):

- State-Identified Brownfields (CDPHE)
- Closed Landfills (CDPHE)
- Petroleum Brownfields (OPS)
- Uranium Mill Tailings Remedial Action sites (CDPHE)
- Inactive Mines (DRMS)
- Institutional Control Sites (CDPHE)
- Voluntary Cleanup and Redevelopment Sites (CDPHE)
- Superfund Sites (EPA)
- Nationally-Identified Brownfields (EPA)
- Resource Conservation and Recovery Act Corrective Action Sites (EPA)
- Landfill Methane Outreach Program Sites (EPA)
- Vacant Industrial Sites (identified using a combination of county-level parcel and land use datasets)

The vast majority of this data was available only as point data that had to be associated with individual parcels using a location query. The collected brightfield parcels identified from all sources in each county formed the basis of the final geodatabase. The final feature class of brightfield parcels was assembled through an iterative process of identifying specific classes of brightfields (such as EPA brownfields or closed landfills), which were all merged into a single feature class of brightfields at the end of that process. For each identified parcel, the types of land contamination and/or abandonment were concatenated and appended to the attribute table as a new field.

4.3 Brightfield Parcel Standardization Methodology

Once all the parcels had been identified in a given county, they were compiled into a single feature class. In the case of duplicates, fields with differing attributes between the duplicates were concatenated to capture all the relevant data (for example, multiple types of contamination on a site), then the duplicates were eliminated in order to keep the parcel count accurate. Based upon the recommendations of the Advisory Committee, parcels of less than one acre in size and any parcels zoned as residential were eliminated from the dataset, as those were considered too small and/or too problematic to be viable for any meaningful electricity generation. On average, one acre of land can generate approximately 250 MWh/yr of electricity in Colorado (Ong, Campbell, Denholm, Margolis, & Heath, 2013), which the Advisory Committee considered to be the lower limit for a financially viable RE development.

Finally, the names of all fields included in the compiled feature class for each county were standardized in order to avoid unnecessary addition of duplicate fields and to allow for attribute queries to operate as intended. Great care was taken to ensure that all attribute field names and values were consistent across all of the counties and parcels included in the project to ensure smooth functionality of the web mapping application.
4.4 Brightfield Parcel Analysis and Geodatabase Compilation Methodology

Since existing site conditions are such an important consideration in the siting of a proposed renewable energy development, a number of site analysis measures were calculated for all of the brightfield parcels in each county, including metrics reflecting parcel area and shape, presence and areas of conservation easements, total square footage of tree canopy (which is an important consideration when siting photovoltaic panels), and other metrics as detailed in the list of attribute fields below. Following the completion of all applicable parcel analyses for all included counties, the parcels were merged together into a new statewide polygonal feature class of brightfield parcels. This feature class was then converted to an additional feature class of point data (with points located at the centroid of each parcel) in the same geodatabase to allow for point data display at zoom levels that are too coarse for useful visualization of polygons. The final geodatabase was also populated with all the overlay toggle layers that appear in the web mapping application, specifically:

- electric infrastructure (including transmission lines and substations)
- Colorado Enterprise and opportunity Zones
- utility service areas
- electric grid hosting capacity for Public Service Company of Colorado service areas
- Federal Emergency Management Agency (FEMA) flood hazard zones
- Colorado Ownership, Management and Protection (COMaP) data
- rivers, streams, wetlands, lakes, and ponds
- topographic contours (five-foot contour interval)
- conservation areas and easements

Each time the geodatabase is updated (with corrections or newly added counties, for example), all map layers must be exported to a hosted map service on ArcGIS Online, which serves as the data backbone of the web mapping application. The symbology and appearance of all layers in the mapping application are established directly in the ArcGIS Pro map interface and are carefully maintained for consistency and legibility. The final set of fields included in the geodatabase were as follows:

**Legal and Regulatory Information**
- Street Address
- Zip Code
- City
- County
- County Assessor’s Parcel Number
- Link to Assessor Record (where available)
- Legal Description of Property Boundaries
- Zoning (as per county zoning maps)
- Land Use (if available)
- Owner Type (private, municipal, state, etc.)
- Owner Names (where available)
- Easement Types (conservation easement, national wildlife refuge, county park, etc.)
- Easement Area (measured in acres)
- Opportunity Zone (indicates whether parcel is located in a state Opportunity Zone, yes/no)
- Enterprise Zone (indicates whether parcel is located in a state Enterprise Zone, yes/no)
- Brightfield Type (type of contamination and data source)
- Facility Name (name of the polluting facility, if applicable)
- Brightfield Notes (an open text field for additional information about site contamination)

**Physical Environment**
- Land Cover (as extracted from the National Land Cover Database)
- Parcel Area (acreage as reported by the county assessor’s office)
- GIS Parcel Area (acreage as measured using GIS software)
- Parcel Perimeter (measured in feet)
- Parcel Shape Index (a measure of the ratio of the parcel’s perimeter length to its area, which indicates the ‘regularity’ of the parcel shape, calculated using the following equation:

\[
\text{parcel shape index} = \frac{\text{parcel perimeter}}{4(\sqrt[4]{\text{parcel area}})}
\]

where parcel perimeter is measured in feet and parcel area is measured in square feet; a value of 1.0 is a perfect square, while larger values indicate increasingly convoluted parcel shapes)
- Built Area (total area of all existing structures as an indication of available renewable energy development area, measured in square feet)
- Canopy Area (tree canopy area, as an indication of potential shading on the site, measured in square feet)
- Distance to Nearest Road (as an indication of site accessibility, measured in feet)

Renewable Energy Potential and Electric Infrastructure
- Solar Global Horizontal Irradiance (measured in kWh/m²/day)
- Solar Direct Normal Irradiance (measured in kWh/m²/day)
- Windspeed at 80m Above Ground Level (measured in m/sec)
- Utility Service Area (the utility provider or electric co-op that services the parcel)
- Distance to Nearest Electric Transmission Line (measured in feet)
- Distance to Nearest Electric Substation (measured in miles)

For sample screenshots of the final web mapping application, which was built as a customized overlay of the familiar ArcGIS Online platform to allow for great functionality, please see Figures 2, 3, and 4 below.

Figure 2. Colorado Brightfields web mapping application default view, with brightfield parcels represented as points and adjustable filters displayed on the left of the screen (2022).
Figure 3. Detail view of parcels represented as polygons, with electric infrastructure and partial list of toggle layers visible (2022).

Figure 4. Detail view of a selected parcel with five-foot contours and aerial orthophoto visible, along with partial attribute list (2022).
5 RESULTS AND DISCUSSION

The Colorado Brightfields project was inspired by the need for a more comprehensive and useful brightfields mapping application that is specific to the needs of Colorado’s energy sector, and which addresses the shortcomings in the precedents identified in (Section 2.1). There are three key areas in which this project outperforms its predecessors: 1) inclusion of a much wider variety of contamination types for brightfields identification, including many that are unique Colorado datasets; 2) provision of polygonal parcel data; and 3) the addition of critical contextual data overlays to the mapping application. Taken together, these improvements constitute a suite of site analysis tools that better address the needs of energy developers and municipalities in making renewable energy siting decisions. A more complete discussion of each of these three areas of improvement is presented below.

5.1 Variety of Brightfield Types

The geodatabase upon which the web mapping application is built contains a much wider variety of brightfield types, based upon many more datasets of contaminated land, as detailed in (Section 4.2) above. As discussed in (Section 2.1) above, the precedent projects that were assessed at the outset of this project relied on only a handful of contamination types, typically EPA brownfields, state brownfields, and closed landfills. The datasets used in the Colorado Brightfields project include not only additional sub-categories of contamination and remediation programs, such as abandoned mines and petroleum brownfields, but also properties that tend to sit vacant due to a perception of contamination, specifically, vacant industrial land. These sites may or may not legally require remediation, but either way, they present many of the same advantages of brightfields over other types of sites for renewable energy development. By providing a wider array of brightfield types, the opportunities for renewable energy developers to utilize otherwise idle land are substantially improved.

5.2 Polygonal Parcel Data

The importance of using polygonal parcel data, rather than simple points, to identify brightfields is one of the most important innovations in this project. While it is true that point data can be populated with a wide variety of attribute data that covers some aspects of parcel geometry, like parcel area and perimeter length, there is no substitute for seeing a graphic representation of the property lines, which allows for a much richer understanding of the site and its context. This is particularly true when that polygon is paired with aerial orthoimagery and the types of contextual data overlays described in (Section 5.3) below. In addition to the polygonal parcel data, the brightfields are populated with the parcel shape index value, a measure of each parcel’s ‘squareness,’ as described in (Section 4.4) above. Given that solar and wind arrays are typically arranged in a gridded configuration, this metric can be an important tool in finding sites that have the most conducive geometry for this type of development.

5.3 Contextual Data Overlays

As described in detail in (Section 4.4) above, the Colorado Brightfields web mapping application includes a wide variety of contextual data layers that can be toggled on and off, including waterways, topographic contours, electric utility infrastructure, and conservation areas. These layers can provide critical information about the viability of a renewable energy development plan, revealing whether a site is too steep to build on, or is protected by a conservation easement that prohibits such development. Indeed, these additional layers provide much of the utility in the web mapping application, collating into a single source many of the critical aspects of site context and analysis that would require dozens of hours to acquire or produce independently.

6 CONCLUSION

The Colorado Brightfields Project represents a critical new geospatial dataset for renewable energy developers, municipalities, land use planners, and other stakeholders in Colorado, and a substantial step
forward over other existing brightfields mapping applications in terms of providing data to end users in an intuitive, yet powerful, online mapping platform. None of the precedents studied offers this unique combination of parcel-level assessor and site analysis data with the capability of toggling the visibility of a wide variety of targeted, highly relevant additional data layers that would impact development decisions. Taken together with the other mapping functionality built into the application, this project not only serves the intended purpose regarding brightfield identification and analysis in Colorado, but also provides a template for initiatives in other states and municipalities that wish to pursue brightfields development. Indeed, version 3.0 of the EPA's RE-Powering Mapper, released about a year after the Colorado Brightfields mapper, adapted many of the innovations found in the Colorado Brightfields mapping application. Despite the overwhelmingly positive reception to the Colorado Brightfields Project by stakeholders, there is still much work to be done. The project team is currently seeking funding to complete the brightfields geodatabase for the remaining 54 Colorado counties. In a very real sense, though, the brightfields geodatabase and mapping application is not an end point, but rather a beginning. Renewable energy development on contaminated or abandoned land has many well-documented benefits, but state policies have been slow to adapt. Like most states currently, Colorado offers no incentives for brightfields energy development. Only twelve states and the District of Columbia offer any type of financial or regulatory incentives for brightfield developments (Strine, 2022). By providing the technology and tools to more easily identify and assess brightfields, Colorado Brightfields can serve as an advocacy platform to help move brightfields development forward at the state and national levels.

7 REFERENCES


HISTORY, THEORY, AND CULTURE

Edited by Lisa Orr, & Stefania Staniscia
CONSTRUCTION OF A NATIONAL IDENTITY IN THE POSTCOLONIAL ERA: LOUIS KAHN’S CAPITOL COMPLEX LANDSCAPE IN BANGLADESH

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1 ABSTRACT
Modernist architect Louis Kahn’s (1901–74) landscape designs are a significant part of his projects. Though these landscapes play a substantial role, like the field, they remain invisible, latent, and thus taken for granted in comparison to his architecture(s), which are more visible and dominant. Therefore, while scholars have studied his projects extensively through an architectural lens, they remain unexplored through the lens of landscape. This paper examines the Kahn-designed National Assembly Building Complex (1963–82) in Dhaka, Bangladesh, considering how his designed landscape aided in the formation of Bangladesh’s national identity during its postcolonial (1947) and postindependence (1971) eras. The key question it asks is: How has the paradox of the design’s manifesting both a Western receptivity and a traditional sensibility operated in its role as a national symbol? With multimodal qualitative investigation: archival research, field observations, and spatial analysis, as well as interviewing Kahn scholars and professionals who were associated with the project, my paper aims to reveal the asymmetric power relations, the spatial hierarchy, and transcultural exchanges that undergird the project. In so doing, this paper explores the role that Kahn’s landscape has played in the formation of Bangladesh’s multilayered postcolonial identity. Holistically, my study probes into Western colonialism and modernism’s instrumentality in homogenizing traditions and cultures across the world.

1.1 Keywords
National Identity, Postcolonial Landscape, South Asian Modernity, Hybridity, Louis I. Kahn

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2 INTRODUCTION

In 1963, the Pakistani Government called Louis I. Kahn (1901–1974) to design the National Assembly Building Complex in Dhaka, East Pakistan (now Bangladesh). After twenty years, the Complex, commonly known as the Jatiyo Shangshad Bhaban, was completed (1983). During that time, the cost had climbed from US 15 million dollars to US 32 million dollars, more than double the original estimate; this was amid the country’s improvised circumstances of the 1970s/80s and heavy reliance on foreign aid (Shafi, 2017, p. 25). With time, the Complex became the most important piece in Bangladesh’s nationalist landscape and aided in forging the country’s national identity.

With significant impact both locally and internationally, in 1986, Kahn’s Assembly Complex participated in the third triennial Aga Khan Award. However, it was rejected (out of 213 nominations) because it was “not ripe” (Master Jury Statement, 1986), rousing controversy. The Aga Khan Award for Architecture is given every three years to projects that successfully address the needs and aspirations of societies across the world in which Muslims have a significant presence. The jury seems to have been deeply divided. To quote one of the jurors, Mehmet Doruk Pamir, the award was rejected because, in the jury’s opinion, “It did not represent Islamic architecture and mostly because it was not representative of the people of Bangladesh.” This cycle focused on cultural continuity, public awareness, Islamic rootedness, and the essence of Muslim culture.

In the next cycle, the decision was reversed, the 36 million sq. ft. Kahn-designed Complex received the Aga Khan award in the 1987–1989 cycle. It was at a time when the country was struggling with its democratic stature, facing military rule, and authoritarianism. This jury report stated, “The architect drew upon and assimilated both the vernacular and monumental archetypes of the region and abstracted and transformed, to a degree of utter purity, lasting architectural ideas from many eras and civilizations” (Steele, 1994). While plurality has been an essential characteristic of Islamic architecture and landscape which the Trust acknowledges, this paper finds the Complex’s syncretic existence in Bangladesh’s postcolonial, non-Western context problematic. Thus, the paper offers a critical view centered around this decision and argues the Complex to be a neocolonial landscape, leaving it to be a result of “double colonization…going through their postcolonial transformations…colonized, decolonized, and then recolonized by global capitalism” (Samayeen, 2020, p. 244).

2.1 RESEARCH OBJECTIVES

Focusing on Louis Kahn’s landscape design, and its relationship to architecture, my research looks at the landscape as a mediatory device as well as an object of representation that aids in the formation of Bangladesh’s national identity in its postcolonial (after 1947) and postindependence eras (after 1971). I am interested, first, in how and why people and the nation writ large accepted the Complex as a fitting national emblem of the newly born country. Second, although Kahn was one of the most acclaimed architects of the twentieth century, his landscape design, which is a significant part of his work, remains invisible, and thus understudied. Many architects and scholars have analyzed Kahn’s designs (e.g., Scully 1962; Ronner 1977; Brownlee 1991; Brownlee and Long 1997; Carter 2005) through a lens of architecture. However, only a few have explored work through the lens of landscape. The two authors who contributed to this dearth of scholarship are historian Kazi Florian Sauter and Khaleed Ashraf. Departing from Sauter and Ashraf’s works, my research centers on nation-building, nationalism, and national identity, examining how tradition, culture, and history are exerted in a physical space and place.

Since landscape design is a field that is embodied with ideological imprints and embodiments, it requires both empirical and theoretical probing. Thus, this research irrespectively relies on the postcolonial and social theories of Homi Bhabha, Ernest Gellner, Clifford Geertz, Eric Hobsbawm, Benedict Anderson, and visual theory as realized in the landscape, theorized by D. Fairchild Ruggles and Dianna Harris. Consequently, bridging the rift between theory and landscape, my paper explores why and how these theoretical ideas of nationalism, culture, and sociopolitical mechanisms are manifested in the Complex landscape in general.
2.2 METHODS
This research uses a multimodal qualitative method: archival research, field observations and spatial analysis, and interviews. The archival research probes communications between state officials and the design team and analyzes Kahn’s drawings and models (housed at the University of Pennsylvania’s Louis I. Kahn Archive). In addition to archival study, this research depends on spatial analyses of Kahn-designed sites in Dhaka, India, and the United States. The professional interviewees include Henry Wilcot, Kahn’s project architect; Roy Vollmer, junior architect; and Amir Hussein, who was the person from the Department of Architecture, Ministry of Works during the Dhaka Complex construction. They all worked closely with Kahn on the Dhaka Project. Current officers in charge from the Bangladesh Government’s Department of Architecture such as architect Kazi Nasir and government’s PWD officers and arboriculturists like subdivisional officer Kazi Md Abu Sayeed, responsible for the maintenance of the Complex landscape, provided a lot of first-hand information as well. Other interviewees include Kahn scholars such as architect B. V. Doshi from India, William Whitaker in charge of the Louis Kahn archive, Professors Shamsul Wares and Qazi Mowla from Bangladesh University of Engineering and Technology, and Professors David Brown Lee, David D. Long, and David Leatherbarrow from the University of Pennsylvania.

![FIGURE 1: The National Assembly Building Complex in Dhaka (previously, was intended to be called Ayub Nagar), site location, and proximity to the airport, cantonment.](image)

3 HISTORICAL BACKGROUND
The commission of the Complex was given to Kahn during a politically tumultuous period for the world due to the Cold War. Since the 1920s, several new capitol buildings were built that reflected the notion of modernity, adopting modern or Western architectural aesthetics (Khan, 2009). Modernism was thus embraced not only in Bangladesh but also in other South Asian cities and the cities of the Global South. The preference for foreign architects and importation of designs may seem antithetical to the spirit of sovereignty and nationalism, but at that time Western designs were regarded as a way of eradicating the stigma of being “of the East,” which often meant being somewhat regressive and antimodern. This idea itself was a form of indirect imperialism vis-à-vis the neocolonialism of the West triggered by Western-educated elites such as Muzharul Islam, a Yale-educated Bengali architect who recommended Kahn, which
still dominates the design culture even today. After 1971, Bangladesh was born based on nationalist ideologies primarily linked with Bengali/Bangla-speaking groups. Consequently, the nationalist ideologies were more pluralistic, secular, and based distinctly on regional characteristics.

In October 1958, Field Marshall-General Mohammed Ayub Khan took control of the parliamentary government of Pakistan by coup d’état. In June 1959, with an approaching election, the central government of Pakistan under him decided to create two new capitals, one in Islamabad in West Pakistan and the other one in Dhaka, in East Pakistan, to be named Ayub Nagar (Nagar meaning city in Bengali, Figure 1). As a military dictator, he pronounced himself devoted to a political system that combined democracy with the Muslim faith under his “Basic Democracy.” He needed the support of East Pakistanis in the election to be held in 1965 (Goldhagen and Kahn, 2000, p. 163). Thus, the idea of the second capital was conceived to satisfy the growing antagonism of the population with the provincial government of East Pakistan. Correspondences show a clear intention to build an identity through the built environment; the client sought a politicized image of Islam that they called “Muslim Architecture” with modern techniques. Also, memos suggest that the perception of Muslim architecture consisted of iconographic elements like domes and arches. These were also deemed symbolic of modernization and development, in an environment that otherwise was rural, traditional, and hence was considered backward.

In this regard, many foreign architects such as Edward Durrel Stone (1902-1978), and Greek architect and planner Constantinos A. Doxiadis (1913-1975) were working in Islamabad, West Pakistan at that time. They were figuring out ways of modernization through architecture and large-scale landscape interventions. Kahn was also briefly in charge of designing the President’s Palace in Islamabad. Doxiadis had laid a grid in Islamabad and sites were given to different designs to develop within the gridded site. However, the grid, a divisive and controlling landscape component, was already a colonial gesture. Kahn, who was envisioning beyond his project scope, stepped over the international architects working on the same and surrounding sites. Nevertheless, he was eventually dismissed from designing in West Pakistan for the failure to provide the demanded Islamic symbols.

To Ayub Kahn, implementing the same dogmas for East Pakistan was far less important; thus, its architectural aesthetics were overlooked since it was a political move and fast completion was necessary. Ashraf noted, “The decision to make a ‘second’ capital at Dhaka in the eastern region (East Pakistan) and to install the National Parliament there, was taken in 1959 not out of reverence for democratic institutions but as a bid to placate the growing discontent among the Bengalis against the hegemonic motives of western Pakistan” (Ashraf, 1994). Hence, while it was an endeavor to placate the growing turmoil of the Bengalis, it was also about bolstering Ayub Khan’s power. After Bangladesh’s bloody birth, the Complex name was changed to Sher-e-Bangla Nagar or the City of the Tiger.

4 THE SITE

With a renewed vision for a progressive Pakistan before Bangladesh’s independence (1971), Dhaka’s landscape transformation from agricultural farmland to the landscape of democracy was itself a neocolonial stance that began with the site selection. The Western idea of democracy was introduced, without appearing to be imposed. Kahn was initially given a site of 200 acres for the design of the new Assembly Complex, but this eventually grew to 2000 acres. The site’s expansive and flat land was being used for cultivation and a brick-making plant. To separate the new Complex from the existing city, it was placed far from the urban nucleus of Dhaka (Figure 1), near the army cantonment, and close to the military airport. This model of distancing from the center is not new; modern capital cities such as New Delhi and Brasilia were also placed in this way. The architect for the project, Vollmer, wrote that the West Pakistan government was naturally concerned with defense issues at the site; security for expected public resistance and political upheaval was a major concern (R. Vollmer, personal correspondence, Dec. 12, 2021).

The program of the Complex included an Assembly Building for the parliament, a supreme court, sports stadium and gymnasium, residence hostels for temporary and permanent housing of members of parliament and employees, educational facilities like schools and a library, a hospital, bazaar, recreational facilities, and more (McCarter, 2005, p. 259). Khandker explains that, like with the Capitol of the United States in Washington, DC, Kahn enacted a height restriction in conjunction with the effect that other buildings surrounding the Sher-e-Bangla Nagar area cannot exceed its approximate height of 194 feet (N. Khandker, personal communications, Jan. 9, 2022). This injunction was to create reverence for the Assembly Building, which is still followed in the Sher-e-Bangla Nagar area.
4.1 Kahn’s Assembly Complex Landscape

Kahn’s architectural conception of the new Building Complex was not restricted solely to any singular built form. Instead, he imagined his design as a cultural ideal that would operate at a large scale, integrating architecture, landscape, and the city. In the Complex Kahn created a dialectical relationship between architectural forms and the surrounding landscape. Known to be simultaneously a modern, postmodern, regional, classical-modern, or Roman-modern architect by different scholars, his works are embedded with syncretism. We see this at the Dhaka Complex, which is modernist yet traditional, Western yet Bengali, open yet monumental, forward-looking yet reverential. With huge open areas, the Complex's designed landscape is significantly bigger in scale than the Assembly Building (Figure 2), and it plays a vital role in constructing Bangladesh’s national identity. Regarding the design process, Kahn used landscape esquisses or early conceptual sketches (Carlhian, 1979), so that the landscape seems to have preceded the architecture. His landscape design at Dhaka, therefore, demands to be read in the same sequence—from landscape to architecture and with special attention to the landscape.

Kahn had a fascination for European castles, and Peter Reed (1989) has written that many of Kahn’s drawings closely resemble the aerial photographs of medieval castles, such as Beaumaris. Many scholars have referred to the building as resembling Scottish and Estonian castles. Similarly, the Assembly Building of the Dhaka Complex also looks like a castle. Kahn imagined the Dhaka Assembly Building as a “Citadel of Assembly.” In his design, it was intended to be visually and axially connected to a “Citadel of Institution” in the north within the larger Complex landscape. Kahn's mind thus dwelled on teleceptive, imaginary landscapes, inspired by faraway places.

In Dhaka, although Kahn had traveled in South Asia when the commission was assigned, the team relied on “The Arabian Nights,” the English translation of the Arabic 1001 Nights. Vollmer (R. Vollmer, personal correspondence, Feb. 21, 2021) mentions that once he was hired by Kahn’s office, he was recommended to read the book by Duncan Buell, Kahn’s office architect, before going to Dhaka. Interpreting Brownlee, it was seemingly an adventure of an unexplored place (following “Adventures of Unexplored Places,” Brownlee, 1997). This knack was also seemingly implicated in Kahn’s interest in

FIGURE 2: Site plan, (Roads A, B, C). The Assembly Complex amid surrounding landscaped areas, the ha-ha at the bank of the lake, ruin-like housing forms, and ghat-like steps. Photo courtesy: Author’s collection.
connecting the past to the present. But this very reliance which they thought could offer Bengal’s closest exotic representation also distances the design team from the reality of the region and explicates an orientalist categorization of cultural binaries—the "East" and the "West," or the creation of the “otherness,” that Edward Said explained (Said, 1979). The quest also ascertained Kahn’s reputation for searching for cultural archetypes. He mentioned “The wish for a fairy tale is our inheritance of first desires. When you have desire, but you have no means, all you have to do is wish, and it is still a fairy tale” (Wurman, 1990, p. 33).

The office’s first encounters with the site were through aerial views, which showed a flat land, vague plot lines, and a detached view of homesteads, buildings, and streets. Professor Qazi Mowla, who worked on the project, explains (Q. Mowla, personal communication, Jan. 12, 2022) that the site was more or less with sporadic small-sized water ponds, locally known as dobas, which essentially demarcated lower elevation and a mixture of land and water. Despite the annual monsoon, the site was not in the flood plain and had not been impacted by the major flood of 1954. For designing the Complex, the whole area was leveled, buildings removed, and the low spots were filled in, turning the site into a “tabula rasa.” In January of 1963, Kahn first went to see the site, a negative encounter in which he called it “a no man’s land completely without distinction; not a contour, a cluster of trees, not a distant landmark” (Curtis, 2013, p. 24). The site now gives only a remote trace of the prior landscape.

4.2 Natural and spatial archetypes – water, ghats, and boats

At this point, Kahn had already visited Mughal landscapes such as Humayun’s Tomb (16th c.) in Delhi and the Taj Mahal (17th c.) in Agra. In many ways, these historic edifices are reflected in his designs. His characteristic travel to search for “the beginning” continued in East Pakistan; he was in search of Bengali essence or “Volume Zero,” as he called it. He visited Shalbon Vihara, a fourteen-hundred-year-old monastery in Moinamoti, eight miles from the district of Comilla, which is by a short helicopter ride, arguably his inspiration for the Complex design (N. R. Khan, personal communication, January 2019). In Dhaka, he also visited the Mughal Lalbagh Fort (17th c.). He took a river cruise on the Buriganga river, the beginning point of Dhaka, a former port city. The riverine landscape of the Buriganga river fascinated him, and he made many sketches.

These esquisse, I argue, marked one beginning of the Dhaka Complex design; the other was his fairy tale imagination (Sauter, 2018, p. 275). So, there were two archetypes in the process, one local and Bengali and the other Western. In the visit, as one of his sketches depicts, Kahn also saw the colonial 120egan-baris (Garden house) or Bungalows such as the Ahsan Manzil (19th c.), and even earlier Mughal and pre-Mughal edifices as ruins. With juxtaposed forms from the Hindu, the Islamic, and the Colonial-era positioned alongside the river, he glimpsed the pluralism that characterizes Bengal. Perhaps the riverine landscape became a pleasureful subaltern exotic landscape that Kahn was seeking or perhaps the water signaled a Bengali essence that existed, free of modern and cultural essentialism.

Due to the monumentality and presence of the large water pond and garden, the red Plaza like Humayun’s Tomb podium, many scholars also argue about the influences of the Mughal landscape on Kahn’s Complex. However, in reverse, this research finds the Capital Complex’s placement amid gardens and open landscaped space more akin to modern landscape designs and particularly to those of capital complexes and institutional campuses of the mid-twentieth century. The soaring monumentality is seen in the capital of Brasilia in Brazil or large modern corporate campuses like Eero Saarinen’s General Motors (1949) in Warren, Michigan, or his ATT Bell Lab (1925) in New Jersey built in that era, which both had water (artificial lake) near the building. Instead, Mughal landscapes were mostly established by the riversides (like the river Yamuna) with visual and yet no tactile relationship to the water. According to Ruggles and Amita Sinha, visuality is determined by cultural codes, and the Mughals established their own “scopie regimes,” which could be identified with the interface of water and land (Sinha and Ruggles 2004).

Also, contrary to the creation of the plaza as in the Mughal example, the relation of the plaza with the architecture at the Dhaka Complex rather creates an illusion. Though it appears as if the Assembly Building rises from the plaza in reality it is detached from it. With a closer look, the isolation is visible, it seemingly rises from the water than the plaza. Therefore, this detachment operates as a ha-ha section (Figure 2, 3). For example, there are smaller, checkerboard gardens that step down and then rise again creating an inaccessible edge with the lake and thus, a ha-ha. This sectional detail recurs in the crescent lake road and its lake edge as well. Kahn’s expansive and exclusive styles use of ha-ha sections and landscape infrastructure in place-making makes him a modern-day Lancelot ‘Capability’ Brown, who was also popular in instrumentalizing ha-ha in vast English landscapes.
Numerous drawings and Kahn’s observations visiting Dhaka’s historic Boldah botanical garden (established in 1909) also show Kahn’s keen attention to *ghats*, a vernacular form that is embedded in Dhaka’s Bengali riverscape. These *ghats* are steps and embankments that act as transitional spaces between the water and the land. Framed by the sky and the water, the recurrent *ghats* are the key elements at the river’s edge, functioning as effective community spaces in Bengal. Also found in *pukurs* or *dighis* (large ponds), *ghats* are a symbol of a pluralist (found in both Hindu and Islamic cultural landscapes in the region) and an iconic placemaking device; they create a riverside horizon, which is inseparable from Bangladesh’s identity and collective cultural association. Often tied alongside *ghats* or floating amid the rivers, *deshi* (domestic) boats are also an inevitable feature of the natural and spatial archetypes. These boats were once the primary means of transportation in Bengal, which are now seen in the outskirts of urban areas and their rural counterparts. These landscape representations also appear in the 500 TK note where the boat and the deltaic landscape are symbolized. Along with the national archetype, currency later also symbolized the National Building Complex on its 50-taka currency note and the national flower on 5-taka currency notes.

Kahn’s sketching of riverscapes with boats, *ghats*, and sporadic ruins peeking in the backdrop recreated a Bengali picturesque landscape. Kahn’s oeuvre of travel sketches, resulting from his trips to Italy and around the Mediterranean (1950–51) and other European and North American cities, has helped in understanding Kahn’s meandering philosophies and idiosyncratic design development. His dramatized landscapes with contrasting colors, transforming sky and shadows in his artworks, turned into three-dimensional design reality in his architectural works that are credited with romanticism. Kahn’s sketches of Bengal’s riverine landscape help us to understand the romantic mental imagery he carried into the Dhaka project.

Though not close in design vocabulary and intent, the National Assembly Building Complex in Dhaka was planned like a city with the Mughal component *baghs* or gardens, water, and rich foliage, in conjunction with urban infrastructure. Today, with its civic plaza, gardens, and landscaped area, the National Assembly Building Complex stands as a large open space in the heart of the dense city. The central Assembly Building is flanked by two open plazas: the Southern Plaza, which opens as the complex’s southern entry, and to the north the “Presidential Plaza.” All the residences and institutional functions are grouped around the Assembly Building.

Kahn asserted that in Bangladesh, one needs to think of “an architecture of the land” (Ashraf & Haq, 2002, p. 36). By that, he meant molding earth and water to create conditions for his architecture. Kahn said, “No building can go in it before the entire site area has plan direction.” One scholar has noted that the rural huts in Bengal are built on mounds and that the Assembly Building was also built on a mound that was created with soil from the excavation of the artificial lake surrounding it. The Assembly retained its supremacy as the “Citadel of Institution” in the composition, set in the center as a crowning element among surrounding buildings, lakes, gardens, and plazas. Being a Beaux Art–trained designer, Kahn placed these landscape elements with a French idiom such as the use of axes, centrality, perspectival vista, *repousoir* (a feeling of infinity), and symmetricity. Initially, Kahn proposed some smaller gardens within the North premise that emulated the gardens in the Palace of Versailles designed by seventeenth-century French designer Andre Le Notre.

The two major arterial roads are set on the East and West sides of the site going in the north and south directions that were meant to give access to the Complex. Later, as major urban spines, they influenced the city’s planning and subsequent growth. There are also three major fares (Figure 2) going East and West: Manik Mia Avenue (A), the internal site street (B), and Crescent Lake Road (C). While all these streets were designed with active sidewalks embellished with plants, Crescent Lake Road, which bifurcates the site was specifically designed to be a “promenade” (Figure 3). Kahn’s idea of the promenade or more commonly known as esplanades is not new in the region. They echo the way the British Raj has inserted colonial infrastructure in the past. Thus, with Kahn, the 1900s discrete planning strategy came anew. These promenades, as colonial defense devices, overlooked “White Towns,” military towns, port cities, and presidential towns such as Delhi, Kolkata, and Madras in India. They created a buffer against the natives or “black towns.”
In Kahn’s design, the lake changed its location several times; initially, in the South, it was then moved to the North. But the main idea remained the same. The artificial lake surrounding the Assembly building and skirting the red bungalows creates a serene landscape that evokes a new Bengali Romanticism. This replication, reiteration, and reproduction of the Bengali riverine landscape archetype consequently generate a rejuvenated “genius loci” (or spirit of the place) of Norberg-Schulz (1992).

The mound rising from the water is a depiction of Bengal’s omnipresent deltaic landscape. Kahn also carefully brought in a boat and embellished the lake with water lilies (or Nymphaea pubescens) commonly known as *shapla*, the national flower of Bangladesh, which further helped in reproducing and domesticating the landscape. Therefore, the water feature of Bengali romanticism contributed to the Bengali nationalist sentiment.

While traditional *ghats* overlook the water and distant horizon with the architecture behind them, the *ghats* at the Complex are oriented toward the soaring Assembly building from each perimeter. As Ruggles and Harris argue, this instrumentality of vision over the landscape is intended and executed through designs (Harris and Ruggles, 2007). Hence, most of the time, public vision is constantly guided in the direction of the symbolic citadel, which seems heroic. Vollmer (R. Vollmer, personal email correspondence, April 3, 2020) confirms that the lake was instrumentalized as a historic and characteristically Western protection device—a castle moat. But at the same time, Khandker (2022) also affirms the moat’s functionality as a security mechanism.

It is not only the water and surrounding *ghats* that contribute to recreating Bengali imagery. Kahn also used local vegetation on the land. Drawings and scholarly materials from the Kahn Collection at AAUP...
as well as Wilcot’s communications verify that the team devoted itself to learning from books, studied in local gardens, and also discussed with local horticulturists in Dhaka’s PWD office. According to Wilcots (H. Wilcots, personal communication, Jan. 6, 2022), a small nursery was placed on the Complex premise, which was not in the original ‘program’ and “was developed as a means to study plants for the Capitol campus.” A recent finding of a plan (done in 1980, from PWD’s Horticulture Department) showed a list and intended exact placements of native plants that Kahn suggested. These plants included aromatic floral shrubs: Mimosop Elengi (local name Bokul) in the hedge and a tall floral tree with a canopy, Cassia Fistula (locally called Sonalu), which are still present in the designated spots. While some of the shrubs were to create hedges, offering aromas, and overall landscape aesthetics the tall native trees were to control the visibility of the buildings. For this reason, the tree canopy, foliage, length, and placement distances were minutely considered. For the promenade area in Crescent Lake Road (Figure 2, road C) as well as on Manik Mia Avenue, Krishnachura, or Flame trees, were suggested. The Botanical name of the Flame tree is Delonix Regia. A plant with a large canopy-like form and red-orange flowers, the tree also provides shelter from sun and rain. This consciousness of vernacular landscape features even further establishes Kahn’s landscape inclinations, which paradoxically and reciprocally worked with his architectures, successfully suppressing their Western genealogy.

Nevertheless, Kahn’s inclination towards natural elements and plants remained more like using “Landscape Forms”; sketches reveal that he studied the plant forms such as the tree shapes being conical or round and also their height, and width. He likewise studied water plants like water lilies, to place them accordingly. Kahn, as Abu Sayeed (Kazi Abu Sayeed, personal communication, July 25, 2022) mentioned gave freedom to the PWD horticulturists to take final decisions. The final selection of plants and their execution was done by the PWD officer and Kahn team (later, after 1974, by David Wisdom Associates).

Through there are landscaped areas (both wetland and dry land) and building areas, which remain separate from each other, there are also spatial moments where landscape and architecture intersect. Kahn saw the Complex as an institution of democracy, which therefore should be monumental. The building tends to appear like a sculpture on the landscape. The peripheral wall of the Assembly (as well as the bungalows) has large, 2-3 storied high voids that let landscape penetrate. Kahn’s inception of design began with weaving multiple layers of landscape and architecture as inseparable entities with symbiotic relationships. In other words, one could see through the large openings (2-3 three floor heights voids) from inside, which Adnan Moshed appropriately calls “windows of the city” (Tagore, 2019).

Visuality and vision, as Ruggles theorized, play a powerful role in the designed landscapes. Kahn effectively employed classical and Renaissance techniques such as perspectives, symmetry, centrality, and axes to create distinctions and a visionary focus on the intensified Assembly building. While its omnidirectional form can be seen from all sides out there, in reverse, the indoor spaces are more enigmatic, establishing a power of vision and thus hierarchy. The double-layered walls are threshold spaces between outdoors and indoors and obscure the positions of the users inside. The building inside has circumambulatory paths on each floor; with slits, gaps, and intermittent openings (Figure 5) that offer views of the surrounding landscape and city. Following Harris and Ruggles, these design features connecting inside with outside or architecture with the landscape are neither fixed nor neutral; they indicate the power relations in the positions of the subject and object (Harris and Ruggles, 2007). The obscured position of the viewer reflects more potency than the subject on the lower ground.

5 BEYOND TRANSCULTURALISM AND CRITICAL REGIONALISM: ASSEMBLY BUILDING ARCHITECTURE

What are some of the design precedents that help us understand Kahn’s Dhaka project? To name a couple: the massive walls of the Roman Baths (Kahn and Latour, 1991, p. 172), and the medieval Cathedral Basilica of St. Cecile (13th to 15th centuries) in Albi, which are reflected in the cylindrical forms. The walls and ambiguity along the circulatory path resemble Giovanni Battista Piranesi’s (1770–78) sketches of the Carceri (Jail). These are all continuations of the architectural culture of the West. These architectural design continuities can also be found in Kahn’s postwar projects such as the Unitarian Church in Rochester and the Hurva Synagogue in Jerusalem, Israel (second proposal 1969, third proposal 1973), and modernization becomes an interchangeable form and a part of universal design language. Surprisingly, the cylindrical form, used in both the synagogue and the church, unfamiliar in the Bengali vernacular design landscape, works as a dominant element in focus and contributes to the construction identity of Bangladesh. Thus, what Aga Khan Trust claims as “lasting architectural ideas from many eras and civilizations” are
adopted Western forms that, by the very tryst of the award, transform to be universal and theoretically license the Complex form to be recognized as local.

FIGURE 4: Sketches and esquisse from Kahn's trip to the Buriganga river translated into reality. Photo courtesy: (top three images) Louis I. Kahn Collection, University of Pennsylvania and the Pennsylvania Historical and Museum Commission. Housed in the Harvey and Irwin Kroiz Gallery, the resources of the Kahn Collection are used with the permission of The Architectural Archives, the University of Pennsylvania (hereafter cited as Kahn Collection, AAUP); the image below: author's collection.

FIGURE 5: View from inside of the Assembly Complex Building to outside, author personal collection dated October 18, 2021.
6 CONCLUSION

What this paper tries to argue is that the role of architecture versus the role of the landscape here is uneven. While the architectural form is affected by Western design language, with interpretative Bengali symbols, the landscape, which was designed with renewed French classical vocabularies, successfully hides those European roots. Thus, Kahn consciously used the Complex’s landscape design as a mediator, a mediating device as well as an object of representation, to synthesize, camouflage, and domesticate his architecture in the larger democratic landscape. Hence, following anthropologist Lucia Michelutti (2007, pp. 639–656), this paper calls it the “vernacularized democratic landscape.” Therefore, I argue, comprised of binaries—identity and otherness—Kahn’s Dhaka Complex landscape is a tool of the colonizers, neocolonizers, resulting in a unique “hybrid” built environment. These inequalities between the West and the East are akin to the colonial hybridity of British architect Edwin Lutyen’s (1869-1944) designed Rashtrapati Bhaban (1912, Viceroy’s House), New Delhi, where the overall site plan reflects a strong genealogy of Beaux Art compositions (same for Kahn’s Dhaka Complex), and the details were Indian derivatives. There is a Mughal-inspired, abstracted garden in the rear of the Bhaban.

While the modernist architectural structure of the Assembly instrumentalizes identity, it is Kahn’s designed landscape that normalizes and mediates the alien form and subsequently creates a hybrid yet democratic landscape. In his seminal book “Location of Culture,” Homi Bhabha (Bhabha, 2012, pp.145–174) explains hybridity as a colonial constraint, a product as well as a tool of colonizers. He describes it as a device that was aptly used in the colonial period to emanate power and that lingers as an essential element of postcolonial conditions. To him, hybridity is used to create a control or appropriation of the colonized by the power-holding colonizers. It is in this sense that we can call the Dhaka project to be neocolonial. The Bengali archetype of water is instrumentalized as an element of romanticized landscape in a method of “mimicry,” echoing Bhabha’s words “almost the same, but not quite.” This echo of a deltaic landscape helps create a seamless synthesis resulting in a colonial, and in this case, neocolonial hybridity yet induces reverie and thus creates a nationalist delusion (Bhabha, 2012, p. 122). As Benedict Anderson argued, this myth is for many but not all (Anderson, 2006). The sentiment of “We are so proud” remains to be an unreal and fetishized democratic landscape and thus hegemonic normality. Thus, it is the power of landscape that functions in the landscape of power as a form of indirect cultural imperialism.

7 REFERENCES


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EQUESTRIAN DESIGN IN THE GARDENS OF VERSAILLES

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1 ABSTRACT

Current literature analyzes Versailles’ gardens primarily from the perspective of the pedestrian (Beneš & Harris, 2001; Hazlehurst, 1980; Wellington, 2016). Louis XIV had commissioned Adam Perelle, Israël Silvestre, and others (Perelle, 1660-1695; Perelle, 1660-1695; Perelle, 1638-1695; Perelle, 1680-1684; Perelle, 1680-1689; Perelle & Perelle, 1600-1699; Rigaud, 1681-1812; Silvestre, 1664-1691; Silvestre, 1676; Silvestre, 1682; Silvestre, 1682; unknown, unknown) to make engravings of events and everyday occurrences in the gardens to document them and provide distinguished guests with souvenirs (Wellington, 2016). 11 of the 59 sampled images featured equestrians, an understudied topic in architectural and garden history (Worsely & Rolf, 2004). These images were viewed online between August 2021 to January 2022, examined, and plotted onto a garden plan. These highly detailed engravings accurately capture many aspects of the equestrian experience in the garden in a few different sports.

This paper seeks to establish equine pleasure usage of the garden and evaluate to what extent the gardens may have been designed for equestrian sports and carriages. While most formal gardens had a separate road to bring horses to the back of the property, Versailles’ many wide allées and wide paths within some of the bosquets suggest that these pathways were used for carriages and equestrians. Through study of the engravings, carriage design and movement, and spatial mapping this paper pulls away at the layers of the design to understand how the vast spaces within Versailles fostered equestrian activity.

1.1 Keywords
Versailles, Equestrian landscapes, Garden history, Le Nôtre, Spatial mapping

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2 INTRODUCTION

King Louis XIV of France, the Sun King, commissioned art to project his image as a living Apollo, most famously in the Apollo Basin on the central axis of the gardens at Versailles. This fountain depicts four fine horses pulling Apollo's chariot upwards as he begins his daily journey of guiding the sun across the sky. Their presence signals the centrality of equestrian culture in court life at Versailles in both image and daily life. One of Louis XIV's first upgrades to his father's hunting palace was a larger stable and kitchen (Hazlehurst, 1980). He later renovated the space for another purpose and expanded the stables into two new buildings prominently placed at the entry to the palace on its central axis that could hold a total of 700 horses, which was comprised of pleasure ride horses, dressage horses, and hunters (Reytier & Saule, 2012; Château De Versailles, 2021; Ministère de la Culture, 2019). As France prepares to host the Olympic equestrian events at Versailles, it is timely to inquire about the role of horses in the design and experience of the famous gardens. Equestrian sports, like other sports in the gardens, integrated the physical and political environment (Dümplemann, 2022) requiring carefully designed and dimensioned spaces. This paper presents some preliminary design investigations on a surprisingly understudied topic.

This paper investigates how equestrian activity was integrated into the design of the gardens of Versailles. Literature and art of the time indicates that both horses and horse-drawn carriages were important in the gardens, as well as the hunting park. The kings had commissioned artists to help record different events that highlighted the use of horses for theatrical haute école pageants and staged jousting feats such as the 1662 Grand Carousel between the Tuileries Palace and Louvre Palace (Wellington, 2016), the 1664 Pleasures of the Enchanted Island fête (Benoît, 2015; Wellington, 2016), and the 1685 Carousel of the Galant Moors (Maral, 2015). There were many more carousels and pageants in between those mentioned. There were also many equestrian statues and paintings of nobility on horseback at the time.

The court’s tradition of skilled horsemanship was linked to antiquity. The Greek general Xenophon's classical treatise, *The Art of Horsemanship*, set out how to select, train, and maintain horses and lay the foundation for haute école in Louis XIV's time, which would, in turn, become dressage in the modern era (Morgan, 1893). Louis XIV's stable of horses came from England, Ireland, Spain, North Africa, and Northern Europe (Château De Versailles, 2021). Louis XIV and other Bourbon kings held large hunting parties about 150 to 180 times a year at Versailles (Château De Versailles, 2019). Any nobleman accepted to the court would have been welcomed to join the hunt (Libourel, 2012). In 1665, Louis XIV established a national stud farm away from Versailles (Ministère de la Culture, 2019) and established a riding school to teach haute école in 1680 (Ministère de la Culture, 2019). Skilled horsemanship in both military and social settings was thus highly valued amongst the aristocracy.

Horse-drawn carriages also played an important role in court life and the gardens of Versailles. These ancient vehicles would have been uncomfortable due to lack of suspension technology, although the addition of luxuriously soft pillows and rugs made them bearable (Libourel, 2012). Initially more popular as a mode of transportation with women, the French kings adopted carriages to travel to their hunting parks from their palaces (Reytier & Saule, 2012). In 1565, King Charles XIV of France also had to enact legislation to limit the number of coaches and carriages in Paris (Libourel, 2012). After the development of elbow spring suspension in 1670, coaches became more comfortable, which would have made them even more popular and more of a nuisance to city dwellers. Nonetheless, their numbers and importance to elite life ultimately affected how streets and buildings were planned. While any gentleman accepted by the French court would have been allowed to attend the king's hunting party, only the king's favorites would have ridden with him in the intimate privacy of the carriage (Reytier & Saule, 2012). The king would have had a pathway for his carriage to take him to the start of the hunt, and so this paper examines how the gardens of Versailles were also designed in response to equestrian and carriage movement.

A plan of Vaux-le-Vicomte drawn by Adam Perelle and Andre Le Nôtre (date unknown), the predecessor park for Versailles, shows a pathway that would have connected the stable in front of the palace to the grand canal. This road connected to some of the parterres in the formal garden, leading the hunting party to ride around the canal to meet at the Hercules statue. This appears to deviate from the longstanding tradition dating back to the Middle Ages where the hunting grounds are separated from the formal gardens. While more research is needed on other predecessors, it is common to see a single connecting pathway from the stables to the parks and hunting grounds at the back of the property, avoiding the formal gardens close to the house. Image 1 shows three precedents (Fontainebleau, Vaux-le-Vicomte, and Saint-Germain-
en-Laye), noting the location of the stable and the hunting grounds. The technique used for deer and later fox hunts included chasing down game with dogs and horses to exhaust the prey (Liddiard, 2007). The hunting strategies lead to the standardized garden practice of keeping ornate gardens closer to the house and chases of the hunting parks some distance away (Liddiard, 2007). All three precedent castles and gardens in Figure 1 show this idea with a pathway that generally avoids going through the formal gardens, which are closer to the main castle building. Since medieval times, European royalty used parks for a variety of sports, including hunting. Thus, it is striking that the route from the stables to the hunting park at Versailles so thoroughly integrates the gardens. In fact, as this paper demonstrates, the scale of the gardens’ designs may have been expanded to make them a destination for equestrian activity in their own right. For example, the carriage crane neck invented in 1665 allowed carriages to turn at a 90° angle, whereas previous carriages could only turn at a 30° angle (Aloest, 2016). Innovations such as this would have changed the ways in which roads were built for the king’s carriages, including those within the elaborate gardens at Versailles.

![Figure 1: Three precedent castles and gardens (Fontainebleau created by Marin 1718-723, Vaux-le-Vicomte created by Google Maps 2022, and Saint-Germain-en-Laye created by Van Loon 1932) that show the location of the stable and a pathway to where the nobility hunted. Note how the pathways tend to avoid formal garden elements. The pink overlay is the area the nobility may have hunted.](image)

Many aspects of the gardens of Versailles have been studied, including its ability to display the king’s power, the use of perspective, and the engineering that went into creating numerous water features and fountains. Most of this literature focuses on Le Nôtre’s designs through the lens of a pedestrian (Beneš & Harris, 2001; Hazlehurst, 1980; Wellington, 2016). Louis XIV commissioned Israel Silvestre and Adam Perelle to make a series of engravings of events and daily life around the palace gardens. Wellington (2016) notes that these engravings accurately capture the look, symbolism, and atmosphere of the gardens and the events. They were often created within a year of the event, whereas most writings on these events were published five to ten years afterwards (Wellington, 2016). The engravings depict people going about their day or celebrating special events such as the opening weekend of the garden of Versailles. A number of
these engravings include equestrians in the allées and parterres. This paper examines and maps these images to better understand the integration of horses into the garden culture at Versailles. It provides a landscape architect’s perspective on scale and dimensions required to perform certain sports and horse-related activities.

3 RESEARCH OBJECTIVES

This paper evaluates to what extent the gardens of Versailles were designed for or adapted to equestrian sport, a generally understudied topic in architectural history (Worsley & Rolf 2004). The study sets out to identify the nature of the equestrian activities promoted by Louis XIV and to identify locations where such activities were represented in the engravings created for court consumption. Even a cursory study of engravings of the Versailles gardens demonstrates that equestrian activities were thoroughly integrated into life at Versailles, and, somewhat surprisingly, into the gardens themselves. Study of representations of horses in the statuary, including the famous Apollo Basin, further underline their importance to the king and his court. The goal of the paper was to use landscape architectural tools:
to locate Versailles’ equestrian features through mapping in order to understand their importance in the geometric scheme of the garden
to analyze the issues of scale, movement and dimension toward an understanding of the extent to which this park was designed for carriages and equestrians.

4 METHODS

The project began with a review of a wide selection of known engravings with equestrians from Israel Silvestre, Adam Perelle, and Jean-Baptiste Rigaud. These were compiled electronically, under the opportunities and constraints of the pandemic, which precluded visits to archives or to Versailles to study the gardens firsthand. 11 of 59 sampled engravings from digital scans included scenes with equestrians and/or carriages (Perelle, 1660-1695; Perelle, 1660-1695; Perelle, 1638-1695; Perelle, 1680-1684; Perelle, 1680-1689; Perelle & Perelle, 1600-1699; Rigaud, 1681-1812; Silvestre, 1664-1691; Silvestre, 1676; Silvestre, 1682; Silvestre, 1682). This corpus included images at the front gates, the Tapis Vert, Apollo Basin, the end of the Parterre d’Eau, heading down the horseshoe ramps of the Latona Fountain, around the Flora Basin, around the Saturn Basin, and around the Ceres Basin. These locations were plotted onto a map of Versailles and traced into AutoCAD. Points and pathways of interest were drawn, refined in Adobe Illustrator, and presented in Adobe InDesign. Sections were taken to better understand how much space there would be for a carriage. These were put together in Figure 2.

In addition to physically mapping the locations where these horses were visually recorded, the specific ways in which the horses were drawn were noted. This is demonstrated in Figure 4. Most horses have a variation of four gaits: walk (a one foot off the ground at a time motion), a trot or a jog (two feet off the ground with opposite feet moving at the same time motion), a canter or a lope (a three-step motion), and a gallop (usually represented in art as the horse being sprawled out to depict a moment that has no feet on the ground). Some horses were drawn in a rearing position (on hind legs with the horse’s front end in the air), which seems to reference the haute école trick. This study gave a better idea of the different sports and uses the pathways within the gardens would have supported.

In addition to this data, modern evidence of horse-accessible routes was recorded. The Gallery of Coaches within modern Versailles held a special exhibition on carriages, including a short video (Aloest 2016; Aloest 2012). Horses and staff from the royal stud farm traveled from the stables to the Apollo Basin while the evolution of the carriage was interspersed. The scenes from the footage were also plotted out on the map of the gardens with the data from the engravings and sculptures. This information was overlaid on the engravings data. Although the video was made hundreds of years later, the purpose of using the video was to confirm that a carriage of the period could indeed navigate the varied routes through the gardens. It also provided accurate photo imagery of how a carriage’s dimensions and turning radius operated in different parts of the garden.
5 RESULTS

5.1 Mapping

Results of the mapping study are presented synthetically in Figure 2 and include important positions held by equestrian sculpture in the garden, locations of the equestrian activity seen in the engravings, a range of skilled handling and gait, and studies of the varied scales of equestrian/pedestrian experience in different parts of the garden.

Statues and depictions of horses were first mapped out. Horses appeared in sculpture and art at the Apollo Fountain, Apollo’s Bath Grove, the Neptune Fountain, at the front of the palace, and at both stables. It is notable that these sculptures are in key locations within the palace complex: at the entry, at key points within the gardens, and along the central axis, culminating in the Apollo Fountain. These positions underline the importance of equestrian culture in the court of Louis XIV and future research might reveal more detail about the place of the horse in the iconography of specific garden areas over time. The statues in and surrounding the garden tend to be in highly trafficked areas where visitors would have seen them and frequently correspond with spots locations where horses were depicted in etchings/engravings.

Next, depictions of the horses, both with riders and pulling carriages, in the etchings/engravings were mapped. These engravings were intended as souvenirs and thus it is difficult to use them as a comprehensive guide to locations of equestrian activity in the garden, but the sample set shows a wide range of locations within the garden for equestrian recreation, not simply on a direct route to the hunting park. Horses were primarily recorded along points along the central axis. From the positioning of the horses in the etchings and engravings, it appeared as though they were ridden primarily in the allées and along the central axis.

Initially, the engravings with horses in them were identified. As mentioned, these engravings would have depicted the atmosphere correctly (Wellington 2016). More detailed study of the engravings in these areas showed the different gaits used by the horses. Faster-paced gaits such as canters and gallops as well as haute école moves would have been used to depict an impressive scene full of excitement and expert horsemanship. Thus, to show Versailles as an exciting hub of equestrian activity, it would have seemed logical for the artists to draw fast-moving carriages and equestrians performing haute école feats and racing. However, the artists often depict a variety of gaits, which will be further expanded on below.

Overall, by overlaying historic maps against the modern maps, it can be determined that the length and width of the pathways of Versailles have not changed much if at all. This would mean that using modern representations of horses and carriages traversing the garden would not produce a significantly different result than taking only historic measurements. The Roulez Carrosses videos directed by Aloest (2016) for the museum provided valuable information about how a carriage could travel through the gardens. There was a gap in information on how exactly the carriage traveled through the Bosquet de la Girandole, but it seemed as though a carriage could navigate all the pathways within it. This suggests there are other parts of the formal gardens equestrians and carriages could traverse.
Figure 2. Plotted equestrian presence in the garden based on etchings and engravings, and scenes from *Roulez Carrosses*. Some pathway sections were taken around the garden to understand how wide the spaces were.
Based on the maps, approximate measurements were taken of the pathways known to have been used by equestrians based on the engravings and movies produced by Aloest (2012; 2016). The sections drawn (Figure 2) show how much space a coach would have taken up on paths of different widths in the garden. In the smallest noted pathway of the Bosquet de la Girandole, a carriage or coach can narrowly pass a pedestrian. The grand sightlines of the allées were wide enough for 2 coaches to pass each other comfortably. For the purpose of the section, the pathway around the Neptune Basin is recorded to be smaller than it appears since there are 2 pathways separated by a grassy lawn in the space. Only one of these pathways was drawn to show exactly how grand just one pathway would be. The Apollo Basin was a gathering place as well as a pass-through area and was exceptional in scale. For reference, a standard American Riding rink, with horses spaced the standard equestrian 1 horse length (8-9 feet) apart, has been placed over the recorded gathering place in front of the Apollo Basin. Figure 3 demonstrates the vast extent of the space between the Apollo Basin and Grand Canal, as 18 American standard riding rinks can fit in the space. Perelle’s (1680-1689) depiction of the Apollo Basin looks initially very visually crowded (See drawing D on Figure 4). The perspective begins somewhere on the Tapis Vert as equestrians and carriages race around the space. It looks as though the equestrians and carriages will crash into each other. However, Figure 3 demonstrates the vast size of the space, which could actually have held more horses and equestrians than depicted.

![Figure 3. The space between the Apollo Basin and Grand Canal. A standard American riding rink is 60' x 120' (right). Equestrians are advised to keep horses at a minimum of one-horse length (or 8-9') away from each other. Approximately 18 standard-sized modern riding rinks would fit into this vast space between the basin and the canal (left).](image)

5.2 Movement

The etchings/engravings confirm the use of horses in the garden for equestrian pleasure and carriage rides. These would indicate how much space horses may have had and indicate what equestrian sport was being enjoyed (carriage rides, pleasure rides, or haute école). Moreover, the conventions used in the engravings to depict the gait of the horses provides evidence that Le Nôtre not only thought about the presence of equestrians in the design of Versailles, but also appreciated the display of skilled forms of movement. Most horses have a variation of four gaits: walk, a trot, a piaf (or jog), a canter or lope, and a gallop (usually represented in art as the horse being sprawled out to depict a moment that has no feet on
the ground). Some horses were drawn in a rearing position, which seemed to reference the haute école trick. The movement of some of the horses in the garden matched the movement of the horses pulling the carriage in Aloest’s video *Roulez Carrosses*. For instance, the horses had to slow down going down the horseshoe around the Latona fountain and around the curve of the fountain. When the horses were given straightaway spaces in allées or ample space such as the area around the Apollo fountain, the horses pulling the carriage cantered just as depicted in the drawings. The study included plotting images from:

- the stables
- the front gate
- the end of the Parterre d’Eau
- the horseshoe ramps around the Latona Fountain
- the Tapis Vert
- Apollo Basin
- around the Flora Basin
- around the Ceres Basin
- the Dragon Fountain
- around the Neptune fountain.

Israel Silvestre’s 1674 etching “View of the Castle of Versailles close to the Garden” shows Versailles before many of the renovations to the garden and palace, the Latona Fountain and its surroundings, and the beginning of the tapis vert and Allée Royal. In the foreground, a procession of walking horses pulling a carriage are depicted in a stately walk. As Louis XIV is usually depicted on the centerline of drawings (Wellington, 2016), the engraving captures the king traveling through the garden in his carriage. In the shadows of the foreground, handlers hold horses still. These may be fresh horses for members of the hunting party, including the king, to ride. Some equestrians in this scene are riding rearing horses. This could either show excitement or mastery of haute école.

Adam Perelle depicted a similar scene from a later time from the upper parterre (1660-1695). This view starts at the very end of the Parterre d’Eau and shows the horseshoe-shaped ramps leading down past the Latona Fountain as well as going down the tapis vert and Allée Royal. (Drawing A Image 4) In the foreground, the horses are moving quickly, while the horses going down the hill seem to be walking. In the distance, the horses are drawn sprawled out in the conventional stance of a gallop. These horses are following a large carriage, which indicates excitement about the event. The fact that these horses are drawn at a gallop indicates that the tapis vert would have been flat enough for the horses and riders to travel safely all the way to the Apollo Basin. A full visual analysis of this image is in Figure 4, which shows cantering horses close to the viewer, horses walking down the ramp, and the mass of galloping equestrians in the back.

Perelle’s depiction of the Apollo Basin (1680-1689) is one of the last formal features of Versailles before entering the hunting grounds of the Petit Parc. This scene is also visually analyzed in Drawing D Figure 4 and offers a lively display of fine horsemanship. The horses in the foreground are obscured in shadow, but Perelle depicted three rearing horses (two of which are performing haute école), one trotting horse, and two men on horseback galloping off towards the woods. In the detailed foreground, the viewer can see six walking horses pulling a carriage, a horse performing haute école and a trotting horse following that carriage. Two cantering horses are seen emerging from the shadow of the woods. There are two teams of horses pulling carriages at a walk and two galloping horses in the middleground. The spatial analysis in Figure 3 suggests that this space could have been a lot more crowded than depicted because of forced perspective.

Equitation is also recorded by the artists within the intersections of the allées, punctuated with fountains. For instance, in Perelle’s engraving/etching of the Flora Basin (1680-1684), horses are shown as following a carriage around a fountain. This scene was visually analyzed in Drawing B Figure 4. The horses pulling the carriage in the middleground are drawn in a walking position. The horses following, which are primarily in the foreground, are drawn as either galloping or in an haute école rearing position. Opposite the party in the middleground, a rider and horse are standing still, seemingly watching the spectacle.

Not all of the images are as visually exciting. Silvestre’s depiction of the Dragon Fountain (1676) offers a scene of quiet recreation. (Drawing C Figure 4) Most of the horses are walking. Some are drawn at a trot and three were drawn performing haute école. Generally, the equestrians are depicted as being calm.
Overall, the engravings/etchings show that these spaces could hold groups of equestrians for various purposes, presumably in displays of skills and fine horsemanship. Some of these engravings/etchings may show a procession to the hunting grounds with the king riding in the carriage, which clearly represents there is a culture of equestrian life specific to the Versailles gardens. Does the outsize scale of the gardens at Versailles indicate, if only in part, Louis XIV’s desire to integrate equestrian activity in the gardens? Further research may illuminate the specific ways that movement on horseback or in horse-drawn carriages would have enabled visitors to experience the fountains and garden themes at a different pace than that of the pedestrians.

Figure 4. Drawing A is Perelle’s Garden of Versailles retrieved from the Metropolitan Museum of Art, Drawing B is Perelle’s Castle of Versailles from Jstor, Drawing C is Silvestre’s Close to the Allée and Dragon Fountain retrieved from Jstor, and Drawing D is Perelle’s The Fountain of Apollo from Jstor. Bottom: Horses’ gaits were recorded using the visual standard based on the position of the feet in engravings. The horses in the etchings/engravings were color coded.
6 CONCLUSIONS

Prior to the French Classical period, horses seemed to have been primarily engaged for hunting parties along the broad rides of parks beyond the chateaux and gardens. It is clear from the etchings/engravings of Versailles, as designed by Andre Le Nôtre, that horses had a place in the gardens. They were ridden through the gardens of Versailles to reach the hunting grounds, but the gardens were also evidently a destination. The large allées of the gardens would have been ideal for riding horses. Xenophon, according to Morgan’s translation (1893), wrote that “… long stretches rather than frequent turns, calm horses down, and leisurely riding for a good while soothes, calms down, and does not rouse the spirit of the horse mettle.” A calm horse is easier to control and would create a better riding experience. The extensive terracing of the gardens provided a relatively flat terrain, which allowed the rider to better maintain balance. When a horse turns a corner, it must readjust its balance, which requires it to slow down and take smaller-paced steps closer to its body. Both a rider and the horse must prepare for the turn together to shift their balance. These long allées would have been spots that a noble could comfortably speed through with minimal concern about his horse losing his footing. Equestrians would have welcomed the break of riding around the training rink at the stables to ride even at a brisk pace down the allées and around the terraces while viewing the different statues, basins, and curated plant displays.

Traversing the gardens of Versailles from a carriage or on the back of the horse would have changed the sightlines within the gardens. It would have increased the height from which people view the art. It may have also heightened intrigue in the garden as the hide-and-reveal elements of the garden would often be experienced at a faster pace. The tall, evenly manicured trees on either side of an allée might have done more than create sightlines and reveal moments for pedestrians. The uniformity may have also blinded the horses from scary distractions that could have potentially spooked a horse. These are ideas worthy of further investigation.

Understanding the materiality of the pathways is also important, though apparently less of a concern in the 17th century. Modern bridlepaths around the world are now surfaced using soft, sand-like soil rather than any form of pavement. This helps to protect both horse and rider from hard, compacted ground. For the horses, it is healthier for their joints. At Versailles, paths were compacted or paved to create a hard, even surface for a better carriage ride, setting up a tension with protecting their horses’ joints. The classical texts, in fact, favored rocky, hard pastures for better hoof development (Xenophon & Morgan, 1893).

The visual impact of riding on horseback or in a carriage on the perception of the garden’s design and iconographic program warrants further study, as the visitors elevated position would have changed the viewing angles and sightlines of the gardens and their features. Thus, pedestrian accounts are insufficient in describing all dimensions of the garden. Further research is needed to illuminate all aspects of how an equestrian or a carriage ride through Versailles would be experienced. Such research would help historians better understand the park, the design elements of the park, what points of reference could be used to evaluate other equestrian spaces, and how these principles could be applied to the temporary designs for the Olympics, and, in turn, to enliven private and public facilities in modern equestrian communities internationally. Understanding equine-related innovations can also help historians reveal new dimensions of historic parks and gardens from classical times to the present.

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ABSTRACT
Cultural Landscape studies have developed rapidly in the United States since the 1920s, during that time, the term had been defined and interpreted rather broadly. While the breadth of the literature of cultural landscape evolved, especially during the 1950s, branching in multi-disciplinary areas, it remains challenging to obtain a comprehensive definition to frame cultural landscape as a term, framework, or application.

This paper is a review of the academic genealogy of “cultural landscape” from an institutional and scholarly perspective highlights the differences and similarities in how the term “cultural landscape” has been defined by scholars and institutions.

A chronological literature review methodology was used to analyze the evolution of the term within different disciplines. It aims to trace and compare definitions from existing compilations of cultural landscape studies and leading governmental and non-governmental organizations’ documents in the US that manage cultural landscapes during the period (1920-2020), from local entities such as National Park services to international institutions such as UNESCO. The paper aims to distinguish four main time periods for the term’s definition development. It shows that the similarities in the definitions by scholars and institutions within the period of 1950-1970 gave way to the continual redefinition and appropriation of the term to suit the academic work within and across different disciplines ever since. While this paper highlights the depth of the existing body of knowledge through an accessible history of the scholarly and institutional definitions that made cultural landscape a significant term, it connects the theoretical perspectives to the practical applications in order to open a discussion about the term’s scholarly and practical use, application, and perception for the new scholars of cultural landscape.

1.1 Keywords
Genealogy, Cultural Landscape, Terminology, Definitions
INTRODUCTION

Cultural landscape studies have developed rapidly in the United States (US) since the 1920s. The term cultural landscape has been used and interpreted broadly. The term was first used in the US by the American scholar Carl Sauer in 1925 in his well-known article *The Morphology of Landscape* (Sauer, 1925). While he didn’t define the term in detail, he related any physical transformation in nature to the cultural man as “an agent” to its imprint in the landscape, resulting in a new conceptual approach to the cultural landscape (Sauer, 1925, p. 343). Since then, a series of academic definitions have developed focusing on the cultural materials of the landscape (Potthoff, 2013). However, no definition was solely used by scholars or institutions. During the 1990s, the term was adopted by several international bodies to protect and conserve cultural heritage. The United Nations Educational, Scientific and Cultural Organization (UNESCO) was the first institution to include the term cultural landscape for protecting and valuing world heritage sites. It prepared guidelines to protect the cultural landscape in accordance with the world heritage convention in 1972 and formally defined it in 1992 (Jokilehto, 2005). In the US, the National Park Service (NPS) officially recognized cultural landscape as a distinct resource typology in 1981.

While the breadth of the literature on cultural landscape evolved, especially during the 1950s, and continues to be studied in multi-disciplinary areas, it remains challenging to obtain a comprehensive definition to frame cultural landscape as a term, framework, or application. Therefore, this paper reflects on the relationship between knowledge claims and practices that underlie cultural landscape studies to understand its lineage, mainly by tracing the definitions of cultural landscape as a term and its development down to its practical use. The practical use will be in the form of codified definitions used by institutions concerning managing cultural landscapes. A genealogy study can generate such an understanding by analyzing the term’s cultural meaning and tracing the different usages of the term over time (Mukerji, 2007, p. 25). Although it will not give us a full analysis of the history of cultural landscape studies, it brings up possible discoveries and points of view relevant to our understanding of the term today.

This study’s main goal is to collect and compare the definitions of the term cultural landscape since its first introduction in the US in 1925 using a chronological review analysis. The comparison is mainly between the scholarly definitions and the formal ones extracted from the previous multi-disciplinary academic work and statutory documents to ground its uses in the present. Comparative analysis of these definitions identifies connections, similarities, or differences to reveal new perceptions about our understanding of the term and its interpretations. The main intention is not to provide a singular definition or concept, but to provide an accessible analyzed bibliography for the existing scholarly and institutional definitions of the term cultural landscape in various disciplines to embrace the range of meanings concerning its practical implications.

To better conduct the analysis, the authors divide the timeline into four main time periods between 1925 and 2020. These periods were identified by analyzing the primary shifts in the development of the cultural landscape term and its usage throughout history. The authors provide a list of founded definitions of the term “cultural landscape” in scholarly and institutional work and documents for each period. The review of definitions for each period reveal that the main characteristics of the related definitions go in parallel with definitions of prior periods. In addition, the review specifies when it was defined and developed or when scholars reinterpreted it as a topic of inquiry and an application in both scholarly and institution work.

2.1 Cultural Landscape, a multi-disciplinary concept

The multiple uses of the cultural landscape term-initiated dialogues between other academic disciplines, forming a base for multi-disciplinary work (Michael Jones, 2003). Scholars and researchers have sought to interpret the cultural implications of the man-made interventions shaping the landscape within different disciplines. For example, after the term, cultural landscape, was firstly introduced academically by the geography department of the University of California - Berkeley, it evolved into an academic program that influenced many studies beyond this new department and discipline (Groth, 2009). Many other fields adopted the concept to address concerns related to topics on culture, geology, psychology, and even environmental transformation that has interpreted by geographers, ethnologists, botanists, anthropologists, geologists, archaeologists and ecologists in their studies, developing multiple ways of using the term cultural landscape in scholarly work. This merit suggests studying the term through a “pluralistic approach,” as “accepting that the same concept can be used in different ways” (M. Jones &
Daugstad, 1997, p. 269), which helped in the emergence of the term “cultural landscape” as a multi-disciplinary concept (Groth, 2009). After the 1960s, within the landscape architecture discipline, the development of cultural landscape was associated with reading the everyday American landscape. The term became increasingly used, and the concept was developed by architects, landscape architects, environmentalists, archaeologists, and urban planners. Those who wrote about cultural landscapes include May Theilgaard Watts, in *Reading the Landscape* (1957), and J.B. Jackson (1984), a foremost scholar of the term (Wilson & Groth, 2003). Scholars from different disciplines also wrote about reading the landscape into what we now know as cultural landscapes. P. F. Lewis (1979) and Don Mitchell (2008) translated the relationship between cultural landscape and the ability to read the landscape into axioms for reading it. This concept of reading the landscape influenced the emergence of the notion of the cultural landscape as a framework for practical research and strategies that concern nature-related subjects and environmental management (Groth & Bressi, 1997). It has been used in administrative and management documents for conservation and preservation reasons (Date, 2012).

The nature of the concept of cultural landscape as a multi-faceted, multi-disciplinary approach influenced its narrative within various academic and practical dialogues and broadened our understanding of its social, political, and economic aspects. For instance, Ickerodt (2006) examined the term cultural landscape in its social and political function as a tool in research and as a teleological narrative. The research provided evidence that the term cultural landscape in the practical world functions as a dialogue with administrative bodies that advocate its importance—transformed into a need to conserve our cultural heritage in retrospect. Therefore, it reasoned the need for codified definitions and guidelines fulfilling the urgent demand for cultural landscape protection.

In an attempt to understand the term, several studies have traced and evaluated its evolution and usage within its different functions and disciplines. In 1983 Peirce Lewis reviewed early literature about the American cultural landscape in his article *Learning by looking*. He highlighted the work of four pioneers’ interpretations of the American cultural landscape: Carl Sauer, Fred B. Kniffen, John K. Wright, and J.B. Jackson. Lewis concluded that the cultural landscape could be seen as a response to the historical imperative that all landscapes were made in the past.

In (1997), Jones & Daugstad studied the usage of the cultural landscape concept in the Norwegian landscape administration documents between 1987-1993. They underlined the inconsistent use of the concept within the governmental policies arising from poorly defined or contradictory implications in applied research documents. Later again, Jones (2003) examined the term’s usage in Norwegian scholarly and institutional literature and documents, identifying seven principal usages that complied with recent landscape types. All of these studies, except for Lewis’s, were shaped within a European academic setting, and only one has studied the definitions. This lack of rigorous definitions’ analysis amplifies the need for such study within different settings and time ranges.

### 2.2 The importance of a definition

The definitions of the cultural landscape have been divergent in terms of having one confined one; however, the analysis here is not to arrive at one precise definition and use, as it was approached to overview various definitions. Seeking one definition is a difficult task, especially with the multi-disciplinary aspect of cultural landscape with the multi connotation of its uses. However, without a proper definition, it might be misused or misapplied to fit the phenomenon, or the study associated with it.

A definition provides the advantages of mapping out conceptual territories of a concept, where the “ownership of terminology is of enormous consequence in dialogue, for by it both ideas and people can be positioned on particular sides of debates. To dictate definition is to wield cultural power” (Michael Jones, 2003, p. 24). Consequently, the power of defining a concept lies in its ability to control of discourse; based on that, any meaning can be expanded or contracted to serve the purposes of its users. This power was defined by Livingston (1992) as “… an inherent boundary-marking, or boundary-making, an enterprise designed to demarcate the true from the false, the legitimate from the illegitimate, the relevant from the irrelevant” (Livingstone, 1992, p. 304). Livingston and Entrikin claimed that, in general, politics has a significant influence on definitions and discourse, where different vocabularies can be employed to suit other purposes. They advocated tracing the integrity of the definitional discourse to ensure no monopolization of the conversation is happening (Livingstone & Entrikin, 1991). It was difficult to trace it in this research; therefore, we only studied the direct meaning of each definition.

On that aspect, the codified institutional definitions are interpreted and applied through the development timeline of the term. Although this study is limited to the use of the cultural landscape term in
the US, it was necessary to incorporate an international organization such as UNESCO that helped developing a legal framework to identify and protect world heritage and its implementation at the national level publicizing the cultural landscape term. They formally defined the cultural landscape in 1972 at the UNESCO Convention for Safeguarding of the World Cultural and Natural (UNESCO, 1972). They refined this definition in UNESCO’s Operational Guidelines for the Implementation of the World Heritage Convention in 1992 (UNESCO, 1992). In addition to many others, including ICOMOS, an international organization with a European lineage, was established in concern of cultural landscape heritage and its conservation to evaluate the nomination of cultural properties made to the world heritage list as a formal advisory body for UNESCO within a European setting in 1972 (Labadi, 2013). According to the Operational Guidelines for the Implementation of the World Heritage Convention, “cultural landscapes are cultural properties that represent the combined works of nature and man” (ICOMOS, 2013). They are “illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic, and cultural forces, both external and internal” (ICOMOS, 2013, p. 2).

Two preeminent institutions in the United States whose work is related to cultural landscape have defined the term: the National Park Service (NPS) and the Cultural Landscape Foundation (TCLF). The National Park Service (NPS) is the leading formal institution concerning the cultural landscape. It was established in 1916 and officially recognized cultural landscape as a distinct resource typology and defined in 1981 as “a geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person, or that exhibit other cultural or aesthetic values” (NPS-28, 1981). In 1984, the NPS introduced Cultural Landscape Report (CLR), an inventory and analysis of the significance of cultural landscapes, as a documentation criterion for cultural landscape recognition.

The Cultural Landscape Foundation (TCLF) is an American non-profit organization with the mission of stewardship through education (Birnbaum, 2014). It is a recent organization that focuses on promoting understanding and awareness of our shared landscape legacy. Yet, it didn’t establish its own definitions but adopted the definition that the NPS has used for the last three decades and simplified its complexity (TCLF, 2021). Data collection for the many definitions of cultural landscape has varied from a scholarly to an institutional point of view. Yet, the literature on cultural landscape definitions was underdeveloped by scholars and academics as it was difficult to confine it to one discipline or institution.

3 METHODS

To trace definitions of the term cultural landscape, we designed a series of steps to collect definitions used from 1925. The search focused only on publications within the United States region. The publications, featuring different disciplines, revealed four main time periods characterized by a common position of the term cultural landscape. These time periods are a) 1925-1950, b) 1950-1970, c) 1970-1990 and d) 1990-2020. Table 1 shows the four time periods within this study, listing the number of scholarly works and institutional documents that fit the criteria to extract a definition of cultural landscape and, therefore, analyze it.

<table>
<thead>
<tr>
<th>Time periods</th>
<th>Scholarly definitions examined</th>
<th>Institutional definitions examined</th>
<th>Focus/Keyword</th>
</tr>
</thead>
<tbody>
<tr>
<td>1925-1950</td>
<td>5 scholarly works have been examined *</td>
<td>2 institutional, managerial documents.</td>
<td>Cultural material/Modified landscape</td>
</tr>
<tr>
<td>1950-1970</td>
<td>7 scholarly works have been examined</td>
<td>8 major documents examined</td>
<td>Vernacular landscape influences the reading of the American landscape, therefore, the cultural landscape. Mainly as the cultural geography</td>
</tr>
<tr>
<td>1970-1990</td>
<td>5 scholarly works and definitions examined</td>
<td>9 major documents examined</td>
<td>Symbolic landscape and a representation of cultural landscape as a common and ordinary part of everyday life</td>
</tr>
<tr>
<td>1990-2020</td>
<td>9 scholarly works and definitions examined</td>
<td>8 major documents examined</td>
<td>Gender class-based, politicized social productive landscapes, preservation</td>
</tr>
</tbody>
</table>

* In this period, the reduced number of documents examined analyzed is due to not being recognized by institutions yet
We used two search engines (Google Scholar & JSTOR) to collect documents and published articles that has a clear definition of the term cultural landscape. Those two digital platforms provided digitized scholarly work and documents to analyze. To make the research process more practical, we used keywords to refine and filter the search results. The keywords used are “cultural landscape” to search for in content and research title. The words “define”, and “definition” were used to reduce the search results within the four selected time periods. Moreover, we limited the search to articles and studies written in English. For undigitized work before 1990, we looked at the bibliography of founded work for more data.

The process of locating definitions was the same for institutional and governmental documents; however, the search was directed toward institutions that manage cultural landscapes within the United States. These institutions’ documents have been examined within the same time ranges of scholarly work. As mentioned earlier, the institutions are NPS and TCLF, but we added UNESCO’s definitions to bring up a broader base to compare formal definitions from institutions’ documents. Although UNESCO is an international organization, we consider it as it includes many cultural landscape sites within the United States.

3.1 Process of analysis

The process is mainly a chronological comparative analysis, comparing scholarly definitions of the cultural landscape to the institutional and governmental definitions. This comparison is to show whether definitions of institutions comply in meaning and purpose with scholarly ones. The analysis is described by finding the main themes, keywords, and limitations among these definitions. Addressing the variation between these definitions, either similarities and/or differences, leads to tracing the term transformations over time. All definitions (scholarly and institutionally) are presented in a timeline table format to ease comparison. The following steps outline the process of analysis: categorizing:

- Identifying the leading scholars that have published about cultural landscape as their major focus of the study.
- Listing the institutional documents that defined cultural landscape and definitions.
- Describing the data collected and categorizing it per year and discipline.
- Locating explicit definitions of the term within each time period.
- Analysis of definitions collects by comparing definitions in terms of similarity, differences, and note changes.
- Summarizing the overall nature of definitions and main characteristics during each time period.

4 CULTURAL LANDSCAPE DEVELOPMENT OF DEFINITIONS

The first period from 1925-1950, represents the introduction of the term in the United States. The second period, from 1950-1970, represents the inclusion of the ordinary landscape as essential in defining and expanding scholars’ understanding of the cultural landscape. Moreover, the institutional and legal organizations adopted the concept and incorporated the term in their policies within this period. The third time period spans from 1970 till 1990. During this period, the term was officially formalized as a framework for conservation in many organizations and academic research. The last period, 1990-2020, includes various studies and multi-disciplinary definitions. While definitions didn’t change much, cultural landscape categories expanded. The following sections will explore the main characteristics of the definitions of each phase.

4.1 1925 – 1950, The preface

This time period is considered the introduction of the cultural landscape term as a concept. Leading scholars were mainly cultural geographers who influenced the cultural landscape studies and highlighted the interrelationship between culture and nature, emphasizing rural landscapes—the definitions of the term cultural landscape collected within this phase deal with introducing and understanding the concept. The notion of culture material has characterized the definitions of this period in relation to the physical change and the morphology of the landscape.

Table 2 shows the main scholarly definitions collected in this period, starting with Sauer’s 1925 definition in his article “The Morphology of the Landscape,” and ending with Hartshorn’s 1939 publication “The Nature of Geography: A Critical Survey of Current Thought in the Light of the Past.” Sauer’s article focused on the transformation of the physical material of the environment and its relationship to the culture.
Sauer identified cultural landscape as: “the geographic area in the final meaning (Chore). Its forms are all the works of man that characterize the landscape. Under this definition, we are not concerned in geography with the energy, customs, or beliefs of man but with man’s record upon the landscape” (Sauer, 1925, p. 46). Although Sauer’s definition was general yet narrowly focused on the tangible land formation, it has influenced cultural landscape studies afterward (Wilson & Groth, 2003, p. 5).

In (1931), Geographer P. W. Bryan published his article The Cultural Landscape, where he defined the concept and explained the various types of cultural landscape. He elaborated on Sauer’s definition and reasoned the change of the landscape to fulfill the human need as:

… human activity, which takes place in order to satisfy human desires, adapts and modifies nature, thus changing the natural landscape, and the concrete or objective expression of this process of adaptation is the cultural landscape, that is, the natural landscape as modified by man. Therefore, the cultural landscape is the objective expression of the relationship between human activities and the natural environment” (Bryan, 1931, p. 268).

These needs, either recreational, socializing, or need for production, are associated with the activity of modifying nature.

Table 2. Main definitions timeline collected on the cultural landscape from 1920-1950

<table>
<thead>
<tr>
<th></th>
<th>Scholarly /Academic 1925-1950</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1925) Carl Sauer</td>
<td>Cultural Geography</td>
</tr>
<tr>
<td></td>
<td>“The cultural landscape is fashioned from a natural landscape by a culture group. Culture is the agent, the natural area is the medium, the cultural landscape the result. Under the influence of a given culture, itself changing through time, the landscape undergoes development, passing through phases” (Sauer, 1925, p. 103)</td>
</tr>
<tr>
<td><em>The Athens Conference (1931)</em></td>
<td>the First International Congress of Architects and Technicians of Historic Monuments at the Congress in Athens</td>
</tr>
<tr>
<td>(1931) P. W. Bryan</td>
<td>Cultural Geography</td>
</tr>
<tr>
<td></td>
<td>“Human activity, which takes place in order to satisfy human desires, adapts and modifies nature, thus changing the natural landscape, and the concrete or objective expression of this process of adaptation is the cultural landscape, that is, the natural landscape as modified by man. The cultural landscape is the objective expression of the relationship between human activities and natural environment” (Bryan, 1931, p. 268).</td>
</tr>
<tr>
<td>(1936) Fred B. Kniffen</td>
<td>Cultural Geography</td>
</tr>
<tr>
<td></td>
<td>“The term “culturogeographic” is advanced to fill the need for a word importing the cultural forms of the geographic landscape. The quantitative and qualitative consideration of the cultural forms of the landscape, by a method analogous to that employed by anthropologists in arriving at culture regions or in establishing culture relationships” (Kniffen, 1936, p. 179).</td>
</tr>
<tr>
<td>(1938) H. H. Swinnerton</td>
<td>Biological study</td>
</tr>
<tr>
<td></td>
<td>“The sum total of the marks made by man upon the face of the Natural Landscape. Man is, of course, not the only creature that leaves his mark, for birds build their nests, moles throw up their tiny hills, rabbits excavate their burrows, and beat out their narrow tracks across the meadow” (Swinnerton, 1938, p. 1)</td>
</tr>
<tr>
<td>(1939) Richard Hartshorn</td>
<td>Geography</td>
</tr>
<tr>
<td></td>
<td>“The present landscape of any inhabited region, in contrast to the natural landscape, … the forms superimposed on the physical landscape by activities of Man” (Hartshorne, 1939, p. 170)</td>
</tr>
</tbody>
</table>

In 1936, Fred B. Kniffen, in his article “Louisiana House Type,” quantified the cultural landscape concept as a method to understand geographic landscape patterns. He used the concept as an evaluation of the physical elements responsible for the distribution of the individual housing types in relation to the landscape to define the culturogeographic region of Louisiana (Kniffen, 1936). It follows Sauer’s and Bryan’s
definitions that specify the transformation by the existence of a physical element. The main shift is in focus on the cultural relationship and nature.

On the other hand, Swinnerton saw the need to redefine cultural landscape from a biological perspective in his article “The Biological Approach to The Study of The Cultural Landscape” (1938) by not associating the cultural landscape exclusively with humans. He also said, “The Cultural Landscape is not itself the organism, but, like an oyster shell, it is merely the product of the activities of an organism, in this case, a Society” (Swinnerton, 1938, p. 83).

In (1935), geographer Richard Hartshorn published an article emphasizing the need to acquire a cultural landscape study in any regional or state site analysis. He pointed out that cultural landscape interpretation can’t be made solely; it has to borrow work of other disciplines such as geology, history, ethnography, etc. (Hartshorne, 1935). Moreover, in his book, The Nature of Geography, he defined the cultural landscape in contrast to the natural landscape as “the present landscape of any inhabited region” (Hartshorne, 1939, p. 170). He expanded the term’s definition to include the idea of a superimposed change in the physical landscape over time. This manifestation is the first interpretation of the cultural landscape into a practical application for its purpose.

In contrast to formal and institutional definitions of the term cultural landscape, there were no attempts to define the cultural landscape as it was not yet legally recognized within this phase. There is a gap in time for new studies that have defined the term in the last ten years of this period, as our search didn’t extract any definition. However, the analysis reveals that definitions mostly carried a similar meaning focusing on the tangible transformation of the landscape. Hence the term was not formally defined; it has given the disciplines free access to a new perspective for academic exploration.

The definitions of this era are associated with two main discourses: the natural landscape in contrast to the cultural landscape, as a man-modified nature, with no relation to its significance as a cultural heritage nor the need for its preservation. This phase is framed with the use of definitions as a product of introduction to the American landscape, primarily through the discipline of human geography, with the main interest of cultural landscape as a product of activities, human intervention, and modified natural landscape. The main audiences for these definitions were the cultural geographers and academics of that interest. The relationship between institutional policies and documents is not established yet in this phase because institutions focus on safeguarding historical monuments and historic sites and structures.

4.2 1950-1970, The interpretation of the Landscape

This time period is mainly about reinterpreting the landscape that has been constructed by culture and thus redefining how we see the landscape. This redefinition led to a change of perception towards the meaning of landscape that introduced the concept of the vernacular landscape (Jackson, 1984). Interestingly, in the 1950s, the term cultural landscape appeared less in scholarly work, although it was needed to describe the intertwined relationship of human groups and their activities within a space (Wilson & Groth, 2003). Most scholars across multiple disciplines didn’t redefine the term but used the pre-assigned definitions from previous scholars and worked more on developing a better understanding of the landscape through the lens of cultural landscapes.

The leading prominent scholar of this period is J. B. Jackson, a human geographer. His significant work in landscape studies bears witness to his contribution to defining cultural landscape and building bridges between geography and landscape studies (Correy, 1998). As he started his Landscape magazine on cultural landscape studies and human geography in 1951, publishing through the 1970s, Jackson provided a platform to broaden the study of cultural landscapes into a professional endeavor for many disciplines (Wilson & Groth, 2003). Lewis described him as “a towering figure in the evolution of thinking about American cultural landscapes and their meanings” (Peirce Lewis, 1983, p. 247). Jackson’s inclusion of vernacular landscapes under the cultural landscape has provided crucial inspiration and context for contemporary design. This cumulative effect has been recognized in his definition of cultural landscape as “a composition of man-made or man-modified spaces to serve as infrastructure or background for our collective existence… which underscores…our identity and presence” (Jackson, 1980, p. 2). This definition, which didn’t come until 1980, connected the modified landscape with our identity and heritage that should be acknowledged and studied.

This time period is mainly influenced by the multiple disciplines reinterpreting the notion of a cultural landscape, using it as a tool for protecting and preserving cultural heritage. The concept of everyday and vernacular landscapes transformed the definition of cultural landscape in order to interpret the landscape
of our ordinary settings. Therefore, when developing a strategy to document a cultural landscape, it is essential to read the landscape in its context of place and time (Birnbaum, 1994).

Although the list of scholars who studied and wrote about the cultural landscape within this period of 1950-1970 was long, it was difficult to find new definitions of the term. Rather, there was more emphasis on reading the American landscape. Erhard Rostlund defined the cultural landscape in 1955, emphasizing the process as: “A long process of development directed by Man.” Another definition by Wagner & Mikesell (1962) states that the cultural landscape “is a concrete and characteristic product of the complicated interplay between a given human community, embodying certain cultural preferences and potentials, and a particular set of natural circumstances. It is a heritage of many eras of natural evolution and of many generations of human effort” (Wagner & Mikesell, 1962, p. 11). Joseph Hajdu quoted Bobek’s definition for the cultural landscape “as the result of man’s actions, and to understand the nature of these actions the nature of man the instigator must be studied. Human acted as a member of a group, so the group as such must be studied (Hajdu, 1968, p. 400). Table 3 shows the definitions collected within the time period 1950-1970. They share the main key notion of identity, collective existence, sense of community, and heritage.

### Table 3. Main definitions timeline collected on the cultural landscape from 1950 to 1970

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1955-1956) Erhard Rostlund</td>
<td>Cultural Geography</td>
</tr>
<tr>
<td>“The sum total of the marks made by man upon the face of the Natural Landscape. Man is, of course, not the only creature that leaves his mark, for birds build their nests, moles throw up their tiny hills, rabbits excavate their burrows and beat out their narrow tracks across the meadow” (Sauer, 1962)</td>
<td></td>
</tr>
<tr>
<td>*UNESCO Recommendation (Landscapes) (1962)</td>
<td>Geography</td>
</tr>
<tr>
<td>the safeguarding of the beauty and character of landscapes and sites is taken to mean the preservation and, where possible, the restoration of the aspect of natural, rural and urban landscapes and sites, whether natural or man-made, which have a cultural or aesthetic interest or form typical natural surroundings</td>
<td></td>
</tr>
<tr>
<td>National Park Service *NPS (1966)</td>
<td>Social geography</td>
</tr>
<tr>
<td>National Historic Preservation Act of 1966, established a national policy of historic preservation, including the encouragement of preservation on the state and private levels</td>
<td></td>
</tr>
<tr>
<td>*(1968) Joseph G. Hajdu</td>
<td></td>
</tr>
<tr>
<td>Quoting Bobek, “the cultural landscape was the result of man’s actions”, and to understand the nature of these actions the nature of man the instigator must be studied. Man acted as a member of a group, so the group as such must be studied” (Hajdu, 1968)</td>
<td></td>
</tr>
<tr>
<td>*NPS (1969)</td>
<td></td>
</tr>
<tr>
<td>National Environmental Policy Act of 1969, declared a federal policy to “preserve important historic, cultural, and natural aspects of our national heritage</td>
<td></td>
</tr>
<tr>
<td>No definition for cultural landscape *</td>
<td></td>
</tr>
</tbody>
</table>

From an institutional point of view, there were neither definitions nor mentions of the term cultural landscape, although it was scholarly studied and used. While UNESCO launched several conventions and charters concerning the world’s cultural heritage and its preservation, it did not formally define the cultural landscape. In 1954 the Hague launched its first Convention defining cultural property without mentioning the cultural landscape. Following In the 1960s, UNESCO exported its recommendations on several matters, such as archeological excavations, safeguarding museums, and safeguarding the beauty and character of the landscape and sites. Parallel in the US, the National Historic Preservation Act of 1966 and the National Environmental Act of 1969 established a national policy of historic preservation to preserve important historic, cultural and natural heritage that has been adopted by NPS. However, institutional documents make no mention of the term cultural landscape. By collected definitions in Table 3, the latter point shows that institutions implicitly introduced cultural landscape without using the term.
Within the time period 1950-1970, we drew three main discourses that influenced the definitions of cultural landscape: the re-reading of the landscape, the introduction to the vernacular landscape, and the ordinary landscape’s significance. Those main concerns helped in the reinterpretations of cultural landscape and our understanding of what it means and impacted the established land use professions, particularly landscape architecture. This impact maybe not have been directly shown in this phase. Still, in retrospect, we can see these definitions as spearheading a new era in the history of landscape studies - the identification and appreciation of what we now call the cultural landscape (Correy, 1998). The main keywords used in the definitions are similar to the previous ones in the time period 1925-1950; however, the definitions in this era have generated a link to the cultural heritage and identity that deepen our understanding of the intertwined relationship of culture, humans, and the natural environment, which have a core link to our heritage and history, which can be read in comparison of the scholarly definitions to the institution definitions.

4.3 1970-1990, A fertile conceptual tool

The general characteristic of this period, 1970 to 1990, is the thriving of various disciplines at the expense of cultural landscape development, using the notion of cultural landscape as a conceptual tool for understanding the cultural aspect of the landscape. The definitions collected in this time period are presented in Table 4, which shows scholars from different disciplines trying to interpret the term, such as anthropology, urban planning, etc. Moreover, the term has been formally and institutionally defined as a key term. UNESCO used the term and defined it at its convention in 1972 as part of the goal to recognize properties of outstanding and universal value (O’Donnell, 2004). Although it is a universal institution for the global protection of cultural and natural heritage, the relationship between the cultural and the natural has not been well understood. The inclusion of both the cultural and the natural is what scholars were trying to obtain through the various definitions and interpretations. The NPS officially recognized cultural landscapes as a separate resource typology in 1981. They defined it as “a geographic area associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values” (NPS-28, 1998). These values have been created as a result of the interaction of nature and culture that shape a heritage worthy of preservation. This has manifested in scholarly studies advancing understanding and appreciation of both physical and human processes in both time and place.

From a scholarly perspective, Carol Galbreath wrote an article redefining cultural landscape and its typology in 1975. This article featuring an urban planning point of view indicates the turn the term took as influenced by other disciplines along with human geography. The list of academic definitions found for the term in Table 4 shows its complexity adding new layers to its understanding as seen in Melnick’s, Lewis’s, and Rowntree and Conkey’s definitions. One of the most comprehensive definitions is by Melnick (1981), which implies the need to expand its physical boundaries, as the intangible value is challenging to capture. Rowntree and Conkey (1980) linked their definition of the cultural landscape to the symbolic action passing through generations, which brings us back to the intangible aspect of the term. Lewis linked his definition of cultural landscape to the common workaday landscape that J.B. Jackson and others indicated. He stated: “[the] cultural landscape is nearly everything that we can see when we go outdoors—common workaday landscape. Our human landscape is our unwitting autobiography, reflecting our tastes, our values, our aspirations, and even our fears, in tangible, visible form” (Lewis, 1979, p. 1). Some definitions of this period can be linked to prior scholars’ work, as Rapoport's (1978) definition is similar to P. W. Bryan's (1933) definition of human adaptation and his culture to transform the landscape into what he uses.

Comparing the scholar and formal definitions within this period shows that the complexity of scholarly work in interpreting the cultural landscape has not been integrated into institutional definitions of the term. It manifested the cultural landscape formally and institutionally, while academically, it has been quickly expanding to capture the integration of the cultural and natural values of the cultural landscape. It framed the expansion of the term cultural landscape into a more complex concept to include narrative, symbolic actions, values, and intangible everyday landscape. It is suggested to include all aspects of the term that have evolved in various cultural landscape disciplines, types, and categories. However, the configuration of human and natural resources has been clearly distinguished as separate categories.
<table>
<thead>
<tr>
<th><strong>Table 4. Main definitions timeline collected on the cultural landscape from 1970 till 1990</strong></th>
<th><strong>(1975) Carol J. Galbreath</strong></th>
<th><strong>Urban Planning</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UNESCO, The World Heritage Convention (1972)</strong></td>
<td>“Places in nature that have acquired significant associations with human activities and human events” (Galbreath, 1975)</td>
<td></td>
</tr>
<tr>
<td><strong>The Alliance for Historic Landscape Preservation (1978)</strong></td>
<td>“That segment of earth space which lies between the viewer’s eye and his or her horizon” (Salter &amp; Lloyd, 1977)</td>
<td></td>
</tr>
<tr>
<td><strong>National Park Service NPS (1981)</strong></td>
<td>“Cultural landscapes are those areas which clearly represent or reflect the patterns of settlement or use of the landscape over a long time, as well as the evolution of cultural values, norms, and attitudes towards the land. They exhibit the different phenomena of man’s lasting impact on the land... and represent a continuum of land use that spans many generations. They have evolved from, or exhibit remnants of, earlier known human settlement patterns or land-use practices for an area... These practices or patterns often stem from years of experimentation, or even from bitter failures. They grow out of continual readjustment of human aims and hopes in the light of environmental forces. Thus, these landscapes exhibit, either conspicuously or subtly, long-held values of their area or culture” (Melnick, 1981, p. 5).</td>
<td></td>
</tr>
<tr>
<td><strong>the Florence Charter (1982)</strong></td>
<td>“Cultural landscape refers to any landscape or material component of a landscape that has been of human consequence for a period of time. A cultural landscape is an area having - or perceived as having - distinctive characteristics and composed of interrelated natural and human elements”. (Melnick, 1983, p. 88)</td>
<td></td>
</tr>
<tr>
<td><strong>NPS (1989)</strong></td>
<td>“a composition of man-made or man-modified spaces to serve as infrastructure or background for our collective existence... which underscores... our identity and presence” (Jackson, 1984)</td>
<td></td>
</tr>
</tbody>
</table>
4.4 **1990-2020, An urge for preservation**

This phase can be described as the peak for cultural landscape as a definitional term and function for its preservation. As O’Donnell (2008) described this time range as “a phase of Thirst for Information and Organization growth …. where the body of early professional work and organizational initiatives led to advances in practices” (O’Donnell, 2008, p. 10). Yet, when we look deeper into the institutional definition of the term, it was static. In 1992, after a decade of extensive debate, UNESCO added “Cultural Landscape” to the categories eligible for its World Heritage List inscription. The NPS defined four types of cultural landscapes. The NPS definition works as a clear foundation for examining the evidence of human use or activity of eleven landscape characteristics within a site. Simultaneously, UNESCO has been altering its categories within the conservation and preservation guidelines of the cultural landscape in the protection of cultural heritage. The main concern for both is the recognition and conservation of only the physical material of these sites.

Several academic definitions were collected in this period that varied in meaning and complexity. Adrian Philips described cultural landscape as “those areas on earth, where man exposed a substantial influence on nature and thereby changed its image significantly” (Phillips, 1995, p. 380). The definition shares a similar meaning but is simpler compared to Aitchison’s definition, which included the aspect of time in his understanding of the term as “… It is heritage of many eras of natural evolution and of many generations of human effort” (Aitchison, 1995). Conzen’s also included the aspect of time in his definition; refer to Table 5. On the other hand, Schine described it as “a material thing and a conceptual framing of the world—a visual and spatial epistemology” which complies with Groth definition of the term as a useful term for understanding the environment (Wilson & Groth, 2003). These definitions show the complexity of the term that established different ways of interpreting the concept.

The term has been defined and used within different institutions based on the UNESCO and NPS definitions, as shown in Table 5. Although cultural landscape has been defined institutionally, academic definitions of the term continued searching for its complexity. The definitions didn’t capture the concept content and meaning’s heuristic potential. That is why the definitions within the theoretical and scientific paradigms were not static (O’Donnell, 2008). As already mentioned, the cultural landscape has been used as a tool to explore ordinary landscapes. It generates a much richer concept than it is commonly advocated and has been redefined as suggested in Table 5, where definitions are neither different nor changed compared to scholarly and institutional points of view.

Definitions have not changed since 2010 in both formal and scholarly fields. Publications focused more on conservation, specifically the documentation and preservation of historic sites. The translation of these sites into world heritage sites and National Parks has influenced our scholarly work and studies investigating the implications of the practice of conservation on cultural landscape on definitions. Types of cultural landscapes have been categorized in order to include all details of the term as they contain both tangible and intangible factors. The definitions show that more involvement is needed from the scholarly and institution work to associate space and time with the cultural landscape.

**Table 5. Main definitions extracted from articles about the cultural landscape from 1990 till 2020**

<table>
<thead>
<tr>
<th><strong>legal &amp; formal institution 1990-2020</strong></th>
<th><strong>Scholarly /Academic 1990-2020</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>National Park Service (NPS) (1990)</strong></td>
<td></td>
</tr>
<tr>
<td>“A geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person, or that exhibit other cultural or aesthetic values” (NPS, 1990)</td>
<td></td>
</tr>
<tr>
<td><strong>UNESCO’s World Heritage Committee (1992)</strong></td>
<td></td>
</tr>
<tr>
<td>“Illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal” (UNESCO, 1992)</td>
<td></td>
</tr>
<tr>
<td><strong>NPS (1992)</strong></td>
<td></td>
</tr>
<tr>
<td>The US National Park Service defined four types of cultural landscapes, not mutually exclusive: historic sites, historic designed landscapes, historic vernacular landscapes, and ethnographic landscapes (US NPS 1992: 108)</td>
<td></td>
</tr>
</tbody>
</table>

150
Cultural landscapes reflect the interactions between people and their natural environment over space and time. "A cultural landscape is a complex phenomenon with a tangible and an intangible identity. The intangible component arises from ideas and interactions which have an impact on the perceptions and shaping of a landscape, such as sacred beliefs closely linked to the landscape and the way it has been perceived over time. Cultural landscapes mirror the cultures which created them" (Aitchison, 1995)

"Cultural landscapes or seascapes might be defined as those areas on earth, where man exposed a substantial influence on nature and thereby changed its image significantly" (Phillips, 1995, p. 380)

The cultural landscape Foundation (1998)
Cultural landscapes are landscapes that have been affected, influenced, or shaped by human involvement. A cultural landscape can be associated with a person or event. It can be thousands of acres or a tiny homestead. It can be a grand estate, industrial site, park, garden, cemetery, campus, and more. Collectively, cultural landscapes are works of art, narratives of culture, and expressions of regional identity (2001) M.P.Conzen
"A cultural landscape is the successive conversion over time of the material habitat of a sedentary human society responding with growing strength and variety to the challenges of nature, the society's own needs and desires. and the historical circumstances of different regions in different times." (Conzen, 2001)

"The cultural landscape is not merely the result of human activity. It is both a material thing and a conceptual framing of the world—a visual and spatial epistemology. As such, the cultural landscape is an important, even constitutive, part of social and cultural processes." (Schein, 2003)

"Cultural landscape is both a useful term and a necessary concept for understanding American environments. It is a way of thinking—one with inherent contradictions and multiple approaches—that people have readily adapted to new questions and social developments." (Wilson & Groth, 2003)

"Cultural landscapes are places where nature and culture have interacted to shape a place over time, the results of the interaction have imbued heritage values, and the cultural landscape is worthy of our respect and stewardship to preserve and conserve it into the future." (O’Donnell, 2004, p. 44)

(2006) Val Plumwood
"...is a concept that invites us to downplay or hide nonhuman agency and to present humans as having a monopoly of creativity and agency in the generation of what are called 'landscapes.' 'Cultural landscape' or 'human artefact' terminology for the land and the nature-skeptical claims often associated with them exemplify the potential for concepts and terminology to hide or nullify what we can't seem to recognize even to save ourselves - the way the systems of nature support our lives." (Val Plumwood, 2006)

NPS Cultural Landscape Inventory (CLI) (2009)
"...a geographic area (including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity or person or exhibiting other cultural or aesthetic values."
4.5 A brief summary of collected definitions within 1925-2020

In 1925, the term was academically introduced in the United States, defining the main elements of the meaning that described the physical change of the landscape with no further intangible aspects included. In contrast to institutional definitions, no recognition nor definitions were presented formally in the practical institution world. The academic world sets the base for the term to be incorporated. More eyes were fixed on this young concept; therefore, more theoretical reinstalment was developed in the 1950s through the late 1970s. More studies were allocated to the landscape and its meaning in this period. Changing our perspective of the landscape has strongly influenced the definition of the cultural landscape forward. Therefore, the definitions in this period were still shy and similar to definition of the previous period.

The term was recognized as a separate category in the institution department with no definitions yet. The peak of definitions was between 1970-1990; a theoretical base was prepared by scholars from the 1950s-1970s to consider redefining the term by incorporating deeper layers of the concept and different usage to utilize its core meaning. It was included in the formal and institution setting, where definitions were introduced to governmental and non-governmental entities concerning the cultural landscape. These definitions share the same core meaning with the scholarly work; however, it was more of a static process of defining. This process has influenced the academic definitions after 1990 as we noticed from the extracted definition the fast rhythm of broadening and reinterpretations of the term to suit multi-disciplinary studies, which often doesn’t match the rigid definition of the institutional one. Part of it seems of re-appropriation to manage the urge to preserve and protect the cultural heritage and to include these sites into these categories to force protection. And another to ease the need for justification. Either way, separating the scholarly from the formally defined terms rather than merging into a confined one. The institutional definitions do not match the academic scope despite the wide span of its application. Figure 1 below summarizes the main characteristics of the definitions of cultural landscape prevalent during each period between 1925 and 2020.

![Figure 1. A chart that summaries the main characteristics of the definition process of cultural landscape between 1925 and 2020 (2022). Diagram by authors.](image)

5 CONCLUSION

A definition is a powerful tool for encapsulating the essence of any concept. In this essay, we demonstrated how the concept of cultural landscape has to travel a significant but brief distance in order to generate a reliable collection of definitions. However, it is true to state that more current definitions in the cultural landscape have acquired their meaning from earlier definitions in scholarly work. However, the concept of "cultural landscape" has been employed to interpret and understand the terrain. It has been altered and improved to look into a variety of issues, including what culture is, which cultural landscapes should be preserved, and how an idea connected to culture is perceived.

The study identified four key eras in the evolution of the term's definition. These times span from 1925 through 2020. Similarities in meanings between 1950 and 1970 gave way to ongoing redefinitions...
and appropriations of the term to fit academic work inside and across many fields. They highlighted the significance of academic discourse in influencing the concepts of fusing nature and culture at the scholarly and institutional levels. According to definitions that were retrieved, this interaction fostered communication between numerous academic fields and helped to manage cultural resources. As a result, it has been challenging to conduct study on the concept of cultural landscape within a single subject. The borders of the cultural landscape, which were originally assumed to be conserved or recognized as a place as a cultural landscape site, have been constrained by the lack of a consistent definition in institutional documents. However, applying those definitions shows continuity more clearly. As we develop it as a tool and framework rather than utilize it as a documentation tool of its physical features, the lack of work defining cultural landscape as a term and a concept needs more attention from scholars and experts in the field of landscape architecture. Definitions of the "cultural landscape" that have evolved via various fields and meanings inherit the blending of nature and culture.

The research demonstrates how scholars and institutions in earlier periods used definitions that were comparable, which led to a continuous redefining and appropriation of the term to suit the academic work inside and across many fields. Between 1970 and 2020, definitions grew in complexity and continued to be expanded. The vernacular, associative, and ethnographic landscapes were recognized as cultural expressions, and professionals accepted a wider range of landscape types and scales. The aspect of time has also significantly added to the meaning of the cultural landscape, which has aided in understanding it as a heritage that should be kept and protected. As a result, official institution definitions were consistent with academic ones. Similarities lie at the heart of how culture alters the landscape, but the intricacy of that recognition.

This paper aims to open a discussion about the term's scholarly and practical use, application, and perception for new scholars and practitioners of cultural landscape, while also highlighting the depth of the existing body of knowledge through an accessible history of the scholarly and institutional definitions that made the term "cultural landscape" significant. However, it identifies the usages and definitions without excluding its relationships to the many fields associated with cultural landscape studies. Further research is advised to explore the implications of the various definitions of the term "cultural landscape" to the field of landscape architecture. As a result, this book offers a simple but valuable bibliography of recent and earlier scientific studies as well as documents from relevant institutions.

6 REFERENCES


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LANDSCAPE ARCHITECTURE FOR HEALTH

Edited by Shan Jiang, & Sungmin Lee
WHOA VISITED PARKS AND TRAILS MORE OR LESS DURING THE COVID-19 PANDEMIC, AND HOW? A MIXED-METHODS STUDY

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1 ABSTRACT
While the COVID-19 pandemic caused a decrease in travel and social activities, there was an exception—travel to parks and trails. Urban residents needed refuge to relax, exercise, and socialize. Thus, overcoming physical and mental issues caused by shelter-in-place and lack of social relationships. Nevertheless, trips to parks and trails vary by socio-demographic characteristics, disadvantageous to those having health issues or low-income. Without appropriate community design and planning interventions, such conditions may worsen existing environmental injustice and health issues.

This study address three research questions: 1) who visited parks and trails during the COVID-19 pandemic?, 2) how did residents feel about their use of parks and trails during the pandemic?, and 3) what improvements in parks and trails did residents want to see? Data comes from an online and intercept survey with 4,325 responses and focus groups with 52 participants in 2020 in Salt Lake City, UT, USA. This study employs mixed methods to concurrently compare and synthesize the results from the different methods (i.e., a convergent design). Survey data shows that park and trail use during the pandemic decreased among older adults, females, homeowners, and low-income households. Also, people living in a denser, more walkable, and more park/trail accessible neighborhood likely increased their park/trail visitations. Respondents in disadvantaged neighborhoods felt safe visiting parks, highlighting the value of urban nature as a resilience infrastructure and community asset during a time of crisis. The study findings provide planning implications to address barriers in park and trail use and promote stewardship of public lands, which are also relevant to other cities looking into the New Normal.

1.1 Keywords:
Green space, Equity, Health, SARS-CoV-2, Urban planning
INTRODUCTION

The COVID-19 pandemic has resulted in a general decrease in travel and social activities across the globe (De Vos, 2020; Parr et al., 2020). But the literature shows an exception—travel to parks, trails, and other outdoor recreation facilities. Park visitation has increased since the COVID-19 outbreak in most countries (Geng et al., 2020) or decreased least compared with other types of travel during the early phases of the pandemic (Hamidi & Zandiatashbar, 2021). Recreation activities in trails also increased in Oslo, Norway (Venter et al., 2020) and smaller U.S. cities (Zhang & Fricker, 2021). People used parks and trails as a refuge to relax, exercise, and socialize, and thus, to overcome physical and mental issues caused by shelter-in-place and limited social relationships (Ugolini et al., 2020, 2021).

Nevertheless, changes in travel to parks and trails vary among different socio-demographic groups. People having pre-existing health issues (e.g., older adults, those with disabilities) or low-income may have more concerns or lack opportunities to visit parks and trails during the pandemic (Abedi et al., 2020; Palgi et al., 2020). Higher-income individuals and females increased outdoor social and recreational activities during the COVID-19 pandemic more than their counterparts in Vermont (Morse et al., 2020). In the U.S. West, counties with more older residents showed more decreases in park visitation in 2020 (Rice & Pan, 2020). Such a socio-demographic discrepancy may worsen well-documented environmental injustice issues in access to parks and trails (Park et al., 2021; Rigolon, 2016; Wolch et al., 2014). Without appropriate community design, planning, and programming interventions, such a condition may worsen existing environmental injustice and health issues in park accessibility and usability. But there is a lack of comprehensive studies examining how much and why disadvantaged people reduced their park and trail use during the pandemic.

The COVID-19 public health crisis and related travel restrictions caused disproportionate impacts within a region, depending on the geography and built environment conditions, not just socioeconomic status (Liu et al., 2021). A recent study in Salt Lake City, Utah, shows that the COVID-19 pandemic has altered the relationship between pedestrian traffic volume and the built environment (Singleton et al., 2020). The higher the number of COVID-19 cases, the less (or more negative) the effects of the density, street connectivity, and destination accessibility on pedestrian volume were observed (Singleton et al., 2020). The exception was access to urban parks, as it became more significant in increasing pedestrian activities during the pandemic (Singleton et al., 2020). Previous studies show conflicting findings regarding the role of population density and neighborhood compactness on park use and outdoor activities. For example, people in compact areas with smaller homes (e.g., apartments or townhomes) and limited living experience in having good access to private greenspaces may still visit parks and outdoor recreation facilities (Hamidi & Zandiatashbar, 2021), while low-density neighborhoods may provide a better perception of social distancing in visiting parks because their physical attributes—setbacks of a housing unit and neighborhood locations far from major roads or high-density neighborhoods—allow residents to maintain their outdoor activities without any physical contacts with neighbors (Mitra et al., 2020). Thus, this study aims to explore the relationships between park/trail accessibility and the physical characteristics of a neighborhoods to explain pandemic-related park and trail use.

Using a mixed-methods research framework, this study aims to integrate quantitative and qualitative analysis findings to reveal the patterns of park and trail uses with respect to socio-demographic and physical characteristics of urban neighborhoods during the COVID-19 pandemic in Salt Lake City, UT, USA. Data comes from an online and intercept survey (n=4,325) and focus groups with 52 participants. Quantitative analyses help examine equity issues in park and trail uses regarding demographics (age, gender, race/ethnicity), socio-economic status (income, homeownership), and neighborhood built environment. Also, through qualitative analysis of focus groups, we explore how residents in disadvantaged neighborhoods feel about their use of parks and trails during the pandemic and how they would improve them in the future. The study findings could help park and recreation organizations and municipalities understand their (potential) users and develop effective design and programming solutions amid the pandemic and afterward (“a New Normal”) to promote good health outcomes.
3 DATA AND METHODS

3.1 Survey data and environmental data

Built on the dried flat land on the west side of the Rocky Mountain, there have been strong demands for creating and maintaining trees, parks, and green spaces for sustainable environmental planning in Salt Lake City. As of 2019, there are 689.8 acres of existing parkland and 1,693.7 acres of city-owned natural lands within the Salt Lake City boundary (a red dotted line in Figure 1). However, the central community of Salt Lake City (e.g., downtown Salt Lake, Sugarhouse, etc.) has the lowest park level of service score because of limited natural lands within these areas. Disparities in access to the park and natural lands between east and west Salt Lake City reveals gaps in diverse transportation choices in the west Salt Lake City neighborhoods, which leads to limited experience in visiting parks and trails using automobile (Salt Lake City Department of Parks and Public Lands, 2019).

As a follow-up plan, the “Reimagine Nature: Salt Lake City (SLC) Public Lands Master Plan” project was initiated in early 2020, and more than 12,000 Sale Lake City community members were involved in the planning process. Led by the Department of City and Metropolitan Planning, the University of Utah, the online and in-person surveys were implemented, and 4,325 online and in-person survey responses were collected from August to September 2020 (Figure 1). The plan is a master plan that will provide a guiding vision for the next 20 years for the city’s four public lands divisions (parks, trails and natural lands, urban forestry, and city golf). The city utilized new advertisement methods and partnered with the University of Utah to employ a variety of digital and in-person techniques to reach underrepresented communities. Tasked to identify future projects that would be transformative and meaningful for underserved populations, engagement was strategic to encourage diverse populations to share their hopes and ideas for this vision plan. Despite a small budget, this engagement campaign has been highly successful regarding the diversity of respondents, total response rate, and how citizens play a strong role in crafting the plan. On June 7th, 2022, the plan was adopted officially by the city council and won the Utah American Planning Association (APA) award for public outreach. Using 215 social media posts and 236 flyer distribution in libraries, apartment buildings, and businesses, we collected 3,717 online surveys. The remaining surveys (609 responses) were collected by visiting 26 parks, ten natural areas, and 20 other areas, such as supermarkets, breweries, etc., in person.

Figure 1. Study area in Salt Lake City, UT, marked with survey respondents, parks, & trails
The questionnaire survey asked, “has your frequency of use of parks changed this year from previous years” with three response options: visiting more often, same frequency, and visiting less often. The same was asked for trails. Also, perceived access to different types of public lands was asked: “Which of these is easy for you to access (through walking or biking) from your home,” with five choices: a city park, recreational trail or bike path, natural area or open space, a street or public space with abundant trees, and a city golf course.

Also, in October of 2020, six focus groups (four in Zoom and two in person) were conducted with 52 individuals from low-income neighborhoods to ask about using parks and trails and what they would like to see improved. Invitations were sent out through community partners. The focus of the interview guide had questions about use of parks generally speaking and during COVID-19, value of parks, stewardship, equity, and improving parks. Questions were the same for both zoom and in-person meetings as well as English and Spanish focus groups. Table 1 shows descriptive statistics of demographic attributes in the three surveys. Compared with the online survey, intercept survey respondents were younger, more female, lower-income, and less non-Hispanic White. The online survey respondents included 71% of homeowners. Because focus group interviews targeted residents in disadvantaged neighborhoods in Salt Lake City, they had more Hispanics and low-income households.

Table 1. Descriptive statistics of demographic attributes in three surveys

<table>
<thead>
<tr>
<th>Variable</th>
<th>Salt Lake City residents</th>
<th>Online survey (n=3,716)</th>
<th>Intercept survey (n=609)</th>
<th>Focus group (n=52)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Under 18</td>
<td>21%</td>
<td>1%</td>
<td>10%</td>
<td>4%</td>
</tr>
<tr>
<td>18-21</td>
<td>7%</td>
<td>3%</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>22-30</td>
<td>19%</td>
<td>21%</td>
<td>32%</td>
<td>18%</td>
</tr>
<tr>
<td>31-40</td>
<td>17%</td>
<td>26%</td>
<td>22%</td>
<td>24%</td>
</tr>
<tr>
<td>41-50</td>
<td>11%</td>
<td>15%</td>
<td>10%</td>
<td>24%</td>
</tr>
<tr>
<td>51-60</td>
<td>10%</td>
<td>13%</td>
<td>6%</td>
<td>11%</td>
</tr>
<tr>
<td>61 or older</td>
<td>16%</td>
<td>19%</td>
<td>7%</td>
<td>17%</td>
</tr>
<tr>
<td>Gender Female</td>
<td>49%</td>
<td>41%</td>
<td>52%</td>
<td>66%</td>
</tr>
<tr>
<td>Male</td>
<td>51%</td>
<td>52%</td>
<td>45%</td>
<td>33%</td>
</tr>
<tr>
<td>Race/ethnicity Hispanic</td>
<td>22%</td>
<td>5%</td>
<td>15%</td>
<td>41%</td>
</tr>
<tr>
<td>White (non-Hispanic)</td>
<td>64%</td>
<td>80%</td>
<td>66%</td>
<td>42%</td>
</tr>
<tr>
<td>Others (non-Hispanic)</td>
<td>14%</td>
<td>15%</td>
<td>19%</td>
<td>17%</td>
</tr>
<tr>
<td>Annual household income ($)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - $14,999</td>
<td>12%</td>
<td>3%</td>
<td>14%</td>
<td>28%</td>
</tr>
<tr>
<td>$15,000 - $24,999</td>
<td>8%</td>
<td>3%</td>
<td>7%</td>
<td>20%</td>
</tr>
<tr>
<td>$25,000 - $49,999</td>
<td>22%</td>
<td>12%</td>
<td>20%</td>
<td>17%</td>
</tr>
<tr>
<td>$50,000 - $74,999</td>
<td>18%</td>
<td>17%</td>
<td>19%</td>
<td>9%</td>
</tr>
<tr>
<td>$75,000 - $100,000</td>
<td>13%</td>
<td>17%</td>
<td>14%</td>
<td>0%</td>
</tr>
<tr>
<td>$100,000 - $150,000</td>
<td>14%</td>
<td>20%</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>$150,000 or higher</td>
<td>13%</td>
<td>21%</td>
<td>7%</td>
<td>13%</td>
</tr>
<tr>
<td>Prefer not to say</td>
<td>-</td>
<td>6%</td>
<td>9%</td>
<td>6%</td>
</tr>
<tr>
<td>Homeownership Own</td>
<td>48%</td>
<td>71%</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Rent</td>
<td>52%</td>
<td>27%</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

1. Data are from American Community Survey 2015-2019 5-year estimates

For regression analyses, we selected a subset of the online survey data that meet certain requirements. To be included in the analysis, a survey record should have 1) valid XY coordinate information within Salt Lake City boundary to calculate neighborhood environmental variables and 2) the point location must match with a stated ZIP code. As a result, the final sample for the spatial analysis includes 1,235 responses.
Park and trail location data were downloaded from Utah Geospatial Resource Center (https://gis.utah.gov/data/; Figure 1). To calculate park and trail accessibility, service areas were drawn from each respondent's location, using Network Analyst tools in ArcGIS Pro. And total acreage of parks intersecting with each ¼-mile buffer was calculated. Literature shows that both objectively measured and perceptual accessibility to parks and trails can also explain actual visitation behaviors (Chen et al., 2019; Park, 2017; Scott et al., 2007). In addition, we collected socio-demographic data (age, race, ethnicity, and income) at the Census block group level from the American Community Survey 2015-2019 five-year estimates, which were downloaded from the NHGIS website (Manson et al., 2020).

Three built environment variables that might be related to park and trail use were included, following the previous studies (Baran et al., 2014; Cohen et al., 2012; Lindsey et al., 2006; Park, 2020; Reynolds et al., 2007; Van Dyck et al., 2013). First, the population density variable was computed as the number of residents divided by the gross area of a Census block group (1,000 persons per square mile). Also, the proportion of four-way intersections as a measure of street connectivity and walkability (Ewing & Cervero, 2010) was computed using intersection location data provided by the Metropolitan Research Center at the University of Utah. Lastly, transit stop density of a block group was measured as the number of public transit stops (bus, rail) per square mile. Table 2 shows descriptive statistics of explanatory variables for 1,235 samples.

Table 2. Descriptive statistics for regression analyses (n=1,235)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older adults (61 years or older=1, others=0)</td>
<td>0.16</td>
<td>0.00</td>
<td>0.37</td>
</tr>
<tr>
<td>Gender (male =1, female=0)</td>
<td>0.52</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>Race/ethnicity (non-Hispanic White=1, others=0)</td>
<td>0.83</td>
<td>1.00</td>
<td>0.38</td>
</tr>
<tr>
<td>Annual household income¹</td>
<td>97,748.99</td>
<td>87,500.00</td>
<td>54,363.52</td>
</tr>
<tr>
<td>Homeownership (owner=1, renter=0)</td>
<td>0.74</td>
<td>1.00</td>
<td>0.44</td>
</tr>
<tr>
<td>Total acreage of parks within ¼-mile</td>
<td>17.47</td>
<td>0.82</td>
<td>34.76</td>
</tr>
<tr>
<td>Trail access within ¼-mile (yes=1, no=0)</td>
<td>0.41</td>
<td>0.00</td>
<td>0.49</td>
</tr>
<tr>
<td>Perceived park access in a neighborhood (yes=1)</td>
<td>0.90</td>
<td>1.00</td>
<td>0.30</td>
</tr>
<tr>
<td>Perceived trail access in a neighborhood (yes=1)</td>
<td>0.62</td>
<td>1.00</td>
<td>0.48</td>
</tr>
<tr>
<td>Population density (1000 people/sq.mi.)</td>
<td>7.01</td>
<td>6.81</td>
<td>3.95</td>
</tr>
<tr>
<td>% commercial properties</td>
<td>0.18</td>
<td>0.07</td>
<td>0.23</td>
</tr>
<tr>
<td>% 4-way intersections</td>
<td>0.35</td>
<td>0.30</td>
<td>0.17</td>
</tr>
<tr>
<td>% low-income households (less than $25,000)</td>
<td>0.17</td>
<td>0.15</td>
<td>0.12</td>
</tr>
<tr>
<td>% non-Hispanic White</td>
<td>0.73</td>
<td>0.81</td>
<td>0.20</td>
</tr>
<tr>
<td>% senior population</td>
<td>0.12</td>
<td>0.10</td>
<td>0.08</td>
</tr>
</tbody>
</table>

¹ Income categories were recoded: less than $14,999 = $7,500, $15,000 - $24,999 = $20,000, $25,000 - $49,999 = $37,500, $50,000 - $74,999 = $62,500, $75,000 - $100,000 = $87,500, $100,000 - $150,000 = $125,000, $150,000 or higher = $175,000

3.2 Data analysis

To provide a more holistic understanding of park and trail use during the COVID-19 pandemic, this study employs mixed methods combining quantitative analyses of the questionnaire survey data and qualitative analyses of the focus group interview data (Creswell & Plano Clark, 2018; Millard-Ball & Kim, 2020). Furthermore, quantitative and qualitative methods are used concurrently to compare and synthesize the results from the different methods through triangulation (i.e., a convergent design; (Creswell & Plano Clark, 2018; Millard-Ball & Kim, 2020). In this study, the findings from the quantitative ordinal regression models are used to conduct more focused qualitative interview transcript coding, and the findings from the qualitative interview research are used to validate and complement the findings of the quantitative analyses. Figure 2 shows a concurrent mixed-method diagram of this study.
Quantitative analyses have two parts: bivariate analyses of the demographic profile of park and trail users and a regression model. In the first part, using the online and in-person survey data, the demographic profile of park and trail users was compared among three groups—those who used parks and trails more, less, or the same frequency in 2020, compared with 2019—in terms of age, gender, race/ethnicity, income level, and homeownership. Respondents were asked about their visitation changes between 2020 and 2019. Then, to check statistical significance among those groups, we ran an ANOVA test for continuous variables (age and income level) and a chi-squared test of independence for categorical variables (being older than 60 years old, gender, race/ethnicity, and homeownership).

Two regression models explain the frequency change of park and trail uses in 2020, respectively, regarding personal and neighborhood environment characteristics. Explanatory variables include personal demographics (age, gender, race/ethnicity, household income), park/trail accessibility (both subjectively and objectively measured park/trail access), built environment characteristics (population density, street network connectivity, and proportion of commercial properties), and neighborhood socio-demographic attributes (percentage of low-income households, percentage of non-Hispanic Whites, and percentage of senior population). The outcome variables are ordinal because they have three ordered options—used parks/trails more, at the same frequency, or less in 2020, compared with 2019. Thus, we use ordinal logistic regression, also called ordered regression. In the model result, the coefficient estimate can be exponentiated to be read as an odds ratio (the odds of being less than or equal to a particular category).

It is noteworthy that we tested two advanced models—multilevel modeling and spatial regression—but did not find enough level-2 variance (Census block group as the level 2 unit; adjusted ICC=0.039 for a park model and 0.042 for a trail model) nor spatial autocorrelation in the model residuals (Moran’s I=0.003 for a park model and 0.005 for a trail model), respectively. Thus, we built simpler models using ordinal logistic regression.

Focus groups were transcribed and then coded using the four themes explored in the conversation: use and value of parks, stewardship, equity, and improving parks and trails. One of the focus groups, with 14 individuals, was conducted in Spanish; this transcription was translated into English.

4 RESULTS

4.1 Demographic profile of park and trail users during the pandemic

ANOVA test results in Table 3 show that people who used parks less often during the pandemic than in 2019 were older, more female, less non-Hispanic White, and more homeowners than those who used parks more often. On the other hand, people who increased their park visitation during the pandemic were younger, more male, more non-Hispanic White, and more renters. Interestingly, park users whose visitation frequency had not changed during the pandemic were among the oldest, most male, most non-Hispanic White, highest income, and most owners. All group-wise differences are statistically significant at $p<.05$ level. The decrease in the frequencies of visiting parks during COVID-19 among older, female, and Hispanic populations implies that demographic disparities in access to urban amenities got worse during the pandemic because of a lack of affordable transportation choices and a higher risk of infection and death by coronavirus when they contacted other active population groups outside their home.
The demographic profile of trail users is also similar to that of park users during COVID-19, but the overall frequencies of visiting trails tend to be slightly lower than those of visiting parks, suggesting relatively lack of accessibility to trails using diverse transportation choices. People who used trails less often during the pandemic than in 2019 were older, more female, less non-Hispanic White, had lower income, and more homeowners than those who used trails more often (Table 3). On the other hand, people who increased their trail visitation during the pandemic were younger, more non-Hispanic White, had a higher income, and more renters. Likewise, all group-wise differences in trail use frequency are statistically significant at $p<.05$ level. An increase in visiting trails among renters during COVID-19 suggests the reality that they had limited space for outdoor activities and wanted to maintain physical distance from their neighbors by visiting trails more often.

**Table 3. Mean values of demographic variables by frequency changes in visiting parks and trails in 2020 compared with 2019 (n=4,325)**

<table>
<thead>
<tr>
<th>Frequency changes to visiting parks in 2020 compared with 2019</th>
<th>%</th>
<th>Age</th>
<th>Age (over 60)</th>
<th>Gender (male)</th>
<th>Race/ethnicity (non-Hispanic White)</th>
<th>Income level</th>
<th>Home ownership (owner)$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visiting parks less often</td>
<td>16.2%</td>
<td>42.9</td>
<td>20.1%</td>
<td>45.0%</td>
<td>75.6%</td>
<td>$91,849</td>
<td>76.9%</td>
</tr>
<tr>
<td>Same frequency</td>
<td>39.7%</td>
<td>44.3</td>
<td>22.5%</td>
<td>58.0%</td>
<td>81.7%</td>
<td>$98,467</td>
<td>77.8%</td>
</tr>
<tr>
<td>Visiting parks more often</td>
<td>43.6%</td>
<td>38.6</td>
<td>11.6%</td>
<td>49.2%</td>
<td>79.2%</td>
<td>$92,951</td>
<td>66.5%</td>
</tr>
<tr>
<td>$p$-value$^1$</td>
<td>-</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.003</td>
<td>.002</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency changes to visiting trails in 2020 compared with 2019</th>
<th>%</th>
<th>Age</th>
<th>Age (over 60)</th>
<th>Gender (male)</th>
<th>Race/ethnicity (non-Hispanic White)</th>
<th>Income level</th>
<th>Home ownership (owner)$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using trails less often</td>
<td>15.1%</td>
<td>44.2</td>
<td>24.5%</td>
<td>48.7%</td>
<td>75.3%</td>
<td>$87,641</td>
<td>72.4%</td>
</tr>
<tr>
<td>Same frequency</td>
<td>42.9%</td>
<td>43.2</td>
<td>22.0%</td>
<td>55.3%</td>
<td>80.5%</td>
<td>$96,017</td>
<td>75.1%</td>
</tr>
<tr>
<td>Using trails more often</td>
<td>41.4%</td>
<td>38.8</td>
<td>9.5%</td>
<td>49.9%</td>
<td>80.2%</td>
<td>$96,413</td>
<td>70.4%</td>
</tr>
<tr>
<td>$p$-value$^1$</td>
<td>-</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.001</td>
<td>.014</td>
<td>.001</td>
<td>.012</td>
</tr>
</tbody>
</table>

$^1$ We ran an ANOVA test for continuous variables (age and income level) and a chi-squared test of independence for categorical variables (over 60 years old, gender, race/ethnicity, and homeownership).

$^2$ Homeownership variable is only available for online surveys but not intercept surveys.

### 4.2 Ordinal regression of park and trail use during COVID-19

Table 4 shows the results of the two ordinal regression models. The coefficients in the models are provided as the log odds, so they are transformed into “proportional odds ratios” for better interpretation. For example, a ten-acre increase in the park area within a ¼-mile of a respondent location is associated with an approximately 3% increase in the odds of “visiting parks more often” (vs. “same frequency” or “visiting parks less often”). The negative log-odd coefficient estimates (or the odds ratio of less than 1) of being an older adult indicates that the odds of an older adult visiting urban parks more often during the pandemic period is 45.2% less likely (1 minus 0.548) than younger people. Or, with the proportional odds assumption, one can say that the odds of an older adult visiting urban parks less often is 45.2% higher than the other group. Older adults may feel uncomfortable and unsafe using an urban park (or any other gathering place) during the pandemic due to the increased risk of the COVID-19 infection.

Among the environmental variables at the Census block group level, respondents living in a neighborhood with higher population density, high percentages of commercial parcels, four-way
intersections, and older adults (65 years or older), and a lower percentage of low-income households were more likely to use parks more often than those living in a neighborhood with opposite conditions. These findings suggest that denser, mixed-use neighborhoods with better street network connectivity can lead residents to visit urban parks more frequently during the COVID-19. In addition, higher-income neighborhoods with older (probably retired) residents showed increased park visits during the COVID-19; retirees may have sufficient time for their outdoor activities and visiting diverse urban amenities while maintaining their living expenses.

Despite the negative relationship between being older and the likelihood of visiting parks more often, the percentage of the senior population in a neighborhood shows a contradictory, positive association. This result may be due to unobserved variables (e.g., the quality of environmental amenities or social capital of a neighborhood) that more older adults choose to live. On the other hand, respondents living in low-income neighborhoods tended to visit urban parks less often than those from more affluent areas. One possible explanation is that the increased uncertainty of employment conditions and fewer opportunities to work at home among low-wage workers could lead them to spend more time maintaining their economic activities rather than recreational ones such as visiting parks or trails during the COVID-19 pandemic. Rapid economic downturn and lack of stable job opportunities forced low-income households and individuals to be vulnerable to unexpected housing risks—exposing higher risks of homelessness and housing eviction. Higher risks of homelessness and housing eviction were evident near downtown Salt Lake City—our study area—during the COVID-19 pandemic (Kim et al., 2021; Garcia and Kim, 2021). Therefore, although low-income neighborhoods near downtown may have good access to parks for their outdoor activities and physical distancing against the COVID-19 infection, their lack of diverse income sources may force them to put first priority on spending more time working for their living and less time for their outdoor activities and physical distancing against coronavirus.

A model about respondents' trail uses amid the pandemic shows similar results regarding being 61 years or older (5% decrease in the odds of visiting trails compared to adults less than 60 years old), population density (3.5% increase in the odds of visiting trails more often), and the percentage of the senior population of a neighborhood (positive). Unlike the park model, where the objectively measured park access was statistically significant, this model shows that respondents' perception of being accessible to a trail near their home rather than its actual distance increases the likelihood of visiting trails more often during the pandemic (32% higher odds). This suggests that easy access to a trail makes respondents feel more comfortable maintaining their physical distancing and outdoor activities during COVID-19. Annual household income shows a positive relationship with trail use (odds ratio of 1.035), while the percentage of non-Hispanic Whites in a neighborhood is negatively associated with it (odds ratio of -0.710).

4.3 The importance of parks and trails during COVID-19

Using focus groups, we analyze how residents felt about their use of urban parks and trails (Table 5). Some participants said that they felt safe in parks because there were not a lot of people. Like Aspen, who said, “I especially like with COVID I didn’t feel like there were a lot of people and I felt safe there.” Regarding the need for social distancing, Linda had a similar comment, “Especially right now, because of the pandemic, nobody bothers you.”

Another common theme is that these natural areas are essential to decompress mentally—making you happier and healthier. Carrie, a white woman, sums up this collective feeling, “you have this string of nature in the urban environment that restores my soul.” Many specified how parks help them to relax, especially during COVID-19. For example, Vanessa, a Latina, stated how she and her husband use the park to destress, “My husband goes to the canyon to run, and I [go to] walk. It is very important to have an area, a green area to be able to go out and more in this pandemic that one has to go out to destress.”

Like Vanessa, other participants also commented how parks have helped their children stay active and entertained during COVID-19. Karla, a Latina mother, commented how her daughter can unplug and be active when they visit parks, “I have an eleven-year-old girl and it is just a story that we go out to the park for a walk. And it is famous for unplugging them from the cell phone and letting them exercise.”

Kenneth, a white male, talked about how his kids have played baseball for the community teams that utilize the parks near them. He said, “We have two boys that have played, and we missed it this year. My youngest son just started playing in high school, and aside from the fact that everything was canceled because of COVID, we missed the whole experience.” In response to COVID-19, many community programs were suspended, which has decreased the amount of time they spent at parks. Kelly, a white
woman from Central City, said, “The social distancing has been putting a damper on things, like not having yoga in the park, not having every community activity.”

Other than parks providing a space to maintain an active lifestyle, participants expressed how public lands allow them to build community and stay connected with friends and family. These spaces are vital for individuals that live in apartments or small homes. Gabriela, a Latina, commented, “My mother loves the house, but it has a very small yard...we always tend to go to a park when we want to grill meat or be with family or get together with friends.” Raquel added, “these green areas have become even more important...since I have not much space other than my porch.”

Unanimously, participants expressed how having parks and public lands in proximity is important. Roberta, exemplified this feeling when she said, “I believe that green spaces and parks are a fundamental part of our life, and more so in these times.”

Table 4. Ordinal regression results of park and trail uses during the COVID-19 pandemic

<table>
<thead>
<tr>
<th>Park Use (less often/same/more often)</th>
<th>Trail Use (less often/same/more often)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>Variables</td>
</tr>
<tr>
<td>Respondent survey variables</td>
<td>Respondent survey variables</td>
</tr>
<tr>
<td>Perceived park access: Yes</td>
<td>Perceived trail access: Yes</td>
</tr>
<tr>
<td>Park acres within ¼ mile</td>
<td>Trails within ¼ mile</td>
</tr>
<tr>
<td>61 years or older: Yes</td>
<td>61 years or older: Yes</td>
</tr>
<tr>
<td>Gender: male</td>
<td>Gender: male</td>
</tr>
<tr>
<td>Race: non-Hispanic White</td>
<td>Race: non-Hispanic White</td>
</tr>
<tr>
<td>Rent: Yes</td>
<td>Rent: Yes</td>
</tr>
<tr>
<td>Annual income²</td>
<td>Annual income²</td>
</tr>
<tr>
<td>Environmental variables</td>
<td>Environmental variables</td>
</tr>
<tr>
<td>Population density²</td>
<td>Population density³</td>
</tr>
<tr>
<td>% commercial properties</td>
<td>% commercial properties</td>
</tr>
<tr>
<td>% intersections</td>
<td>% intersections</td>
</tr>
<tr>
<td>% low-income households</td>
<td>% low-income households</td>
</tr>
<tr>
<td>% non-Hispanic Whites</td>
<td>% non-Hispanic Whites</td>
</tr>
<tr>
<td>% senior population</td>
<td>% senior population</td>
</tr>
<tr>
<td>Observations</td>
<td>Observations</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>Log Likelihood</td>
</tr>
<tr>
<td>AIC²</td>
<td>AIC⁴</td>
</tr>
</tbody>
</table>

1 ***: p < .001, **: p < .01, *: p < .05, ^: p < .1
2 Annual income categories were recoded: Under $14,999 = $7,500, $15,000 to $24,999 = $20,000, $25,000 to $49,999 = $37,500, $50,000 to $74,999 = $62,500, $75,000 to $99,999 = $87,500, $100,000 to $149,999 = $125,000, $150,000 or higher = $150,000
3 Population density was rescaled to 1,000 people per square mile.
4 AIC = Akaike Information Criterion (AIC)
<table>
<thead>
<tr>
<th>Theme</th>
<th>Sub-theme</th>
<th>Narrative excepts</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use and value of parks during the pandemic</td>
<td>Mental health</td>
<td>You have this string of nature in the urban environment that restores my soul</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Staying physically active</td>
<td>My husband goes to the canyon to run, and I [go to] walk. It is very important to have an area, a green area to be able to go out and more in this pandemic that one has to go out to destres</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Safety from the virus</td>
<td>I especially like with COVID I didn’t feel like there were a lot of people and I felt safe there</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Social activities and community integration</td>
<td>We always tend to go to a park when we want to grill meat or be with family or get together with friends…. these green areas have become even more important….since I have not much space other than my porch.</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Child’s development</td>
<td>I have an eleven-year-old girl and it is just a story that we go out to the park for a walk. And it is famous for unplugging them from the cell phone and letting them exercise</td>
<td>16</td>
</tr>
<tr>
<td>Stewardship</td>
<td>Clean-up interventions</td>
<td>And then we invited them to clean-up, invited their families, and I mean you could get community members to help do that every year.</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Educational programming</td>
<td>We went to Franklin Elementary, which is right on the river, and we spoke to some of the classes about pollution and how that comes through the storm drains, and we just did a little lesson about that.</td>
<td>18</td>
</tr>
<tr>
<td>Equity</td>
<td>Disability-related</td>
<td>And the disabled people don’t have this nice place they can just roll their motorized chair down and be next to the river, and that’s been a thorn in my side since I became aware</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Active modes of transportation</td>
<td>If one goes on the trail or paths, because there are many cars, a lot of traffic, but the trails do not always connect. There must be paths for children, for adults too, because it is lacking here. We are always mobilizing by car.</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Public transit access</td>
<td>… is kind of still far because there’s not a bus to get there</td>
<td>12</td>
</tr>
<tr>
<td>Obstacles and improving strategies</td>
<td>Better maintenance</td>
<td>Resources for the parks are not there. The trees are dying. They’re not maintained.</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>More community activities and programs</td>
<td>The social distancing has been putting a damper on things, like not having yoga in the park, not having every community activity.</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Safety from crime</td>
<td>If there were more lights or if people were to be more visible at night, I feel like that would make it better</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>More amenities</td>
<td>We’re talking about amenities for children, which is a lower priority than recreational amenities for older people</td>
<td>11</td>
</tr>
</tbody>
</table>
4.4 Ways to improve parks and trails beyond the pandemic

A quote that essentially sums up what makes a great park comes from Kelly who said: “Just going to the park area is more healing, and I want to be somewhere where it’s nice and well maintained and has amenities available.” Participants described enjoying parks with amenities like bathrooms, water fountains, playground equipment, exercise equipment, sport areas, benches, barbecues, pavilions, and picnic tables. The main aspect of concern was safety: “There are other parts of the parkway that are not nice (referring to not being clean) and have crime.” Another participant said, “Safe, it has to be safe. I mean one of the things that you know we have a problem with, especially in this neighborhood is safety.” A female participant added, “I do have access to the Jordan River trail, but I don’t use it anymore, because it’s unsafe. It is extremely polluted and is extremely unsafe at night, especially for women.” Improved lighting was proposed as a solution, “If there were more lights or if people were to be more visible at night, I feel like that would make it better.”

A community leader shared her efforts to improve parks around clean-up interventions and educational programming around stewardship, “We went to Franklin Elementary, which is right on the river, and we spoke to some of the classes about pollution and how that comes through the storm drains, and we just did a little lesson about that. And then we invited them to clean-up, invited their families, and I mean you could get community members to help do that every year. We were going to do it this year, but COVID happened.” Additional programming recommendations included interactive events such as a scavenger hunt that focuses on historical education. Other creative program ideas included sponsoring little libraries in parks to promote passive recreation such as reading in public spaces. In addition, people spoke about sponsoring events at the park like yoga, vendors, music, art, cultural events for everyone including older adults, youth, and family activities.

Timothy, a white male, living in the Westside, said that the city needed to better maintain parks (e.g., clean up the trash). In particular, he suggested using “capital improvement money” for “ongoing maintenance.” There was also a discussion of community responsibility and volunteerism as Kelly highlighted, “Resources for the parks are not there. The trees are dying. They’re not maintained. But we have people who can volunteer.” The topic of engaging the community in the stewardship of parks was very prevalent.

Finally, some spoke about improving the accessibility of parks, “And the disabled people don’t have this nice place they can just roll their motorized chair down and be next to the river, and that’s been a thorn in my side since I became aware,” said Timothy. Although, in terms of accessibility, some spoke about access to transportation to get there. Jonathan said, “is kind of still far because there’s not a bus to get there.” Karla also mentioned how connecting bike paths to parks would minimize her driving, “If one goes on the trail or paths, because there are many cars, a lot of traffic, but the trails do not always connect. There must be paths for children, for adults too, because it is lacking here. We are always mobilizing by car.” Timothy added that because of their lack of access, parks are, “withheld from the public that owns it and paid for it.”

5 DISCUSSION AND CONCLUSIONS

In this study, we explore the demographic profile of visitors to urban parks and trails during the COVID-19 pandemic. People who used parks and trails less often during the pandemic (16% of our sample) were more likely the disadvantaged population in terms of age (older adults), race/ethnicity, and income. In addition, male residents and renters increased their park and trail visitation during the pandemic, compared with females and homeowners, respectively. Regression models also confirm that after controlling for demographics and neighborhood environments, park and trail usage during the pandemic decreased with being older, being female, and having a lower income. The qualitative analyses of interviews also showed that younger people visited parks more after the pandemic outbreak. In addition, park and trail use seemed more important for interviewees with smaller places and no yards, primarily renters.

Such outdoor recreation activities further decreased in disadvantaged neighborhoods with a higher portion of low-income households. Among neighborhood-level built environment variables, population density, walkability, and park/trail accessibility are positively associated with park and trail visitation. In other words, people living in a denser, more walkable, and more park/trail accessible neighborhood likely increased (or did not decrease) their park/trail usage levels amid the pandemic. These findings align with other recent studies. Residents of compact regions in the U.S. were less likely to reduce their trips to parks.
March 16-19, 2022

during the shelter-in-place order (Hamidi & Zandiatashbar, 2021). During the pandemic, youth with better access to parks in high-density neighborhoods engaged in outdoor activities more than average (Mitra et al., 2020). Some built environment characteristics remain significant in explaining park and trail uses both before and during the COVID-19 pandemic. Previous observational studies (Baran et al., 2014; Cohen et al., 2012; Park, 2020; Van Dyck et al., 2013) show that the park use level is higher in denser and more walkable neighborhoods. Trail traffic volume was higher in a neighborhood with a higher density and more commercial uses (Lindsey et al., 2006; Reynolds et al., 2007).

Our qualitative analysis further examines how residents feel about their use of urban parks and trails during the pandemic and how they would improve them. Given the perceived risks of indoor gathering, respondents felt safe visiting parks, shedding light on the value of urban nature as resilience infrastructure during a time of crisis (Morse et al., 2020; Venter et al., 2020). Parks were thought of as great community assets and places of personal refuge within a city (Grima et al., 2020). Carrie’s comments highlighted how people wanted to take advantage of parks as a fantastic resource, to have a “respite” to “restore one’s soul” in a highly urbanized area. For Vanessa, parks were necessary to “de-stress,” and for Karla, it was an opportunity for her kids to “unplug” during the pandemic while exercising and having a more healthy lifestyle. When asked about improvements, park users urged to provide parks with more amenities like bathrooms, active recreation facilities, and places to gather. Programming was viewed as a way of educating young people and others about nature. Events in parks, from festivals to clean-ups, were perceived as a way of fostering stewardship. However, more than spacing funds in improving parks, some thought that it was more important to maintain them and to remove barriers to access, such as those experienced by people with disabilities or zero-car households.

Thus, the key findings from this study identified concepts and ideas that resonated with the community to support the values of promoting equity, livability, and sustainability. Based on the feedback from residents in the survey and the focus groups, the Public Lands Master Plan (https://www.reimaginenatureslc.com/) proposed the transformative idea of “Reimagining Neighborhood Parks.” This idea involves engaging neighbors in redesigning and adding fixed activities to parks that reflect their interests. In addition, the concept promoted volunteerism and adopt-a-park/ friends groups. Another concept that promoted stewardship through programming for nature-based education was “Coming soon to a park near you.” This idea tries to promote partnerships for programming in parks such as arts, fitness, etc. Another theme is to “Reimagine Downtown SLC’s wide streets” in key locations to create a green loop of trees and green space, pedestrian- and bicycle-friendly paths, and flexible space for pop-up festivals and recreation. The concepts of “put environment first” and “grow our urban forest” were selected as being most urgent and important. The plan emphasizes the protection and expansion of nature in cities as a way to sustain environmental health.

Not only its findings but the process of this study also informed the Public Lands Master Plan, which has implications for urban planning and design for parks and trails. First, in-person outreach in areas of the city that are traditionally underrepresented was successful in keeping them engaged throughout the process and beyond. Second, our analysis of the first survey led to preliminary plan ideas and transformative projects that were shared in a series of focus groups with representative community stakeholders and public lands partners to refine the master plan direction. Initial input expressed a heightened awareness that many complex factors impact planning for Public Lands, such as homelessness, climate resiliency, racial justice, urban ecological system balance, population increases, and public funding priorities. These topics have broad implications for the city and could have been dismissed as outside Public Lands' ability to influence. Instead, Public Lands became a champion for these topics, convening workshops with 12 divisions within the city and nearly 60 organizational partners. Third, focus group conversations with residents were formed to discuss these topics more deeply and to learn from a wide variety of lived experiences. The focus groups cultivated stronger relationships resulting in new collaborations and solutions. The last plan input opportunity asked if the planning team had incorporated input appropriately, crafting a draft vision, goal, and projects that reflect community values and desires. Overall, 87% of respondents were satisfied with the initial plan direction, providing many helpful suggestions for adjustments that informed the final plan contents.

Further, based on our findings from this mixed-methods study, we call for special interventions during public health crises such as the pandemic. Temporary design and programming interventions could encourage low-mobility populations and those without private recreational space to have access and use urban parks and trails more often. Specific strategies through planning and transportation agencies include
street closure, traffic lane relocation, speed limit reduction, automated walk signals, and shared mobility programs, as well documented in Combs & Pardo (2021).

Also, we suggest that parks and trails in a city should not be closed or restricted during a public health crisis. Those restrictions could rather cause severe physical and mental health issues, especially for those without time and space to relax, exercise, and socialize. This study highlights the value of urban nature as a resilience infrastructure and community asset. Thus, in order to reduce crowding and related health concerns within those urban natural areas, cities can apply temporary design changes for social distancing, such as tactical urbanism interventions (Design for Distancing Ideas Guidebook, 2020; Herman & Drozda, 2021).

One major limitation of this study is the cross-sectional nature of the surveys. The COVID-19 impacts on people's social and recreational activities have been dynamic (Vannoni et al., 2020; Zhang & Fricker, 2021). Another limitation is that the study questions were about use of public lands in general with a few COVID-specific questions. While this study reveals a snapshot of urban residents' behavioral changes and perceptions regarding park and trail usage amid the pandemic, a more comprehensive understanding of such dynamics and predicting the New Normal may necessitate a longitudinal study. A follow-up study can address how information from this study was incorporated into the plan and its influence (or not) on subsequent implementation. Additionally, our survey targeted residents in Salt Lake City because it was a part of the process to develop the Salt Lake City’s Public Lands Master Plan. The modeling and interview research results are still based on a single place (i.e., Salt Lake City, Utah), and further research could see whether the findings of this study can be generalized to other urban areas.

While we are hoping to see the end of the COVID-19 pandemic, cities should implement preemptive planning approaches to prepare for the "New Normal" (Gkiotsalitis & Cats, 2021; Salama, 2020). To improve the overall accessibility and usability of parks and trails, this study emphasizes the importance of density, land use mix, street network connectivity, and walkability near parks and trails. We also find the values of promoting equity, livability, and sustainability for long-term planning goals, which can be incorporated into municipal comprehensive plans and regional transportation plans. Cities need transformative ideas around their parks and trails in preparation for the next public health crisis.

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LANDSCAPE PLANNING AND ECOLOGY

Edited by Chingwen Cheng, & Dongying Li
TREE CANOPY ON VACANT LOTS: NEGLECTED RESOURCES FOR ECOLOGICAL LANDSCAPE CONNECTIVITY

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1 ABSTRACT

Vacant land in cities has been treated as negative spaces associated with high crime rates and economic decline. However, usually underappreciated, vacant land also supports ecological functions such as biodiversity as much of the land is covered by flora and fauna. Little literature has examined the importance of tree canopy on vacant lots in the context of landscape connectivity. Using Hartford, Connecticut as a case study, this study aims to test a streamlined approach to evaluate the landscape connectivity of urban tree canopy on vacant lots by simulating scenarios of tree removals that often occur during vacant land redevelopment. The workflow using morphological spatial pattern analysis and network-based connectivity indices were tested to quantify the composition, configuration, and landscape connectivity value of tree canopy at two scales: on each vacant lot and in the entire municipal area. The findings indicated that compared with other scenarios of developing vacant lots with less UTC coverage, when vacant lots with more than 80% area covered by UTC were developed, the values of landscape connectivity decreased significantly, along with the largest loss of core habitats and corridors. Besides, several vacant lots with the highest landscape connectivity values were identified that were worth being preserved and protected from urban development. The results provided a feasible analytical tool to identify key vacant lots of great landscape connectivity value and informed urban forest management and vacant lot transformation decision-making to strategically choose vacant lots for development and greening in maximizing ecological values, preserving fauna habitats, and pursuing biodiversity.

1.1 Keywords
Tree canopy, Vacant land, Landscape connectivity, Network Analysis, Biodiversity
2 INTRODUCTION

Vacant lots, defined as unused or abandoned land in cities, are always seen as negative spaces followed by high crime rates, decreased land value and blight appearance (Bowman, 2004; De Biasi, 2017). Such issue was more challenging in post-industrial cities where the massive amount of core urban areas became trash-filled vacant land, brownfields, and blighted structures due to deindustrialization, population loss, and disinvestment in infrastructure and public service (Kapp et al., 2012). For example, Detroit, MI as one of the post-industrial cities experienced high urban vacancy with more than half of city parcels becoming vacant land (Foster & Newell, 2019). However, even though less considered, a large amount of vacant land in the urban landscape also has considerable ecological resources such as mature tree canopy cover and wildlife species, which in turn provides numerous ecosystem services such as runoff mitigation, carbon storage, provision of habitat and air pollution removal (Kremer, Hamstead, & McPhearson, 2013; McPhearson et al., 2013). For example, Burkholder (2012) summarized that vacant land in urban areas can provide ecosystem services through its contribution to urban atmosphere, urban pedosphere, urban hydrosphere, urban biosphere and biodiversity respectively.

Landscape connectivity is an essential characteristic of a landscape network, defined as ‘the degree to which a landscape facilitates or impedes movements of organisms among patches’ (Taylor et al., 1993). It is proven to affect species richness, diversity, pattern and rate of the biotic and abiotic flows in ecological networks, which in turn would largely alter biodiversity in a landscape (Humphrey et al., 2015; Mitchell et al., 2013; Tilman et al., 2017). Studies have examined that the composition and configuration of the tree canopy are associated with landscape connectivity as it affects species sheltering, interspecies interaction, and metapopulation dispersal in a forest landscape network (Hyseni et al., 2021; Leibold et al., 2004; Turner & Gardner, 2015). Isolated forest patches (i.e., low landscape connectivity or habitat fragmentation), on the other hand, could negatively impact the genetic diversity of organisms by decreasing population size and disturbing species dispersal dynamics for both plants such as Cercis canadensis and animals such as beetle communities (Foster, Neumann, & Holloway, 2019; Ony et al., 2020).

Once becoming one of the largest cities in the nation in the 1800s because of its firearm and other manufacturing industries, Hartford, Connecticut is a post-industrial city in the Northeastern U.S. with population decline, decentralization, and vacancy issues (Bisson, 2016). Efforts have been taken on vacant land transformation in Hartford with actions of selling publicly owned/acquired vacant land to private sectors, for example (Hartford Land Bank, n.d.). However, little has been done in assessing the ecological values and benefits of vacant lots, especially landscape connectivity values that tree canopy on vacant lots provides in the entire ecological network. Meanwhile, the forest landscape in Connecticut has been identified with fragmentation threats and preserving landscape connectivity becomes an urgent task for state-level landscape management (Hurd and Civco, 2010). Thus, it is worth assessing tree canopy on vacant land on a trajectory of landscape connectivity before reclaiming vacant land and understanding to what extent vacant land development could fragment the current landscape network.

In this study, two integrated approaches on landscape connectivity analysis were applied: 1) morphological spatial pattern analysis (MSPA) and 2) network-based connectivity indices (Saura and Vogt, 2009). Such streamlined approach provides practical and replicable framework for forest and urban vacant land management to evaluate tree canopy covers and identify key tree canopy elements for entire landscape network (Saura et al., 2011). We quantified the composition of tree canopy on vacant land in Hartford and examined its spatial distribution throughout the whole city area. The number, morphology and configuration of canopy elements were further analyzed, as well as the contribution of each tree canopy patch to network connectivity. Key canopy patches on vacant lots contributing to major structural connectivity for the entire landscape were then identified.

3 RESEARCH OBJECTIVES

Using Hartford, Connecticut as a case study, we aim to understand the potential impact of vacant land development scenarios on landscape connectivity and to provide an innovative and integrated workflow to prioritize and preserve vacant lots based on landscape connectivity value of tree canopy on them. Such streamlined analysis method and its results could inform strategic tree conservation practice and vacant land management in maximizing ecological values, preserving fauna habitats, and pursing biodiversity.

To do so, the following research questions were addressed in this study:
1. How does the composition, arrangement and morphology of tree canopy vary and distribute across all vacant lots in Hartford, CT?
2. How does landscape connectivity change within city landscape under different vacant lot development scenarios (i.e., By removing all tree canopy on vacant land, how much interpatch connectivity and intrapatch connectivity would be lost in Hartford urban forest network?)
3. Which vacant lots should be preserved and prioritized for potential urban forest patch/green spaces transformation?

4. METHODS

4.1 Geospatial Data Collection and Vacant Lots Identification

City limit, vacant property, parcel polygons and cadastral data were obtained from Hartford municipal open data portal (City of Hartford, 2020). The street addresses from vacant property database were geocoded by the geocoder published in Hartford GIS server in ArcMap. The resulted point layer was then spatially joined with city parcel data to create vacant parcel layer. The vacant land comprises 3.8 percent of city area and occupies 441.64 acres of land. Thus, this study investigated tree canopy on 759 vacant lots in the City of Hartford (Figure 1). Readily available 1-meter resolution land cover data was derived from 2008 high-resolution aerial imagery (Jarlath O’Neill-Dunne, 2010). Tree canopy raster data in Hartford was then extracted by the city limit from the land cover data and reclassified to binary raster layer with value 1 representing all other land covers (i.e., buildings, grasslands, water, and shrubs etc.) and value 2 representing tree canopy land cover. The study applied an integrated workflow from landscape pattern analysis to network analysis for evaluating landscape connectivity, and to identify prioritized vacant land for ecological network preservation (Figure 2).

4.2 Composition of Tree Canopy on Vacant Lots and Data Analysis

The composition of urban tree canopy (UTC) on vacant lots in Hartford was quantified in ArcMap. Zonal statistics as table tool was used to calculate the tree canopy area on each vacant lot using the resulted binary tree canopy raster layer (see Section 4.1). The resulted table was joined with the vacant parcel layer attribute table and the percentage of tree canopy per vacant lot was calculated by field calculator tool in ArcMap.

Five vacant land development hypothetical scenarios were set up in order to evaluate the importance of tree canopy patches on vacant lots regarding landscape connectivity and to explore the impact of potential tree removals on the loss of landscape connectivity due to vacant lot development.

1. Baseline: All vacant lots and their UTC stay as-is.
2. Vacant lots with <20% area as UTC is developed.
3. Vacant lots with <50% area as UTC is developed.
4. Vacant lots with <80% area as UTC is developed.
5. All Vacant lots are developed.
Figure 1. Spatial distribution of vacant lots and tree canopy in Hartford, CT. Map by the authors.

Figure 2. Conceptual Workflow. Diagram by the authors.
The scenarios were set up based on the frequency distribution of the percentage of UTC on all vacant lots (see section 5 for detailed composition results). To generate binary UTC layers under those four additional scenarios (Scenario 2-5), four landscape extent shapefiles were generated at first by clipping out conditional vacant parcels under Scenario 2-5 respectively from the city limit shapefile using erase tool. Next, the Extract by Mask tool in ArcMap was applied to extract the remaining UTC cells under four demolition scenarios, with removed UTC cells becoming nodata. By these means, four additional tree canopy raster layers plus original urban tree canopy data for five simulated scenarios were ready for the next steps.

4.3 Morphological Spatial Pattern Analysis

Morphological spatial pattern analysis (MSPA) is a geometry-based image analysis software used to quantify the spatial properties of image elements (Vogt & Riitters, 2017). The toolbox is widely used in environmental studies to analyze image maps for spatial pattern, network, fragmentation, distance, and change detection (Soille & Vogt, 2009). MSPA, performed using algorithms in GuidosToolbox (version 2.9 Revision 1), is an analysis to segment and categorize binary images, tree canopy map in this study, into seven classes based on the size, shape, and distance of segments, with user-defined edge width parameters specified (Soille & Vogt, 2009). Seven classes identified by MSPA: core, islet, loop, bridge, perforation, edge, and branch, represent different ecological functions and contributions to the connectivity of a landscape network (Soille & Vogt, 2009). Of those seven classes, core and bridge classes function as interior habitats and corridors for species shelter and dispersal in an ecological network; islets and branches are isolated tree canopy patches and non-core canopy patches connecting the core area at one end respectively (Ossola et al., 2019).

20 meters of Edge width was used to set up MSPA, according to the edge effect on species diversity and microclimate found in urban landscapes and the goal of not to generate too many cores considering limited computation capacity in the next steps (Li et al., 2018; Vallet et al., 2010). Only the forest cells surrounded by at least 20 m of other forest cells were considered as core patches. Since Guidos Toolbox only allows maximum of 10 pixels for edge width, Resampling tool was applied to the original tree canopy image, to transform the tree canopy binary map resolution from 1m to 2m. The input layers for MSPA representing tree canopy network under five demolition scenarios were generated after assigning value 1 for Nodata value using Reclassify tool and transforming the layers to 8-bit pixel depth using Copy Raster tool in ArcGIS. The input binary layers have value 2 for tree canopy cells (foreground) and value 1 for non-canopy cells (background) as required in MSPA (Vogt & Riitters, 2017).

4.4 Network Analysis for Landscape Connectivity

In this study, landscape connectivity was measured by structural connectivity metrics that examine the physical contiguity of the forest patches without considering species-specific traits (Saura et al., 2011; Tischendorf & Fahrig, 2000). Using structural connectivity metrics thus could simplify the analytical processes of identifying prioritized patches in a landscape network and benefit the goal of informing strategic management plans in urban and landscape planning practices. Structural connectivity metrics were implemented by Conefor 2.6, a platform using graph-based theory to quantify habitat availability at the landscape scale (Saura & Torné, 2009). The metrics calculated by Conefor include landscape-scale metrics such as Equivalent Connectivity for Integrated Index of Connectivity (EC(IIC), and patch-scale metrics, delta values of Integrated Index of Connectivity (dIIC) (i.e., the importance of habitat patches in a connected landscape) (Pascual-Hortal & Saura, 2006). In advance, it calculates dIIC by partitioning it into three fractions (Eq. 1): intrapatch connectivity(dIICintra), interpatch connectivity (dIICflux), and connector (dIICconnector), which represents three different ways that a habitat patch can contribute to the landscape connectivity. According to Saura and Rubio (2010):

\[
dIIC = dIIC_{intra} + dIIC_{flux} + dIIC_{connector} \quad (1)
\]

The input files for structural connectivity metrics were generated by the MSPA Conefor input function in GuidosToolbox where a network is comprised of nodes (i.e., core class from previous MSPA output) and links (i.e., bridge class from previous MSPA output). Besides, the Link Importance tool in GuidosToolbox was also applied to obtain the output node and link layer with unique ID specified. In Conefor, network analysis was then set up with the following parameters selected: (1) partial link type, (2) calculating Number of Links (NL), Number of Components (NC), Integrated Index of Connectivity (IIC), (3)
showing deltas for individual patch importance, (4) link importance: link removal, which enables dIIC calculated as percentage change of IIC for the entire landscape by removing each core at a time, and (5) A_{L}=2,883,577 which is the total amount of landscape pixels in this study (Saura & Torné, 2009). The landscape-scale indices were measured for five scenarios revealing the change in landscape connectivity in the entire network because of vacant land development. Patch-scale indices quantifying the contribution of each core patch for landscape connectivity are only implemented once under the baseline scenario.

The output metrics values were imported in ArcMap and spatially joined with vacant parcel shapefile based on the ID value of each patch. Through this step, each vacant parcel obtained four landscape metrics values: dIIC, dIIC_{intra}, dIIC_{flux}, and dIIC_{connector} which represented the integrated connectivity contribution and three different types of contribution: the connected habitat within the patch, the potential amount of species dispersal from and to the patch, and the contributed connectivity by the patches acting as steppingstones in the network (Saura & Rubio, 2010).

5 RESULTS

Tree canopy cover comprised 33.93% of each vacant lot area on average, with a minimum of 0% UTC and a maximum of 100% UTC on certain vacant lots. Most vacant lots contained less than 20% UTC but there were around 100 vacant lots (about 12.4% of total vacant lots) covered more than 80% by UTC, from which five demolition scenarios were developed. Even though there were 0.234 acres of UTC on vacant lots on average, certain lots contained a maximum of 24.712 acres of UTC, totaling 153.434 acres of UTC on vacant land in the city of Hartford.

MSPA results revealed that originally 16.28% of tree canopy cover areas in Hartford were core patches, while islets comprised more than half of the UTC in the city (Table 1 and Figure 3). Islets were the isolated patches which are too small to serve as primary habitats in the network (Ossola et al., 2019). Besides, loops, branches, and bridges totally represented approximately 15% of UTC (Table 1). By removing UTC on conditional vacant lots under five scenarios, the loss of UTC area increased from 21.54 acres up to 152.77 acres (under Scenario 5). From Scenario 1 to 5, the percent of the core area increased from 16.28% to 16.68% in Scenario 4 and then decreased dramatically to 15.95% in Scenario 5 (Table 1). Similar increase-decrease dynamics were also presented at the percent change of edges, perforations, loops, branches, and bridges. However, the percent of islets increased across all scenarios from 49.87% to 51.97% when all UTC was removed, which indicated the increasing level of fragmentation during the process of vacant land development and following UTC removals in the network (Table 1). Different from the percentage change, the numbers of core, edge, loops, branches, and bridges decreased consistently from Scenario 1 to 5 due to continuing loss of UTC, indicating the loss of primary habitats and connecting corridors in the network (Table 2). Yet, the number of islet objects decreased from Scenario 1 to Scenario 2 and then increased dramatically by adding more than 200 UTC fragments in the landscape from Scenario 2 to Scenario 5 (Table 2). This indicated that Scenario 2 involved removals of mostly existing islets, but since Scenario 3 more core tree canopy patches were removed which fragmented the existing connected landscape and brought more fragmented patches (i.e., islets).
Figure 3. MSPA outputs for tree canopy network in Hartford, CT. Map by the authors.
Table 1. Percent of MSPA canopy elements (%) in the entire forest landscape in Hartford, CT.

<table>
<thead>
<tr>
<th>MSPA Class</th>
<th>Core (%)</th>
<th>Edge (%)</th>
<th>Islet (%)</th>
<th>Perforation (%)</th>
<th>Loop (%)</th>
<th>Bridge (%)</th>
<th>Branch (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>356</td>
<td>238</td>
<td>1477 2</td>
<td>14</td>
<td>301</td>
<td>618</td>
<td>3325</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>351</td>
<td>233</td>
<td>1470 3</td>
<td>14</td>
<td>298</td>
<td>613</td>
<td>3298</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>344</td>
<td>227</td>
<td>1475 4</td>
<td>14</td>
<td>296</td>
<td>598</td>
<td>3245</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>329</td>
<td>218</td>
<td>1487 7</td>
<td>14</td>
<td>290</td>
<td>582</td>
<td>3129</td>
</tr>
<tr>
<td>Scenario 5</td>
<td>314</td>
<td>209</td>
<td>1498 1</td>
<td>13</td>
<td>256</td>
<td>539</td>
<td>3004</td>
</tr>
</tbody>
</table>

Table 2. The number of MSPA elements in the entire forest landscape in Hartford, CT.

<table>
<thead>
<tr>
<th>MSPA Class</th>
<th>Core (%)</th>
<th>Edge (%)</th>
<th>Islet (%)</th>
<th>Perforation (%)</th>
<th>Loop (%)</th>
<th>Bridge (%)</th>
<th>Branch (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>16.28</td>
<td>49.87</td>
<td>0.52</td>
<td>16.09</td>
<td>2.44</td>
<td>5.71</td>
<td>16.28</td>
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<td>Scenario 2</td>
<td>16.39</td>
<td>49.79</td>
<td>0.53</td>
<td>16.13</td>
<td>2.45</td>
<td>5.77</td>
<td>16.39</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>16.57</td>
<td>49.93</td>
<td>0.53</td>
<td>16.18</td>
<td>2.45</td>
<td>5.69</td>
<td>16.57</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>16.68</td>
<td>50.28</td>
<td>0.54</td>
<td>15.94</td>
<td>2.41</td>
<td>5.62</td>
<td>16.68</td>
</tr>
<tr>
<td>Scenario 5</td>
<td>15.95</td>
<td>51.97</td>
<td>0.48</td>
<td>15.35</td>
<td>2.36</td>
<td>5.6</td>
<td>15.95</td>
</tr>
</tbody>
</table>

Equivalent connectivity for Integral Index of Connectivity, $EC(IIC)$, representing the amount of habitat resource that one single canopy patch should have in order to provide the same $IIC$ value as the current entire landscape, slightly decreased from Scenario 1 to Scenario 4. However, a dramatic decrease in $EC(IIC)$ occurred in Scenario 5. (Figure 4a). A similar trend was found for the change of the number of links ($NL$) and number of components ($NC$) that from Scenario 1 to Scenario 2, only 2 links and 3 components were lost. However, from Scenario 3 to Scenario 5, 31 links and 25 components were broken. Besides, from Scenario 1 to 5, 8.67% of structural connectivity was lost.

Results of patch level metrics further revealed that there was no linear relationship between node importance of vacant lots and the percentage of vacant lot area covered by UTC. Most vacant lots only contributed less than 0.01% $IIC$ of the entire landscape, considering intrapatch connectivity ($dIIC_{intra}$), interpatch connectivity ($dIIC_{flux}$), connector contribution ($dIIC_{connector}$) or integrated value ($dIIC$) (Figure 5). A similar phenomenon was also found based on the percentage of total habitat area that one node contributed ($dA$) and the percentage of total links that one node connects with ($dNL$). However, there are several key vacant lots that contributed to great intrapatch and connector connectivity values respectively (Table 3 & Figure 5). Those lots were the areas that need to be preserved and added with more trees based on their contribution to the landscape connectivity for the entire landscape (Table 3 & Figure 5).
Table 3. Characteristics of prioritized vacant lots and node importance metric values.

<table>
<thead>
<tr>
<th>#**</th>
<th>Size (acre)</th>
<th>dA (%)</th>
<th>dNL (%)</th>
<th>dNC (%)</th>
<th>dIIc (%)</th>
<th>dIIc_intra (%)</th>
<th>dIIc_flux (%)</th>
<th>dIIc_connector (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.3</td>
<td>9.73650</td>
<td>0.89286</td>
<td>-1.27389</td>
<td>3.95630</td>
<td>3.90977</td>
<td>0.04642</td>
<td>0.00011</td>
</tr>
<tr>
<td>2</td>
<td>8.1</td>
<td>0</td>
<td>3.27381</td>
<td>-6.36943</td>
<td>0.03238</td>
<td>0</td>
<td>0</td>
<td>0.03238</td>
</tr>
<tr>
<td>3</td>
<td>3.6</td>
<td>0.63442</td>
<td>0</td>
<td>0.63694</td>
<td>0.01660</td>
<td>0.01660</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>3.3</td>
<td>0.89538</td>
<td>0</td>
<td>0.63694</td>
<td>0.03306</td>
<td>0.03306</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 4. (a) Equivalent connectivity for Integral Index of Connectivity, EC(IIC) value (b) Number of Links (NL) and Number of Component (NC) values among different scenarios. Graphs by the authors.

*dA*: percentage of total habitat area; *dNL*: percentage of the total number of links; *dNC*: percentage of total number of components; *dIIc*: percentage of total IIc; *dIIc_intra*: percentage of total intrapatch connectivity; *dIIc_flux*: percentage of interpatch connectivity; *dIIc_connector*: percentage of connector connectivity. **See the distribution of numbered parcels in Figure 5.
Figure 5. Node Importance of forest habitats in Hartford and the prioritized vacant lots. Map by the authors.
6 DISCUSSION AND CONCLUSION

Using Hartford, Connecticut as a case study, this study preliminarily explored the potential impact of vacant land developments on landscape connectivity by five hypothetical scenarios and tested the feasibility of using MSPA-Conefor streamlined approach to prioritize and preserve vacant lots based on the landscape connectivity value of tree canopy on them. Tree canopy on vacant lots in Hartford comprised 23% of tree canopy in the entire city (153.4 acres and 669.2 acres respectively). Among all UTC in Hartford, only about 16% were core areas and an additional 5.7% were bridges (i.e., corridors). Besides, the current tree canopy network was not well connected (IIC=0.0064), compared with the figure in Detroit, another shrinking city in the U.S., at least around 0.1 (Zhang et al., 2019). Even though UTC on vacant lots only contributed to less than 10% of landscape connectivity among the entire canopy in Hartford, preserving key habitats on vacant lots was still worth it in order to enhance biodiversity. According to the simulated vacant land development scenario analysis, only when the vacant lots with more than 80% covered by UTC were developed, the core area, the number of links, and overall landscape connectivity decreased dramatically. This result emphasized the importance of vacant lots with a high percentage of UTC (>80%) regarding landscape connectivity and informed vacant land management decision-making to consider vacant land with less UTC first when repurposing them for urban development. Besides, this study identified four groups of vacant lots with the highest connectivity values by evaluating the importance of landscape connectivity for each UTC core patch in the city and aggregating with vacant lots data.

The findings of this study successfully proved that developing vacant land without considering landscape connectivity values of UTC on them could cause habitat loss and fragmentation. The results highlighting vacant lots with a high UTC percentage inform vacant land management and urban planning policies to strategically choose vacant lots when developing them, especially when there is need to remove existing trees. Besides, MSPA-Conefor streamlined approach tested in this study could be replicable to other municipalities and applied to the vacant land transformation of different scales, in order to preserve regional landscape connectivity and biodiversity. Moreover, such an approach to identifying key lots for landscape connectivity could also be integrated with greenspace network planning and urban tree planning goals (Sanches & Mesquita, 2016; Zuñiga-Palacios et al., 2020). For example, the City of Hartford set up the planning goals of enhancing biodiversity and increasing urban tree canopy cover up to at least 35 percent within 50 years with little consideration of utilizing and preserving tree canopy on vacant lots (City of Hartford, 2019). The vacant lots with greater landscape connectivity values identified in the study and lots around them then could be targeted for additional tree planting as a win-win solution for reclaiming vacant lots, increasing UTC, and enhancing landscape connectivity.

This study is not without limitations. First, due to limited data availability, vacant land data and land cover data were not temporally matched. Even though this is a pilot case study to test the feasibility of MSPA-Conefor approach in vacant land connectivity assessment such limitation could compromise the robustness of the study results. Second, in order to explore the impacts of vacant land development on landscape connectivity change, this study set up hypothetical vacant land development scenarios purely based on UTC coverage distribution among all vacant lots. Such an approach to scenario simulation lacks practical consideration of factors that influence the likability of vacant land being developed including ownership, property value, zoning, land use, etc. Future studies could improve study methods by considering more realistic factors or adopting existing vacant land development models to explore the relationships between vacant land development and landscape connectivity change (Frazier & Bagchi-Sen, 2015; Newman et al., 2016). Third, this study doesn't analyze further based on the resulted importance of vacant lots for landscape connectivity. Further analysis could explore morphological, social, and ecological characteristics of vacant lots that were associated with high landscape connectivity such as size, ownership, neighborhood social-economic status, property value, and zoning which could further inform urban planning.
7 REFERENCES


PEOPLE-ENVIRONMENT RELATIONSHIPS

Edited by Ole Sleipness, & Hope Hui Rising
SPECULATIVE CYBORGS FOR MULTISPECIES COHABITATION*

*some material contained herein published previously in On Site review 41: Infrastructure

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1 ABSTRACT

We are in the middle of the Sixth Extinction. Biodiversity is threatened worldwide. Cohabitation between humans and nonhumans is essential to our mutual health and survival. The design fields of architecture and landscape architecture shoulder the burden of their contribution to a reduction in biodiversity, but within these same disciplines lies the potential to restructure humans’ relationships with other species. When we design spaces for humans, we are also, often unintentionally, designing or destroying spaces for nonhumans. What happens if this is thought of as a design opportunity? How can lessons learned from ecosystem-based design in landscape architecture be applied to new thinking in architecture? This paper, presented as a series of conceptual design provocations sited in three distinct ecosystems within the Chihuahuan Desert Ecoregion (CDE), focuses on how the practice of design can be a tool to rethink human-nonhuman relationships. Design thinking in this research revolves around the idea of an expanded wall section to reconceive wall layers as habitable spaces, the guest room to question who we design for and when spaces are utilized, and the system site to acknowledge site beyond parcel. The idea of the cyborg brings together landscape and architecture, humans and nonhumans through a focus on processes to support co-survival.

1.1 Keywords

Cohabitation, Nonhuman, Biodiversity, Cyborg, Adaptive architecture
2 PLEA FOR MULTISPECIES DESIGN

Betterment of human life endures as a primary, and noble, goal of the design fields. The sixth extinction (also known as the Holocene extinction or Anthropocene extinction), an ongoing predominately human-caused mass extinction event that many expect will register in geologic time as comparable to the other Big Five mass extinction events (Barnosky, 2011), requires us to question design priorities. Human alterations to the built environment, such as works leading to habitat loss and fragmentation, are complicit in nonhuman species extinctions (Ceballos, 2020). That the human species can, largely unthinkingly, doom an innumerable quantity of nonhuman species to extinction should be frightening. In an era where both human population growth and nonhuman species loss are exponential, for our own mutual health and survival a design paradigm shift which decenters humans and prioritizes cohabitation between humans and nonhumans is needed. But if we must revise our fundamental goals of design, how do we move forward?

Perhaps as a starting point we might look toward design strategies based in philosophies that firmly ground the human species within a complex mesh of relationships. Referencing Donna Haraway’s scholarship on the cyborg, landscape theorist Elizabeth Meyer, in her 1997 essay, The Expanded Field of Landscape Architecture, offered the idea of the “landscape cyborg” as “a hybrid of human and nonhuman natural processes” (p. 53). Kees Lokman uses Meyer’s concept of the landscape cyborg in a 2017 Journal of Landscape Architecture article to frame SCAPES Landscape Architecture’s Oyster-tecture and Living Breakwaters projects as examples of “mutualistic relationships between ecology, infrastructure, technology, and society” (p. 64). The cyborg is evident in Oyster-tecture as an infrastructure that simultaneously supports growth of ecological (oysters as water filtration machines and oyster reefs as wave attenuators) and cultural (“reef culture,” Orff, 2016, p. 89) systems of mutualistic cohabitation grounded in the history of the region. The Living Breakwaters project, which went into construction off the south coast of Staten Island in September of 2021, is a coastal protection strategy developed in response to the destruction of Hurricane Sandy that also revives ecosystems and creates recreation areas. In both projects, oysters, through the strengthening effects of their calcium carbonate deposits on the breakwaters, are co-engineers of the physical infrastructure (Orff, 2016). In this way, and also due to their keystone species status within the ecosystem, they are truly co-constructing landscape cyborgs of human and nonhuman processes along with human partners. Recognizing the landscape as an entity continually co-reproduced through living and nonliving processes asks design to become a flexible tool that responds to innumerable more-than-human systems as they shift over time.

Writing about her own work, Kate Orff, founding principal of SCAPE, positions her design approach within mutualism and cohabitation: “Mutualism in biology describes a relationship between two species in which both benefit from the association. Designing for mutualism means recognizing and fostering the links between environment, organisms, and land-use practices – both human and animal – and identifying the complex cycles that tie together different species and systems … The concept of cohabit reaches further: in order to begin reversing the trends of extinction and creating an obverse trend, we need to start designing in a way that actively benefits a diversity of species and fosters a regenerative context that makes room for nonhuman animals, shaping urban spaces to support more biodiversity” (Orff, 2016, 83-84). Within the discipline of architecture, “habitecture” projects such as Joyce Hwang’s Bat Cloud and Terreform ONE’s Monarch Sanctuary strive to provide nonhuman species habitat concurrently with human “habitat”. With a few exceptions, many architecture projects stop short of fully integrating with ecological and cultural systems, of becoming cyborgs. How might lessons learned from landscape architecture inspire innovative architectural designs that decenter humans and generate cyborgs of mutualistic cohabitation?

3 SPECULATIONS ON CYBORGS OF MUTUALISTIC COHABITATION

This article offers the speculative project, “Guest Room: Multispecies Condensers” set within the Chihuahuan Desert Ecoregion (CDE), as a series of provocations about the practice of design as a tool to rethink human-nonhuman relationships. The project includes related but different condenser designs on three separate sites in Janos, Cuatro Cienegas, and Chihuahua, Mexico that each explore a process of ongoing co-creation of multispecies habitat.

In a sense, we are all companion species interlocked in codependency through cohabitation on Earth. When we design spaces for humans, we are also, often unintentionally, designing or destroying spaces for nonhumans. What happens if this is thought of as a design opportunity? What if we imagine a world where design generates positive impacts for humans and nonhumans simultaneously? We must
accept design as a practice that inherently alters human and nonhuman spaces and realign design to shape shared conditions from a multi-species perspective to support human and nonhuman co-survival.

4 BIRTH OF MULTISPECIES CONDENSERS

This project was conceived through exposure to the writings of Donna Haraway, Martin Heidegger, David Abram, Richard Grusin, and Elizabeth Kolbert among others, incubated through an architectural master’s project process supervised by committee chair Gabriel Fries-Briggs and committee members Nora Wendi and Anthony Fettes, and birthed to the world through talks, exhibitions, and writings starting in 2021. It is an “individual” effort (built on the work of others and supported behind the scenes by more) to create a professional statement and initiate a longer research agenda. The following project structure helped focus the scope of the designs.

“Guest Room: Multispecies Condensers” explores cyborg design strategies for three threatened CDE ecosystems: the grasslands of Janos, aquatic systems of the Cuatro Cienegas Basin (CCB), and the urban systems of the city of Chihuahua (Figure 1). The Chihuahuan Desert Ecoregion, one of the most biodiverse arid regions in the world (Pronatura, 2004), is an example of significant loss but also a place of hope that many species call home. Major threats to biodiversity in the region include land use changes such as overgrazing, increased water use and urbanization that damage or destroy habitat.

The project was designed mainly in section. By limiting the designs to sectional “slivers” of buildings and landscape intentionally without the context of a larger building plan or program, the project emphasizes human and nonhuman processes. These “slivers” exist somewhere between typology and singular design project.

Project representation was used to critique normative project renderings by showing the projects from nonhuman points of view (fish view, bird view, and bat echolocation “view”), including focusing on design elements nonhuman species would be most likely to interact with (underwater habitats, bird nests and seed sources, and bat boxes and agave nectar sources) instead of human dominated spaces (Figure 4).

Project framing methods of the “guest room,” the “expanded wall,” and the “system site” focus on humans and nonhumans and generate different types of cyborgs of landscape and architectural spaces for cohabitation.

4.1 Guest Room

The conceit of a “guest room” facilitates questioning who we design for. A guest room is a space of temporary shelter and welcome with flexible program; it becomes what it needs to be to provide for occupants. In extending the concept of a guest room to nonhuman species a cyborg space is made. The cyborg guest room is a space created for and altered by multiple species. It immediately provokes thinking about sharing (how, when, who) and use (activity, duration, scale). The cyborg guest room is a time cyborg shaped by multispecies ecological and cultural rhythms.

4.2 Expanded Wall

The expanded wall (Figure 2) reconceives typical wall functional layers (thermal protection layer, water protection layer, and sun protection layer) as habitable spaces. The idea of an expanded wall is a productive tool for thinking about space as a series of different occupiable microclimates. The expanded wall is a graduated cyborg, existing along a spectrum from supporting predominantly human to predominantly nonhuman processes.

4.3 System Site

The system site is not a parcel but instead a specific ecological community to which the project is attuned. The project interacts with the system site to accrete as an infrastructural cyborg by coopting human processes inherent to the design (i.e. piped potable water use) to support natural ecosystems (i.e. use gray water to irrigate grassland plants).
4.4 **Figures**

**Figure 1.** Chihuahuan Desert Ecoregion major threats to biodiversity and impact areas.

**Figure 2.** Expanded Wall Building Section Concept.
Figure 3. Water Layer of the Aquatic Design.

Figure 4. Imaginary UV Bird’s View of the Grassland Design.
Figure 5. Cohabitation within the Urban Design.

5 DESIGN PROVOCATIONS

Human occupation of an area often brings certain infrastructures, constructed elements, and human labor. These designs utilize these systems for nonhuman, in addition to human, benefit. The grassland design is a speculation about how to resist grassland ecosystem disappearance within the Janos Priority Conservation area of the CDE. The aquatic design is a speculation about how to replenish underground aquifers within the Cuatro Cienegas Basin that have held water continuously since the Precambrian (Souza, 2012) while simultaneously expanding aboveground aquatic habitat range. The urban design is a speculation about how to reintroduce the desert scrub ecosystem into the urban environment of the city of Chihuahua that replaced it. These proposed provocations hybridize landscape and architecture systems to create architectural machines to support targeted ecosystems. For more information on these designs see Boles’ article “Guest Room: multispecies condensers” in On Site review 41: Infrastructure (forthcoming in 2022).

5.1 GRASSLANDS DESIGN PROVOCATION

Like species retreat to Pleistocene refugia during the last ice age, the grassland design aims to create grassland refugia to support grassland species survival after the CDE grasslands disappear, which is expected to occur by 2025 (NABCI, 2016). The structure and systems of the refugia generate the conditions for heterogenous grassland community pockets to adapt, over time growing into an infrastructural cyborg; human processes provide the resources to perpetuate a nonhuman ecosystem that otherwise would cease to exist. As part of the design, plumbing systems are coopted for nonhumans as water resource opportunities. Municipal piping brings potable water to the site. After human use, gray water is used to irrigate the grassland plants, replacing precipitation patterns altered by climate change as the main water supply. Another element of the design, wind screen adobe site walls, are altered over time by natural processes to become grassland patches. In this design, the adobe block earth and fiber mix is adjusted to create a range of blocks; a diversity of local soils are used and local grassland plants (seeds and stems) replace straw for tensile strength. As the unprotected adobe site walls slowly erode from wind and water forces, seeds are released from the blocks and, those that are not eaten by rodents and migratory birds, are “planted” in the loose soil. Heterogenous grassland patches result.
5.2 AQUATIC DESIGN PROVOCATION

In the aquatic design, constructed elements create the conditions for a series of aquatic habitats to persist. The design systems are focused on cleaning water through distillation and injecting it back underground to maintain aquifer bacteria habitat (Figure 3). During this process, the water is utilized to support a variety of other aquatic species and human activities. The project is sited along a river to divert water into the design poza (pool) through acequias (small canals) and seeps. During floods, the river overtops the banks and flows directly into the design. The poza bottom slopes to provide a gradient of habitats. Poza overflow spills into a playa where it evaporates, leaving behind salt deposits. Each of these design spaces, the river, the acequia, the poza and the playa, have their own ecologies. The design machine uses steel wind powered “straws” to suck up water from the poza and deliver it to a rooftop solar still. Distilled water drips into circular thermal water storage tanks that also act as an insulative building layer and building daylighting scheme. Overflow from the tanks is injected into the karst aquifers.

As a cyborg, the building and landscape support each other. In such a hot, arid climate, shade from the building floor is important to reduce evaporative loss from the poza. In return, air flowing across the poza surface is cooled before entering the building through floor vents. The landscape provide water for the “straws” and the straws, along with multi-stemmed bridge supports, come with lily pad stalks to provide shelter for fish. Surrounding the aquatic areas, vertical screens of metal stalks filled with grass stalks provide shade and habitat. Each spring, the bird nest material source is replenished by weaving dried grasses between the metal stalks. By the fall, the grasses have been taken by birds or fallen to accumulate as a duff layer, providing ground habitat and enriching the soil. Over the winter, sunlight passes through the screen, providing passive solar heating.

5.3 URBAN DESIGN PROVOCATION

The urban context is quite different from the grassland and aquatic contexts. While the grassland design aims to regenerate a disappearing ecosystem and the aquatic design strives to maintain existing habitats, the goal of the urban design is to reintroduce an ecosystem which was erased. As the city of Chihuahua grew, existing landscape was converted to urbanized areas, effectively eradicating patches of the desert scrub ecosystem from its former environs. The desert scrub ecosystem, the most prevalent land cover of the CDE (Pronatura, 2004), remains surrounding the city but within the city a different urban ecology has emerged. The urban design, as a mutualistic cyborg, utilizes human systems to support urban patches of desert scrub species and desert scrub systems to support human activities. To nourish a water and nutrient intensive communal back yard corn field, harvested rainwater is augmented with bat guano fertilizer before it is used as subsurface irrigation. Guano from hanging bat boxes drops into hollow columns of a patio arcade. When it rains, roof water flushes guano from the columns into a water treatment tank where it is combined with street water runoff before being used for irrigation. To foster bat populations, not only are shelters (bat boxes) provided for them but habitats to produce their food supplies, agave nectar, are also integrated into the architecture. Agave species are planted on top of deep columns of soil that support the roof and connect it with the ground, avoiding pitfalls associated with shallow green roof systems while simultaneously providing structural support for the heavy vegetated roof. Also included in the design are a shaded urban sidewalk connected to a pollinator wall, roof bee boxes and human access path, and a back yard cholla cactus skeleton shade system that doubles as support for bird nests (Figure 5).

6 CYBORG OF CYBORGS

These three design provocations for the Janos Priority Conservation Area grasslands, the Cuatro Cienegas Basin aquatic habitats, and the city of Chihuahua urban areas offer ideas about how the landscape cyborg can itself become a hybrid with an architecture cyborg. By combining landscape and building, human and nonhuman, design elements can function within multiple systems to address multiple goals simultaneously. The effect of these elements working together to support each other is mutual cohabitation.

7 FUTURE ADAPTATIONS

The design provocations discussed here can themselves be tools to inspire new design concepts. These speculative paper architectural proposals are discourse generators, not design solutions. The
projects aspire to a new attitude toward design that would hopefully inspire additional designs, even iterations of these designs, which taken together and paired with policy change have a chance to affect meaningful large scale change. These designs are intended to be read as a family of related ideas for designing shared microclimates that support humans and nonhumans to highlight the commonalities of species survival.

Looking forward the cyborg may be a particularly helpful approach to adapt to a rapidly changing climate in a way that prioritizes humans and nonhumans. The concept of the cyborg pairs well with ideas of adaptation because the cyborg is predicated upon processes, systems of fluctuation. How can architecture adapt over time to accommodate nonhumans as a form of resiliency in the face of climate change? What can be learned by rethinking “adaptive architecture” as architecture adapted by nonhumans? What architectures result from partnerships between human and nonhuman co-constructors of the built environment? Expanding landscape cyborgs of mutualistic cohabitation into architectural projects brings this adaptive power into the heart of typically human-centered spaces to restructure species relationships for co-survival.

8 REFERENCES


WALKABILITY AS AN INDICATOR OF SOCIAL INEQUITY: EXAMINING THE NEIGHBORHOODS OF THE BUFFALO OLMSTED PARKS SYSTEM

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1 ABSTRACT

In 1868, the City of Buffalo invited Frederick Law Olmsted and Calvert Vaux to design a complete parks system for their growing industrial city. Immigrants who created the working bedrock upon which the city was built, had segregated into ethnic subcommunities in distinct neighborhoods. They took a comprehensive approach to assure these ethnically distinct neighborhoods had opportunities that met their unique needs within walking distance of their homes. Today, the neighborhoods surrounding the parks have very different demographic characteristics. This article reports on the walkability and demographic characteristics of six distinct neighborhoods served by the Buffalo Olmsted Parks System (BOPS).

This walkability audit adds to the growing volume of walkability studies evaluating the pedestrian environment from home to park. Researchers posit that there is a direct correlation between walkability scores and socio-economic indicators: the higher the walkability score, the higher the socioeconomic status of the neighborhood.

Walkability scores were aggregated and compared with socio-economic and demographic indicators to evaluate whether a correlation exists between a neighborhood’s walkability and its general socioeconomic status. Walkability scores were assigned using the Pedestrian Environment Data Scan (PEDS) evaluation metric on streets within a three-quarter-mile walking distance of six facilities within the BOPS. Streets were assessed using Google StreetView imagery, and evaluations were ground-truthed with in-person site visits. Walkability scores and demographic information were spatially analyzed using ESRI ArcGIS.

This study found that walkability is linked to both race and socioeconomic status; therefore, walkability can be an indicator of social justice issues affecting the neighborhood.

1.1 Keywords

Buffalo Olmsted Parks System, Pedestrian Environment Data Scan (PEDS), Walkability, Environment audit, Social justice

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2 INTRODUCTION

In 1868, landscape architect Frederick Law Olmsted was invited to Buffalo to design a city park. Instead of designing a single park for the city to enjoy, Olmsted proposed a parks system that would provide a diversity of activities and pursuits for this growing and vibrant community (Beveridge et al., 2007). There are six main parks that comprise the Buffalo Olmsted Parks System. From the north, they are: Riverside Park, Delaware Park, Front Park, Martin Luther King Jr Park, Cazenovia Park, and South Park. In addition to these parks, the Buffalo Olmsted Parks System (BOPS) includes a series of greenways, circles, and greens that connect the parks and extend them into the surrounding neighborhoods. Olmsted was able to see only three of the parks to completion: Delaware, Front, and Martin Luther King Jr Parks, along with their attendant greenways and circles. The remaining parks were realized by his successor firm, Olmsted Brothers (Olmsted's son and stepson took over the firm after Olmsted retired in 1901).

From the beginning, Olmsted planned the park system to meet diverse needs within the city. Delaware Park, originally called The Park, was planned as the crown jewel of the system. It showcased Olmsted’s ideas of healthful nature with pastoral walks, boating on a constructed lake, and extensive views to calm the soul and green the city. Front Park (The Front) was located at the city’s western edge, fronting Lake Erie. Views of the lake were important to this park, as were athletic fields and other facilities on which to play and actively recreate. Martin Luther King Jr Park (The Parade) was located on the east side of the city, and featured an extensive children’s playground, a military parade ground, and a barracks building. These parks reflected the ethnicity of their surrounding neighborhoods: Delaware Park was located in the “blueblood” city-father neighborhood of the city elite, while Front Park was placed in a predominantly Italian neighborhood where family gatherings were highly valued, and Martin Luther King Jr Park was placed in a German/Polish neighborhood where a more militaristic spirit prevailed (Beveridge and Hoffman, 1997).

In the decades after the Olmsted parks were implemented, economic conditions for the City of Buffalo declined. This decline put stress on the city’s budget, resulting in cuts for funds and personnel needed to maintain the parks. In 1978, an advocacy group was formed to champion the cause of the Olmsted Parks (Herrera-Mischler, 2008). In 1994, this group was renamed the Buffalo Olmsted Parks Conservancy, and in 2004 a partnership agreement between BOPC, the City of Buffalo, and Erie County was signed, making the BOPC the official steward of the Olmsted Parks System, overseeing its management, maintenance, and operations.

2.1 Background

Buffalo is historically an industrial city. It has been a hub for transportation and storage of goods and materials since 1814, when the Erie Canal terminated there. Its location on Lake Erie just south of Niagara Falls ensured it became the collection point for goods and raw materials shipped from as far away as Duluth, Minnesota. When railroads became the dominant shipping means later in the 19th Century, Buffalo quickly became a railway hub and a centre for the manufacture of steel and offshoot industries (automotive, appliances, tool and die, etc.). Thus, Buffalo’s fortunes were strongly linked to the success or failure of American manufacturing and industry.

As a manufacturing and industrial hub, Buffalo was a magnet for migrant populations hoping to realize the American Dream. European immigrants were the mainstay of population growth for much of the first 100 years of Buffalonian history. Successive waves brought Irish, Germans, Poles, and Italians to the region (Goldman, 2007). Some African Americans migrated northward as escaped slaves from the southern United States in the years leading up to the American Civil War, but due to the Slave Fugitive Act, many of these individuals opted to continue on to Canada, whose laws prohibited their extradition back to the United States (Williams, 1999).

In the decades after the Civil War, African Americans migrated northward in an effort to secure less oppressive living and working conditions than they typically found in the South. This pace accelerated in the first half of the 20th Century as American support for and participation in foreign wars increased. wartime support required increased industrial productivity, leading to a spike in wages in the northern industrial powerhouse cities like Buffalo. As a result, African Americans flooded into Buffalo and other “Rust Belt” cities like Pittsburgh, Chicago, and Detroit seeking employment in the lucrative manufacturing sector.

Buffalo’s ward system historically developed through family networks (Williams, 1999). Typically, a pioneering individual would come to Buffalo to investigate conditions, secure employment and housing, and then report back to their home community on the opportunities found. This would spur relocation from that community to Buffalo, with newcomers relying upon the pioneering individual for initial support and
networking. Often, newcomers would stay temporarily with their friends until they became settled, then establish their own household nearby. Thus grew the ethnic neighborhoods for which Buffalo became so well known in subsequent decades (Goldman, 2007).

Ethnic neighborhoods experienced change as one immigrant population displaced another. Displacement occurred in two ways. First, as some immigrant groups became more successful, they abandoned their inner-city neighborhoods in favor of suburban locations further from the city core and the attendant pollution. Second, as new migrant groups entered the city and began to establish themselves, they found opportunities for housing piecemeal within the established ethnic neighborhoods. As the new ethnic group grew, they “pushed” the established ethnic groups out. This shift may have arisen from dissatisfaction among the more established ethnic groups in the loss of the status quo, their discomfort in associating with new ethnicities, races and cultures, or simply from the economic expedient of selling a house in one location in favor of a new one in a more desirable location—a move that was already in the making due to the improved economic situation (Yin, 2009). For whatever reason, the shifting occurred over the course of the 20th Century such that, by the 1950s, much of Buffalo’s core neighborhoods in the downtown and east side had transitioned from German and Polish to African American (Bureau, 2019).

The power structure in Buffalo, both political and economic, has traditionally been held by a limited group of people. (Dillaway, 2006). The first permanent settlers along Buffalo Creek were displaced Senecas who were relocated from Fort Niagara; followed by white prisoners captured during the American Revolutionary War. The remote outpost temporarily known as New Amsterdam was renamed Buffalo because of the creek beside which it was situated. Buffalo’s prosperity was assured when it was selected as the terminus for the Erie Canal in 1825, thus ushering in commerce, manufacturing, and hydropower. The canal and subsequent railyard fostered significant changes and the need for in migration of workers.

The first city leaders and powerbrokers were, by and large, the white American citizens who, from the time of the American Revolution, had founded and fostered the growth of Buffalo economically and culturally. As other ethnic groups moved in and gained influence, the Irish, Italians, and Germans began to play a growing role in city governance and power brokering. A system of ethnic and racial fractionalism over politics and power was facilitated by Buffalo’s ward-based system of governance. Since most of Buffalo’s political wards were ethnically based, decisions and policies were enacted over ethnic and racial lines for much of Buffalo’s history. This resulted in some ethnic or racial groups traditionally being advantaged while others have been disadvantaged due to a lack of political or economic power.

Overtly discriminatory policies were enacted at different times throughout Buffalo’s history. These events were in keeping with larger trends of discrimination prevalent throughout America at those times and reflect local application of wider societal views and values. These included discriminatory housing (i.e., redlining, blockbusting, highway alignment decisions) and employment (lower wages, more dangerous/less desirable work assignments) practices that helped to shape Buffalo today (Yin, 2009; Williams, 1999).

As of the 2019 American Community Survey, Buffalo is 52.3% female, 43.1% white and 36.5% Black, including individuals who identify as Hispanic or Latino, compared to a national profile of 50.8% female, 60.1% white and 13.4% Black. The poverty rate is nearly 300% the national average, while the under-65 disability rate is 150%. In addition, average housing values in Buffalo are significantly lower (40%) than the national average, while rents are closer (73%) to the national average (Bureau, 2019).

3 RESEARCH OBJECTIVES

The objectives of the current study are threefold. First, the study seeks to graphically portray a community’s walkability as impacted by its major parks. Second, the study seeks to clarify the lingering impact, if any, of unjust historic housing and development practices in a city. Third, the study seeks to demonstrate the link between those practices, a neighborhood’s walkability relative to the community at-large, and the correlation between walkability and socio-economic status and race/ethnicity.

3.1 Why walkability?

Urban planners have studied walkability judiciously for the past 40 years. In 1981, urban designer Donald Appleyard developed guidelines for creating safe livable streets (Appleyard, 1981). His guidelines focused on improving connectivity through residential neighborhoods. He concentrated on safe walking and biking routes to common destinations, such as shopping, school, work, and the neighborhood park; thus, reducing reliance on the automobile. Over the years, studies have found that walkability is a reliable indicator of physical health and social cohesiveness. Some researchers have compared walker
demographics with streetscape features using the expanded D’s (Ewing et al., 2016; Hearst et al., 2013; Forsyth et al., 2009; Forsyth et al., 2008; Lee and Moudon, 2006; Lee et al., 2017) to explain the effect of the built environment on pedestrian behavior (Cervero and Kockelman, 1997; Ewing and Cervero, 2001; Braun and Read, 2015; Freeman et al., 2012). The expanded D’s include density, diversity, design, destination accessibility, and distance to transit. They provide a framework for studying enhanced mobility and proximity to Olmsted Parks in relationship to racial diversity, residential property values, sidewalk design, connectivity, and maintenance.

Walkability has been used as an indicator, as well as a predictor, of social equity and environmental justice. As an indicator, walkability has been used to better understand societal connections between the environment, the economy, culture, and the built environment. Recently, heat vulnerability indices such as tree canopy, impervious surface, and temperature have been measured and correlated to poverty data (Kobell, 2021). Other indicators of social equity and environmental justice include habitat and water quality (Browne et al.) Prediction of environmental injustice is more difficult, requiring further quantitative and qualitative studies to understand the complex issues involving seemingly disproportionate environment-related health burdens borne by minority and low-income populations. Hagen (2018) provides an extensive discussion of how traffic calming has addressed environmental justice inequities in minority and low-income areas. Lowe (2016) audited, then correlated, sidewalk continuity data to census tract-level poverty and racial composition. She found disparities in the quality of pedestrian infrastructure that warrant further research. Additional research emphasizes the value of participatory engagement and focusing on hot spots to bring public attention to much needed issues (Viola 2015).

Social economic status and exposure to nature have been linked to a variety of health indicators like cancer, obesity, nutritional deficiencies, and hypertension (Cleland et al., 2010; Hearst et al., 2013; Frumkin, 2001; Frumkin, 2005; Moudon and Lee, 2003; Wolf and Robbins, 2015). Researchers recognize that social economic status is also linked to social capital, which is quantifiable. By measuring social economic status, a sense of community health may be ascertained. People live healthier lives in communities where there is high social capital. Over the years, overwhelming evidence that walkability is linked to improved physical and mental well-being (Lund, 2003; Kerr et al., 2007; Clark and Scott, 2013), increased home values (Cortright, 2009; Chapple and Zuk, 2016), and household income (Arvidsson et al., 2013; Day, 2006; Stewart et al., 2009).

Walkability may be linked to peoples’ sense of belonging to their community. Feelings of isolation and levels of stigmatization may be associated with residents’ perception of street safety and quality of maintenance (Stewart et al., 2009; Lowe, 2016). Decline of Buffalo’s infrastructure has resulted in a commensurate decline in many neighborhood streets and parks. This has a direct effect on people’s health and the community’s sense of place. Ensuring residents have safe, attractive routes to nearby parks and open space is reasonable for residents regardless of socioeconomic status, age, race, ethnicity, or gender (Lowe, 2016).

3.2 Why Buffalo?

Buffalo’s economy has experienced boom to bust cycles from which it has struggled to recover for the last 50 years. Like many industrial-based cities, Buffalo has diverse neighborhoods made up of immigrant groups that have become established over time. While the economic decline has impacted the entire Buffalo community, minority neighborhoods i.e., Black and Latino communities, have been disproportionately impacted. This present study characterizes Buffalo’s neighborhoods based on proximity to the six major parks (see Figure 1) in the Buffalo Olmsted Park System (BOPS). The largest of the parks in the BOPS is Delaware Park. It is well maintained and surrounded by an affluent, aging white population, whereas Martin Luther King, Jr and Front parks are surrounded by neighborhoods which are predominantly Black and Latino, respectively. The neighborhood surrounding Martin Luther King Jr Park has particularly suffered from discriminatory housing policies, making it more vulnerable to Buffalo’s economic decline (Office, 2019). All of the BOPS parks have undergone significant upheaval and change from their original designs, and have also faced severe disinvestment, including funding and maintenance shortages (Newman and Crockatt, 2019; Herrera-Mischler, 2008).

Further evidence of Buffalo’s decline is the 1960s implementation of an expressway system to facilitate the rapid movement of people from the suburbs to downtown and back, promoting the flight of wealth and talent into surrounding communities and draining Buffalo’s historic neighborhoods. These expressways (Kensington and Scajaquada) crossed and divided two of the BOPS parks, Martin Luther King Jr (Kensington) and Delaware (Scajaquada), and their adjacent neighborhoods. In addition to noise and air
pollution, these expressways have significantly impacted walkability between residences and parks, creating barriers for pedestrians to access recreation and further fostering the decline of social capital and public health.

Even though the ethnic/racial composition of the neighborhoods surrounding the parks has changed over time from one ethnicity/race to another, Buffalo’s Olmsted neighborhoods are still very ethnically/racially distinct. This neighborhood distinctiveness, coupled with the neighborhood structure provided by the Buffalo Olmsted Parks System, makes Buffalo an ideal city to study the correlation between walkability and socioeconomic status.

4 METHODS

The researchers conducted a Walkability Assessment via the Pedestrian Environment Data Scan (PEDS) for the 351.47 miles of Buffalo’s street network that falls within a fifteen-minute walking service area of the seven major parks in the Buffalo Olmsted Park System (Figure 1). To initiate the study, ArcGIS Network Analysis was used to identify all streets within a five-minute, 10-minute and 15-minute walking service area of each of the seven parks, ignoring freeways and other paths where walking is prohibited. These walking times equate roughly to one-quarter of a mile, a half mile, and three-quarters of a mile, respectively. ArcGIS also assigned unique identifiers to each road segment in the park system service area for evaluation. (A road segment is the portion of road from one intersection to the next). In all, four thousand three hundred ninety-two segments (N=4,392) were identified and evaluated over a two-month period.

Assessments were primarily conducted remotely using Google StreetView imagery collected between 2011 and 2020. The neighborhoods were evaluated for walkability using the Pedestrian Environment Data Scan (PEDS) version.3 assessment tool (Wimbardana et al., 2018; Clifton et al., 2007) which was adapted for this project to focus specifically on the sidewalk and the pedestrian environment, rather than including bicycling and the road condition. In addition, some questions about the general appearance of the walking environment (building articulation, tree cover, powerlines, etc.) were combined into the subjective analysis:

- The segment is attractive for walking.
- The segment is safe for walking.

These subjective analysis statements were answered by members of the evaluation team using a Likert scale of 1 to 5, with 1 meaning “I disagree strongly with the statement” and 5 meaning “I agree strongly with the statement”. Scores of 1 and 2 on these questions subtracted points from the walkability score, while scores of 4 and 5 increased the overall score. To ensure consistency between evaluators, sample segments were evaluated by each member of the team. The evaluators assessed these sample streets individually, then compared their scores together with the other evaluators. No significant difference was found between individual evaluators on the subjective analysis.

To ensure validity of the remote imagery, a ground-truthing site visit was conducted midway through the evaluation process by all evaluators. During this site visit, specific streets were visited and compared with their Google Street View data. In general, the walking environment conditions being evaluated remained unchanged from when the Street View imagery was collected.
4.1 Neighborhood characterization

Neighborhoods were further characterized via demographic data available from the 2009 US Census Estimate and the New York State GIS warehouse. The study examined the following characteristics: race and ethnicity; household income; age; gender; property value; and renter-occupied versus homeowner-occupied properties.

Finally, PEDS data was entered into GIS to spatially examine the walkability evaluation overlaid with the racial/ethnic and household income demographic data. Researchers visually examined the patterns of which demographic groups live in low walkability areas.
5 RESULTS

When the data are examined visually and spatially, some telling inferences become evident:

1. In looking at the racial/ethnic distribution in Buffalo (Figure 2), there are still distinct, racially focused neighborhood lines. Buffalo’s practices of ward-based politics focused on ethnic and racial segregation into neighborhoods is evident in the current demographic makeup of the city’s neighborhoods. Buffalo’s East Side is predominantly African American, while much of the rest of the community is comprised of white-majority neighborhoods. There are a few pockets of Asian-majority blocks (n=77; in the statistical analysis (see below), these segments were reported as “non-white”, as were segments located in Black/African American majority census blocks. Our analysis also followed the practice of the US Census Bureau in including persons of Latino or Hispanic descent in the relevant White and Black/African American racial categories. Walkability scores roughly break along racial lines. Neighborhoods with a non-white majority exhibit lower walkability scores than do areas in the rest of the city. White-majority areas tend to be in medium to high walkability neighborhoods.

2. Household income was examined from the standpoint of its relationship to the national poverty level (Figure 3). The categories we created were:
   1. Significantly below the poverty level (0-50% of the national poverty line)
   2. Below the poverty level (51-75% of the national poverty line)
   3. At the poverty level (76-110% of the national poverty line)
   4. Above the poverty level (110%+ of the national poverty line).
When these data are overlaid with the walkability scores, there is a correlation between walkability and household income. Specifically, areas with low walkability scores tend to coincide with lower household income blocks (Below and Significantly Below the poverty line).

Figure 3: Neighborhood walkability scores versus household income. Map by the authors.

3. Lower household income blocks also tend to relate to the racial divide in Buffalo, with most of the lowest income levels found in the non-white majority census blocks. For example, of 126 segments within the "significantly below poverty line" level, 81% were in non-white census blocks.

5.1 Statistical analysis

<table>
<thead>
<tr>
<th>Income</th>
<th>White</th>
<th>Total</th>
<th>Non-White</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>Significantly Above</td>
<td>24.10</td>
<td>7.29</td>
<td>1610</td>
<td>20.55</td>
</tr>
<tr>
<td>At</td>
<td>21.50</td>
<td>7.24</td>
<td>581</td>
<td>19.42</td>
</tr>
<tr>
<td>Below</td>
<td>18.91</td>
<td>8.95</td>
<td>348</td>
<td>16.00</td>
</tr>
<tr>
<td>Significantly Below</td>
<td>13.96</td>
<td>3.87</td>
<td>24</td>
<td>15.48</td>
</tr>
<tr>
<td>Total</td>
<td>22.71</td>
<td>7.77</td>
<td>2563</td>
<td>18.22</td>
</tr>
</tbody>
</table>

Table 1: Walkability scores by race and income.

To limit the potential confound of group size during statistical analysis, we grouped the race variable such that the levels were white ($N = 2563$) and non-white ($N = 1059$), rather than white ($N = 2563$), African American ($N = 982$), and Asian ($N = 77$). We conducted a $2(Race: White, Non-White) \times 4(Poverty Level:$
Significantly Below, Below, At, Significantly Above) Factorial ANOVA. The dependent measure was Walkability.

In accordance with our hypothesis, we observed a significant main effect for race \( (F(1,3621) = 10.77, \ p = .001, \ \eta^2_p = .003) \) and a significant main effect for poverty level \( (F(3,3619) = 47.53, \ p < .001, \ \eta^2_p = .038) \). All effects of poverty level were significant at the \( p < .001 \) level. There was also a significant interaction \( (F(3,3619) = 2.72, \ p = .043, \ \eta^2_p = .002) \). Descriptive statistics can be found in Table 1. Thus, results indicate that a surrounding population of mostly white residents significantly correlates with higher walkability than the walkability of areas with mostly non-white residents. Examination of poverty level also indicates that walkability is significantly correlated to income level of residents in the area. More specifically, we examined that average walkability appears to significantly decrease in relation to the income level of residents regardless of race. Areas significantly above the poverty level have better walkability than those at, below, and significantly below the poverty level (See Table 1 and Figure 4). Contrary to our hypothesis, at the significantly below poverty level condition primarily non-white areas had higher walkability scores on average than primarily white areas. We predict this difference may be attributed to the small proportion of segments in white \( (n=24) \) versus non-white \( (n=104) \) census blocks, accentuating the walkability score distribution in those segments. Primarily non-white areas at all other income levels indicate lower average walkability scores than primarily white areas.

Figure 4. Walkability scores by income and race.

6 CONCLUSIONS

These correlations lead us to conclude that walkability scores are an indicator of racial and income levels in a community and can be a predictor of social justice issues. Review of the data suggests Buffalo’s practices of public/private partnerships for parks’ stewardship and management have left MLK Jr Park underfunded, while Delaware Park, which houses the headquarters of the parks commission, is well-funded and well-cared-for. Data gathered for this study may be helpful as the BOPC implements its new master plan for overseeing management, maintenance, and operations of the parks.

The study is significant for five reasons. First, this is the first major study using PEDS in Buffalo, NY. Second, the site evaluators used a modified PEDS form to advantage even though the PEDS form is not found in recent literature (most recent is 2013). Third, this study used a highly successful and comprehensive interdisciplinary methodology involving the use of GIS with PEDS and ground-truthing. Fourth, BOPS not in current peer-reviewed literature; the most recent work is Charles Beveridge’s Olmsted’s Papers project (Johns Hopkins University Press) 2007. Finally, using Olmsted’s original work as a benchmark for socially responsible public work was refreshing.
7 DISCUSSION

The study will continue to examine secondary data gathered during the past year to see how all the data influence park development and reinvestment over the life of a new 20-year park master plan, especially in MLK Jr, Front, and Delaware parks. Analyses of gender, age, and property values are ongoing and will be the basis of future articles.

Further afield, researchers might evaluate another city’s Olmsted-originated park master plan for evidence of segregation or discrimination; examine walkability more closely; and make recommendations for improvements. Olmsted Parks System candidate cities include Boston, Massachusetts, USA, and Louisville, Kentucky, USA.

The first limitation is that the investigators did not examine ethnicity due to the US Census Bureau’s practice of including individuals of Latino/Hispanic descent within total counts of white or Black/African American populations. A second limitation was winter weather. Ground-truthing was conducted midway through the evaluation process. During the site visit, all researchers noted the lack of pedestrians in parks and on the sidewalks due to cooler weather. Future research might ground-truth the site(s) in warmer months. A third limitation needs to be acknowledged: the four white male evaluators from outside the Buffalo area may have brought subjective cultural and/or racial biases with them.

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RESEARCH BY DESIGN AND IMPLEMENTATION

Edited by Paul Coseo, & Yi Luo
THE POTENTIAL OF 3D CONCRETE PRINTING IN LANDSCAPE ARCHITECTURE DESIGN PROCESS

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1 ABSTRACT
The use of additive manufacturing as a construction method is becoming more widespread across various design fields. As a large-scale form of additive manufacturing, 3D concrete printing involves pushing concrete through a nozzle onto a printing bed to building layers. The process produces three-dimensional solid objects from a digital design file. There is very little loss in the construction process providing benefits in cost, time, safety, and environmental impact. Additionally, the lack of formwork creates boundless possibilities for shapes. Fluid and even parametric forms, which formerly required multiple, complex, and costly steps to generate, can be created in a single process. Through a design prototype documentation process, this study explores the potential for 3D Concrete Printing in landscape architecture. The authors worked with Pikus 3D, one of the first companies in the U.S. providing 3D printing services, to document the design, refinement, and printing process of two benches. The study results indicate that 3D concrete printing has great potential for future use. However, each printer has unique limitations including angle, turning radii, layer height, and texture. Some limitations, such as durability, are still not fully understood and will require future research. However, as a process, the study reveals that a designer with basic modeling knowledge could work with a 3D printing company to create a unique object in an extremely short timeframe. While the first bench took several weeks of back and forth to refine, the second was conceptualized, modeled, refined, and printed in a single day.

1.1 Keywords
Additive manufacturing, 3D concrete printing, Landscape architecture, Design process

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2 INTRODUCTION

Concrete is widely used as a construction material (Bos et al., 2016), however cast concrete structures are limited in form and design flexibility. Cast construction techniques require formwork and intensive labor to create desired forms (Asprone et al., 2018b). Three-dimensional concrete printing (3DCP) is being studied by the construction industry and academic institutions as a viable alternative to current construction techniques. The advent of 3D printing allows for cementitious material production in ways yet to be realized. It offers promising possibilities for the future of concrete structures including walls, benches, and other site features, which has the potential to significantly change design and construction processes. Three-dimensional concrete printing is a form of additive manufacturing in which a computer is used to design, model, and print an object. (Asprone et al., 2018a). Concrete is layered one on top of the other without extensive labor and formwork (Bos et al., 2016; Panda et al., 2017; Wolfs et al., 2019). Various building and civil engineering applications have already utilized this construction method. However, it is an emerging technology that requires research to understand its full potential for structural integrity, longevity, variation in form, and general design process. During the past ten years, the development of 3DCP has made significant improvements which have allowed for a better understanding of its potential in architecture and civil engineering.

In 2020 faculty and students at Mississippi State University designed the first 3D printed objects to be used in landscape architecture with Pikus 3D’s rapid printing technology. As documented in an article in Landscape Architecture Magazine (Rae, 2021), the process was unique in that it showed how quickly designs could be refined and implemented using parametric modeling tools. With the ability to print a 6’ tall object in a matter of minutes, the technology allows for rapid printing, testing and refinement with full-scale objects. This study attempts to more fully document a back-and-forth process with a designer and the manufacturer to better understand the limitations and potential of the technology for landscape architects.

3 BACKGROUND

Layered production, generally known as 3D Printing, was invented in 1983 by Chuck Hull, an American engineer. It is an additive manufacturing procedure for creating three-dimensional solid objects from a digital file. There are various types of materials such as hard plastic, metal, carbon fiber, concrete as well as other materials used to generate an object (Goldberg, 2003). There are three main types of printing: Contour Crafting, Concrete Printing, and D-shape. These types are divided into extrusion-based methods and power-based methods. 3D Concrete Printing is based on the extrusion of cement mortar in a layer-by-layer procedure. Printing could be performed without using labor-intensive formwork, allowing functional voids to be incorporated into the structure (Lim et al., 2011). Three-dimensional concrete printing is based on the extrusion of cement mortar in a layer-by-layer procedure. Printing can be performed without using labor-intensive formwork, allowing functional voids to be incorporated into the structure. (Lim et al., 2011). Since there are no trowels to smooth the concrete, a small depositing resolution is required to obtain higher levels of print resolution resulting in greater control over internal and external geometries (Lim 2012).

Concrete printing produces a distinctive ribbed finish through post-processing, which can be controlled and manipulated to maximize its effects. However, if a smooth finish is required, the wet material can be troweled during construction, or the printed finish can be ground to a smooth surface. Since this step has not yet been automated, it must be completed manually (Lim 2012). The bonding between filaments and layers in concrete affects the hardening properties of the components, as noted by Le and Austin (2012). A low shrinkage factor is also essential as freeform components are manufactured without formwork, which would result in faster evaporation of water in the concrete, causing cracking. (Le & Austin 2012). The deficiencies of substandard building materials have led to the development of a new ‘cementitious’ material with high strength, approximately three times that of conventional concrete, to overcome the weaker structure of layered components (Lim et al., 2011). Concrete printers currently exist in three types, gantry, robotic arm, and crane. While the last two have been adapted to on-site printing, a gantry system is the most common, is most often used in a factory setting, and can move in the X, Y, and Z directions. This machine has the advantage of its height, is easily adjustable, and can print both large and small objects.

The structural performance of printed elements can be affected by several factors during the printing process. Most studies mention the time interval between printing two filaments as one of the most
significant parameters. The strength decreases with increasing intervals of time as a result of decreasing bond strength of the interface and an increasing number of air voids at the interface. (Le et al., 2012b; Wolf et al., 2019). The speed of a 3DCP machine is typically expressed in millimeters per second. To achieve good concrete filament deposition, the speed needs to be adjusted precisely. According to the pump speed, the speed of printing should be determined. Le et al. (2012) recommended finding a balance between the print speed of the nozzle and the pump speed if the pump speed is operated separately from the printer. Moreover, the object geometry has no direct impact on the mechanical properties of the material, however, for the nozzle geometry, it could be critical to account for sudden changes in print directions. Also, the vertical position of the nozzle with respect to the initial layer is of importance for the strength properties of the interface (Wolfs et al., 2019). The nozzle standoff distance can influence interface strength properties and surface quality, i.e., surface roughness (Panda et al., 2018).

Nozzle geometry and cross sections vary in shape and size. Vertical extrusion refers to filament extrusion from the bottom of the nozzle, while horizontal extrusion refers to a printing process in which filament is extruded horizontally at the back of the nozzle. There is also an option to combine the two, where the critical parameter would be the angle of the deposited material (Jansen, K, 2020).

Besides a few novelty projects and the small garden effort described at Galloway Elementary in Jackson, MS (Rae, 2021) there are no significant or even noteworthy landscape architecture focused projects in the U.S. that have utilized 3DCP as a primary construction technique. The tool is capable of creating mathematically driven forms that appear in the works of cutting-edge site designers without the laborious processes required through subtractive construction techniques. However, while there is a range of literature on the technology in academic settings, each manufacturer uses a proprietary process and secret mixture of concrete that is otherwise untested for strength, longevity, and sustainability.

4 METHODOLOGIES

With such a new technology that is completely untested in traditional landscape architectural practice, it was important for this to study document exactly how a designer would work back and forth with a 3D printing company and develop a solution for a site design element. Prototype design documentation allowed the researcher to document the design process as a method of gathering all the variables of the design process as well as the nuances of communication required for a landscape architect to engage a 3D printing company in the process effectively.

Design documentation describes the whole process of building the product, and it is a collection of documents and resources covering all aspects of the product design (Dairo, 2019). In this study, the researcher used the design documentation method within a specific workflow (Figure 1) to identify and analyze the possibilities and limitations of the 3DCP in the design process and the subtleties of communication required to successfully engage a 3D printing company in a project design. For this exercise, two benches were designed using Rhino software according to the limitations of the 3D concrete printer. It was necessary for a 3D model imported into slicing software to be transformed into G-code that the printer could follow. The bench was printed by the manufacturer to check for errors, and the process was repeated with a second bench after uncovering the limitations of the printer with the first bench. In this process, Kirby Lockard, a designer for Pikus 3D, based in Salt Lake City, worked with the researcher to print the benches that adhered to the printer’s requirements. Observations and conclusions were limited to the design process.
5 RESULTS

The following steps were documented through the design process of two benches. Issues were observed through visual analysis of the model or final print. Solutions were developed through a collaborative process between the designer and the 3DC Printing Manufacturer.

5.1 First Bench Design Documentation

Step 1: Information Gathering

The designer shared the idea of creating a 1'6" x 1'6" x 6' long bench with a printer. After reviewing the Pikus’ brochure for limitations of its printer, which included turning radii, layer slopes, layer heights, and basic surface pattern options, the designer asked the following questions before beginning the design (Lockard, 2020).

What type of concrete 3D Printer do you use at Pikus?

“Our printer is on a Gantry system which means it moves pretty similarly to a CNC Router or some of the most typical plastic 3D printers where the build plate remains stationary. Our build area is approximately (5m x, 4my, 3.9m z). We Print on a custom conveyor system to roll the completed prints down the line after the build area is filled.”

Which software do you recommend modeling the bench in?

“I 100% recommend Rhino and Grasshopper. We slice out of grasshopper, so the objects must be imported to Rhino eventually, and some programs do not export perfect geometry to Rhino. It can be done, but there may be unique ways you need to export, or there could be issues that seem to come out of nowhere. I have begun to use Blender for models that need more organic sculpting, but again I must export it to Rhino later.”

Is there anything else you want to add that can be helpful for the start of the design process?

“A strategy I would recommend would be focusing on designing in section. You can also look at it as designing the actual tool path that the printer head will follow as it deposits material. If you can draw serial sections of what you are thinking, you can then loft those sections to create your surface. I often sketch the sections of key areas to start working on the needs of a design (Seat height, backrest, toe kick) into the overall form of the design. Think of the printing constraints (especially slopes) and how they might influence the
orientation of your part during Printing. Maybe you need to print something on its side or upside down to overcome the constraints.

If a design is not infilled or structured differently, you may need to adjust the form to support critical areas. For example, you may need an arch underneath a horizontal flat face to support the weight being added to it. Prints do not need to be straight extrusions of a profile. They do not even have to be flat on the top layer. I am sure there will be some other helpful hints that come up as you work on your design.”

Step 2: Conceptual Design and Sketching

With testing the limits of the printer in mind and uncovering issues, a folded plane concept was developed for the first bench design (Figure 2). After an initial sketch was developed, a review call with Pikus was set up to review the design and make adjustments before modeling. Then a video call was arranged in which the designer demonstrated some of the 3DC printed objects produced by Pikus 3D, and she added that the company would be limited to a single color per print in the foreseeable future. In addition, she indicated that there should be some degree of color fade-in and fade-out. However, this will be a gradual transition rather than an on/off option, and the standard multi-color/C_MYK value method mentioned by her will remain in development for quite some time.

The discussion with the printer revealed a general understanding of how forms may be printed in the company.

Figure 2. Conceptual sketch of the folded plane bench (2020). Illustration by the authors.

Step 3: Three-Dimensional Modeling

As a result of the printer’s recommendation, Rhino 3D modeling software was chosen to model the design process. Rhino 3D is a powerful digital modeling software used in various applications such as Computer-Aided Design (CAD), 3D Printing (3DP), Rapid Prototyping, Computer-Aided Manufacturing (CAM), and reverse engineering, including architecture, product design, industrial design, multimedia, and graphic design (Novedge, n, d). In addition to the printer comments, the designer considered two points before starting modeling in Rhino (Evans, 2014).

Units and Tolerances

“Before beginning the modeling process, the correct tolerances should be set by identifying the tolerance of the program the model will be exported to and setting the rhino tolerance at ten times that tolerance. It is possible to set the Rhino file tolerance in the document properties window, units tab. While exporting a model from Rhino, the units are almost always read as millimeters, so it is best to set the units to millimeters before exporting the file for printing.”

Checking the 3D Model

“The 3D model must be watertight for successful 3D printing, i.e., if the model were dropped into a bath, no water would leak inside. For a model to be watertight, it must be constructed from a closed polysurface. The most common reason why a model becomes unprintable is the presence of bad objects and naked edges.”
The initial bench model was generated in Rhino, starting with the bench sections, and then completed with the maximum slope of 30 degrees from the vertical axis and the thickness of 35mm (Figure 2).

**Step 4: Revising**

A second feedback call with the printer revealed ten critical issues that needed to be resolved before the final revision (Figure 3). While it is not possible to delve into each issue in this paper, the major issues resulted from the design being a single plane object with overhanging angles and sharp corners. Each of the summarized issues resulted in a design modification in the final model.

**Issue 1:** The print cannot be made at an angle.
Solution: Place the bench on a fabricated angled base (pallet).

**Issue 2:** The bench slopes (freestanding edges) should not exceed 30 degrees from the horizontal axis.
Solution: Decreasing the angle of all slopes from 60 to 30 degrees.

**Issue 3:** The extreme base angle could not be printed.
Solution: Decreasing the base angle from 30 degrees to 15 degrees.

**Issue 4:** The overhangs of the sloped surfaces were not printable.
Solution: Fixing the angles and dimensions of the bench to minimize overhang angles.

**Issue 5:** The need for supporting a horizontal surface.
Solution: Breaking the bench into smaller parts and adjust which side of the object touched the pallet.

**Issue 6:** The 90-degree corners were not following the printer’s nozzle shape.
Solution: Changing the 90-degree angles to be rounded at the corners.

**Issue 7:** The layer should not be less than 35 mm in width.
Solution: Changing the thickness of the bench to 35mm to be suitable for printing.

**Issue 8:** Positioning the first layer of the bench on the pallet.
Solution: Placing the entire first layer of the bench on the pallet.

**Issue 9:** Losing the resolution of the printing.
Solution: Getting rid of excess thickness at the end of the top layer.

**Issue 10:** The last horizontal layer of the bench should not differ in thickness.
Solution: For each bench module, all horizontal layers must have the same thickness, which was set to 10mm to be the same as the slicing software settings.
Figure 3. Issues and refinement solutions of the first bench (2020). Illustrations by the authors.
**Step 5: Final Design**

The final model incorporated the multiple design revisions required for the printer to create the object. At the end of the process, the plan was to print the bench in self-supporting sections that could be pieced back together at the end of the process. The process illustrates that the printer needs to respond to basic forces, and it has limitations that have to be considered.

**Step 6: Slicing**

A slicer program converts a 3D model (usually in STL or AMF format) into G-code that a printer could follow. By intersecting the input model with parallel lines evenly spaced, two-dimensional domains could be generated. This two-dimensional domain is then stacked on top of each other in order to represent the full model. Every plane is then broken down into a series of linear movements which will result in the desired object profile. The slicing software is a critical part of the 3D printing process as it creates the G code directions for the printer to follow. It allows the user to specify their printing preferences, such as a slower print speed for more aesthetic parts or a higher infill density for stronger products (Additive-x, 2016; Evans, 2014)

After sending the final design Rhino file of the bench to the printer, the designer was asked to create a hollow mesh shell from the bench that would be the path of the nozzle used to print the bench in the slicing program.

The printer mentioned in this step that they have a proprietary slicing tool compatible with their printer. However, before sending the final version of the bench file to the designer for the slicing step, it was decided to slice the bench in Rhino to determine its shape and based on the literature review and the company’s designer explanations in previous stages of the design, it was realized there was a problem with the nozzle path rounding at one edge. So, the slices were fixed.

**Step 7: Printing**

The bench was placed on a sloped pallet and printed at Pikus’ facilities in Salt Lake City, Utah (Figure 4). Printed in two parts and assembled afterward, the 30-minute print, still resulted in several obvious aesthetic issues that would require further refinement. Corners were not executed properly, due to an error in the slicing code, and transitions along gentle slopes were extremely obvious due to printer resolution. However, with a few simple modifications, the issues could be fixed easily.

Perhaps the most challenging aspect of the process was simply the length of time it took to get from a sketch to a print. Without a timeframe and working around schedules, the back-and-forth process lasted nearly three months. However, there were many lessons to take away from the process. Notably, that 3D printers work best with volumetric objects. With this in mind, a second bench design was developed that worked with versus against the limitations of the printer.
5.2 Second Bench Design Documentation

Working off the knowledge gained from the first design process, a second bench was designed to work with the printer and its strengths. The following process was executed from concept to print in a single day revealing the potential strengths of the technology for site design elements.

Step 1. Information and thoughts

In designing the second bench, information and ideas were gathered from the first bench, and the decision was made to design a bench that could be printed as a whole object with a volume that allows for simplistic printing paths and could shape that support itself completely from a flat plane.

Step 2. Conceptual Design and Sketching

A quick sketch was developed and sent to the printer in the morning. Seeing no issues, the process moved to modeling.

Step 3. Three-Dimensional Modeling

The bench model was generated in Rhino, starting with the bench sections and dimensions. After that, it was sent to the printer for feedback. The printer only had one concern with the initial model.

Step 4. Revising

Issue 1: Controlling the loads
March 16-19, 2022

Solution: Adding a support to the bench design.

One of the concerns with the technology is the lack of knowledge about structural capabilities. The benches implemented at Galloway Elementary were backfilled with concrete to ensure structural integrity. Here the printer recommended an additional interior support path that would act as a support along the length of the bench. This modification can be seen in Figure 5.

*Step 5. Final Design*

After adding the internal support, the bench file was sent to the printer who identified no other issues with the model.

*Step 6. Slicing*

The printer executed their proprietary slicing procedure with a grasshopper plugin. The resulting sliced file showed no additional issues, and the file was ready to print.

*Step 7. Printing*

At the end of the day, the 25-minute print was executed at Pikus’ warehouse in Salt Lake City, Utah. The bench was printed on end and then laid down for inspection. There were no obvious issues with the print and it was considered ready to ship if it had been ordered for a project. The resulting print and process can be seen in Figure 5.
Figure 5. Complete design process for the second bench executed in one day. Illustrations by the authors (2020). Images by Pikus.
6 CONCLUSIONS

This was a revealing research effort that has many implications for how 3DC Printing might influence the way we design and build objects in the landscape in the future. The first realization is that the technology is advancing at an incredible pace. Early examples of 3D printing took days if not weeks to execute. It's not long before one realizes that this is not what we traditionally think of as concrete. Special additives allow the mix to cure at incredible rates. A 6’ long bench printed in less than half an hour sounds almost like science fiction. It’s not hard to imagine a day when contractors have a machine on-site printing objects in situ. That said, there are still issues with the technology that will require research. Specifically concerning is the lack of knowledge of the material’s structural properties. While this limits most design professions, it is actually not as concerning where landscape architects primarily deal with free-standing objects that only have to support themselves. Indeed, the technology might be used primarily as a decorative finish or even decorative formwork over a more traditional material until the understanding of the technology advances.

The process itself, which requires a collaborative relationship with a knowledgeable printer, is uniquely revealing in its potential for the future of landscape architecture and design. For a designer to create a sketch in the morning and have a solid concrete object printed, not as a mockup but as the final product, by the end of a single day is unheard of. What might this mean for turn-around times? For inventory of elements? Could there be a day where elements are selected and printed from a catalog on demand? This speed might lead to a design process that is much more fluid and integral to the manufacturer.

Perhaps most revealing for the profession is what it might mean for the nature of design aesthetic. Everything we design has roots in a combination of the materials, craftsmanship, and technologies that are used to create them. What does an object built with a 3DC Printer look like? There are no forms required. Only subtle limitations to print angles, height, etc. Clues to this future might lie in contemporary designers who have adopted parametric scripting tools like Grasshopper to develop sinuous forms driven by mathematical formulas. In most of the relevant examples, objects are meticulously carved from stone through painstaking subtractive processes. This technology makes these modeling tools much more approachable and the resulting product much more affordable.

7 ACKNOWLEDGMENTS

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8 REFERENCES


RESILIENCE AND CLIMATE ACTION

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DESIGNING FOR NATIVE BEES IN THE FACE OF CLIMATE CHANGE: A CASE STUDY OF CREATING NOVEL ECOSYSTEMS FOR RESILIENT LANDSCAPES

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1 ABSTRACT
Bee habitat infrastructure should be an essential priority for humankind facing climate change today. Pollination resiliency is necessary to conserve our current standards of life by reducing environmental and physiological stressors for bees. Designing conservation landscapes within human dominated systems for a diversity of native bees is complicated. Native bees fill a huge ecological purpose yet suffer from habitat fragmentation. Landscape designers need clear instructions to effectively plan and design bee habitat scientifically proven design for pollination ecological function. This research aims to add clarity and specific solutions to help combat the many layers of complexity concerning bee habitats and identify best management practices to help landscape designers make sound, ecologically based bee habitat. This paper presents a collection of bee design ideas and concepts tested by undergraduate students. Design strategies were assigned to aim to: 1) improve habitat for native bees, 2) improve understanding of urban bee habitats and needed habitat network augmentations, and 3) design to educate and convey information/increase landscape literacy for focal bee genera. Bees are keystone species, important to the conservation of many other plants, animals, and ecosystems. Human-dominated habitats, especially those with close proximity to agricultural areas, serve as potential source habitats for bees. This research utilized landscape architecture students to explore scientifically accurate designs for and about bees. With precise instruction about bee needs, students designed well for bees and either strove to provide best possible habitat or used art for conservation. Through precise bee ecological training, landscape architecture undergraduate students did very well designing for bee conservation. Bolstering urban plantings can help to mitigate the climate change effects on bee populations via effective garden and pollinator network designs.

1.1 Keywords
Native bees, Landscape design, Ecology, Pollination, Gardens, Habitat
2 INTRODUCTION

Urban spaces have the potential to provide bee habitat (Bonthoux et al., 2014; Frankie et al., 2003, 2009; 2014; 2019, Lowenstein, 2015), however, the quality of design work can have varied effects. The plant palette and spatial characteristics of a site have a large impact on the ecological quality of bee habitat (Chacon and Greco 2022a;b). Strategies for improving bee habitat can help make design decisions for habitat landscapes facing climate change. To protect ecosystem services (i.e., pollination from insects and some vertebrates) we must focus on bolstering and building resilience among bee populations (Pollinator Partnership 2021; USDA 2021; Xerces 2011). The main goal for designers of bee landscapes should be to create highly functional (high connectivity and high circuitry) pollinator landscapes. In other words, designers should build landscapes which are appealing for bees to feed, reproduce, and live in. There is quite a bit of information on bees which is contradictory or not based on science and this is confusing and detrimental to designers. This research investigates the degree to which specific scientifically based instruction affected design outcomes for landscape architecture students.

Good habitat design must be local area specific and consider the site’s context. For example, plants should be suitable for predicted California’s future climactic conditions, in many cases, be less dependent on water and more resilient to drought stress (Reid and Oki 2008; Hartin 2018). Designers should aim to compensate for land cover which is not conducive to making suitable habitat. Thus, designers need to look at ways to reduce the footprint of impervious surfaces, such as roads, roofs, building sides, among many others. There is a need to convert wasted landscape space into habitat for bee habitat resiliency (Xerces 2011; Bonthoux et al., 2014; Siros-Delisle and Kerr, 2018) in the face of climate change in human-dominated landscapes. The Earth is undergoing a new epoch, influenced mainly by human activity, coined the Anthropocene (Lewis and Maslin 2015). Similarly, the vast majority of Earth’s landscapes have been shaped by humans, coined the Anthroscape (Eswaran et al., 2010). Furthermore, creating good habitat is only one part of the solution for creating effective native bee designs. Showcasing bee educational information, such as scientific findings is necessary to increase public awareness, interest and conservation.

This work investigates the degree to which urban human dominated bee habitats represent ecological bee refugia in California. Then, we demonstrate how student landscape designers can be helped to conceptualize on various improvements of human landscape types. Planning for native bee conservation under the ecological threat of climate change requires examining ecosystems from a target bee’s perspective. Solving novel ecosystem issues requires holistic study, based on scientific data to meet the needs of native bees.

Moreover, bees represent a large number of different organisms, therefore, it is impossible to design for all bees at once. Instead, focal bee genera will be selected based on the data and results from Chacon and Greco, 2022a; b. Student ecological designers are tasked with maximizing site design. Designs for bees will focus around the biological needs of focal bee genera, with an emphasis on those having potential for maintaining ecosystem services in urban ecosystems. Ideally, focal bee genera conservation will act as an umbrella, also helping to support bees which have narrower habitat requirements. Selection of plants for bees was an important element of bee habitat design, seen in (Chacon and Greco 2022a;b), but this research goes further, aiming to teach site visitors about bees. Design is utilized to captivate, inspire and educate humans about the fantastic pollinators that we depend on. Ecologically functional faunal bee urban landscapes, built upon the principles of resiliency, will help to guarantee pollination ecosystem services in the future.

This research concentrates on presenting strategic bee design concepts which are explored by landscape architecture students. Bee designs focus on providing the best possible plant selection for temporal continuity, spatial habitat continuity, creativity, public education and artistic themes. Examples of design intervention will be made to demonstrate how different degrees of designing for bees could be achieved with varying results in the real world. Design holds a key role not just in providing habitat, but also in promoting education and communication in memorable ways. Designers have the power to alter the transparency of their landscapes’ functions (Thayer, 1994), and bee landscapes must be thought of in this way to help protect against the uncertainties of climate change. Through striving to create high quality habitat and increase landscape literacy (Spirn 2000; 2021) this research aims to educate landscape architects in promoting pollination ecosystem services into general practice and the future.
3 MAIN RESEARCH QUESTIONS

- Which target bee genera should designers concentrate conservation efforts as focal and/or umbrella species to promote future ecosystem services?
- How can designers foster greater bee habitat “landscape literacy” with their designs?
- Which aspects of mutualism between humans and bees benefit from each other through design?
- What best management practices (BMPs) or design practices can landscape architects use to implement or enhance bee foraging habitat in cities?

4 MATERIALS AND METHODS

4.1 STUDY AREA DESCRIPTION
The University of California Davis Arboretum and Public Garden (hereafter ‘Arboretum’) was the study site for all fieldwork and analysis completed in Chacon and Greco 2022a;b. This research deals with the Arboretum site too, but also examines case studies of the ecological role of bees over the greater landscape extent in the Californian cities including: Mill Valley, Glendora, and San Luis Obispo (SLO). All study sites are considered to have a Mediterranean climate with cool wet winters and hot dry summers. In recent years it has become apparent that drought has affected all of these study sites. While the Arboretum study was in the order of a couple miles, the subsequent urban studies were in the order of tens of miles.

4.2 PICKING FOCAL BEE GENERA
4.2.1 Focal Bee Opportunities and Constraints
Target bee species were identified for conservation based on genera which were found capable of utilizing urban ecosystem landscapes have been emphasized in conservation efforts for this research, including: *Andrena*, *Apis mellifera*, *Bombus*, *Megachile*, *Osmia*, and *Xylocopa*. All of these bees are listed as common bee genera found throughout the state of California (Xerces 2011; Frankie et al., 2014). These bees provide pollination ecosystem services despite the unique qualities of urban bee habitat. We believe that prioritizing pollination is most important when facing the extreme influences and danger of climate change today. While it would be more ideal to plan for conservation of all bees, that is likely not possible or conducive to conserving pollinator landscape functionality. Since so many ecosystems and portions of them are dependent on pollination occurring, it is absolutely essential to conserve the pollination functionality above all other goals.

Bees which are exceedingly prone to habitat fragmentation and exhibit highly specialized feeding behaviors are likely not good candidates for human-dominated ecosystem services conservation efforts. For example, obligate vernal pool bees, consisting of *Andrena* species: A. (*Diandrena*) *blennospermatis*, A. (*D. *) *submoesta*, and A. (D.) *puthua*; A. (Hesperandrena) *limnanthis*, A. (H.) *duboisi*, A. (H.) *lativentris* (Thorp and Leong n.d.). While the most specialized bees may seem be good focal bee candidates because of their extreme geographic limitations (very small foraging radii of only up to 10 meters) and obligate feeding nature (only feeding off one or two plant species) we argue that this would not be a good strategy. Designing for specialist bees, such as vernal pool bees would be inappropriate for most other bees and not focus on the goal of functional pollination in urban areas. Instead, extreme specialists, such as vernal pool bees should have their own conservation areas and strategies, aside from the urban bee communities and habitats.

A balanced approach, therefore, would employ a coarse and fine filter conservation strategy (Noss et al., 1997) for preserving pollination ecosystem services. In other words, ecological design strategies should be employed that conserves a variety of bees, both generalists and specialists. Conservation planning exclusively for specialists such as obligate *Andrena* vernal pool bees should be detrimental for most other bee types, as they have a high degree of specialization. Instead, the focal bee must be chosen with landscapes in mind. Special conservation areas, such as vernal pools, would have their own conservation plans, while anthro-centric, human-dominated, landscapes would focus on focal bees capable of providing pollination to provide resiliency against the harsh environmental conditions facing us in the Anthropocene (Lewis and Maslin 2015). Human dominated landscapes, also known as the anthro-scape (Eswaran et al., 2010), will require pollination conservation plans which would encompass bees capable of pollination across the greater landscape. Functional pollination would help to ensure that ecological biodiversity remains stable, along with all the other plants and animals that depend on pollination.
Therefore, by choosing strategically which bees to focus on, designers can help to build resilient bee pollinated landscapes now, and for the future.

4.2.2 Focal Bees For Landscape Designers, Focus and Limitations

Target bee species were identified for conservation based on bee genera which were found capable of utilizing urban ecosystem landscapes. The bees which have been emphasized in conservation effort, for this research, include: *Andrena, Apis mellifera, Bombus, Megachile, Osmia, and Xylocopa*. All of these bees are listed as common bee genera found throughout the state of California (Xerces 2011; Frankie et al., 2014; Chacon and Greco 2022a; 2022b). Furthermore, author KC studied the interest level with which student designers were attracted to work with. There were obvious trends among landscape architecture undergraduate college students for particular bee physical and lifestyle traits. The abovementioned commonly found native bee genera were also quite popular with students as subjects for design projects. Thus, while some bees, such as *Halictus*, were excellent foragers in Chacon and Greco 2022a they were not popular with student designers, most likely due to their relatively hairless bodies and subterranean nesting style. Other less popular bee genera included: very small *Lasioglossum*, especially the tiny *Dialictus* subgenus types and/or small and hairless *Hylaeus* (though one project was attempted with an endangered *Hylaeus* in Hawaii, discussed below, but not pictured), Cuckoo bees were vastly unpopular, and never utilized for a project at all. Overall, students were instead, drawn to bees with special attributes, such as: hairy, colorful, robustly bodied bee types (rather than ordinary looking specimens).

Notably students were commonly drawn to working with European honey bees, *Apis mellifera*, instead of with native bees. This is likely because most people think that European honey bees are quintessentially conventional. We all know the patterns of honeycomb and images of hives, and bee keeping. So, even students who were educated about the importance of bees native to California, still clung to knowledge about these naturalized bees at times, despite their biology and ecology differing from the local abundance of bee varieties. This could also be due in part to the media attention given to *Apis mellifera*, to “save the bees”. There are countless social media trends on this theme, many, possibly most, of which present mis-information. It is clear that people are not aware of the diversity of native bees in our own landscapes in California. Even designers are not aware of biological and ecological differences and needing education and scientific themed projects. We must work hard to work beyond the “seductive” honeycomb patterns, black and yellow bee cartoon images, social hives, and posts about dandelions “saving the bees”. Afterall, which bees are we trying to save? How can we do it? Landscape researchers are calling for action on better landscape architecture education for college students (Kiers, et al., 2020). Part of that climate education should be about how bee pollination network resiliency is necessary. It’s time for designers to take a stronger scientific stance on essential bee conservation issue today.

4.2.3 Habitat Mapping for Bees

Habitat mapping for any animals often begins with mapping landscape vegetation and then assessing how the landscape’s vegetative form and properties meet the needs of the animal species as Wildlife Habitat Relationship [WHR] models (Chacon and Greco 2022a;b). Bee mapping models aimed for scientifically made, high resolution maps in the order of miles (Chacon and Greco 2022b). However, this research explores these abovementioned mapping techniques and testing more spatially extensive areas, but in doing so, with lower floristic resolution. Additionally, this paper focuses on recommending design solutions to existing urban bee habitat shortcomings. This research analyzes the patterns of urban vegetation in relation to native bee habitat area. It is accepted that urban areas have different bee community compositions than wild land areas (Frankie et al., 2014; Leong et al., 2015; Nicholson et al., 2020; Prendergast and Ollerton 2021; Xerces 2011). Next an extrapolation of the ecological function of gardens found Chacon and Greco 2022a;b to the larger landscape scale can be made to help gain understanding about how the bee metapopulation functions. Students were advised to assign the following habitat quality characteristics for landscape cover types: wild, agricultural, and urban. Each are described below.

**Wild land:** Excellent habitat for native bees, probably honey bees as well. Most plants peak blooming earlier in the season (see Mary Wattis Brown California Native Garden in (Chacon and Greco 2022a)). Wild habitat patches are often located very far from other wild patches. Often made of hilly areas unsuitable for agricultural crop growing and/or grazing. Native plants, but interspersed commonly with non-native invasive plants as well. Fire in these areas encourages native pollinator population boosts (Mola and Williams 2018; Ponisio et al., 2016).
Agricultural land: Infrequent use for most native bees. Vast, monotonous plantings, hostile management (i.e., pesticide spraying) and habitat matrix quickly changing (i.e., crops grown/harvested), no place to overwinter for bees, may provide foraging habitat with juxtaposition to bee source habitat. Scale often represents a major obstacle for bees to travel through at the landscape scale, i.e., mono-cropping acts as a sink, too vast to traverse. Irrigation could allow for blooms and therefore foraging habitat while wildlands would be desiccated. Management of crops and the surrounding areas can drastically sway the quality of bee habitat (Chaplin-Kramer et al., 2011; Greenleaf, S. and Kremen, C. 2006; Kremen et al., 2002; Wilson et al., 2017; Shackelford et al., 2019). Further spatial bee habitat studies should shed light onto how urban areas function as native bee genera habitat. A focus on urban areas which are adjacent to agricultural lands seem to hold promise, as that land presents potential for urban bees to subsidize pollination ecosystem services within agricultural lands, with benefits such that hedgerows provide.

Urban land: Urban land is an ecological refugia for many native bees and naturalized honey bees. The landscape matrix is highly dissected and plant palettes vary greatly, some of which provide excellent habitat for particular bee genera. It also provides a longer foraging season than wildlands, partly due to plant choices, but also use of irrigation. These planting combinations are often unique combinations and function as novel ecosystems. This land cover acts as source habitat for many bee species, helping them maintain their populations despite the juxtaposition to less hospitable landscape types. There is much variability within land types, even from parcel to parcel or land use categories such as single-family home, residential, high density residential, commercial and industrial. In areas which are highly hostile to bees, pollination is decreased, even among European honey bees, (Garibalidi et al., 2011)

Urban landscape types: Classifications of different landscape cover types were done in somewhat coarse aggregates. For example, park vegetation, road edges, lawns, etc. This was a common choice among students who could quickly select green on maps via Photoshop (Adobe 2021a). Alternatively, some students took the time to trace vegetation with Illustrator (Adobe 2021b) or InDesign (Adobe 2021c) with similar results. Finally, some students also utilized ArcGIS (ESRI 2021) land cover categorizations in GIS data using ArcGIS (ESRI 2021b). Future studies could be done to compare each technique.

4.2.4 Designing for Bees

Landscape design for bees is explored with help of student designers from California Polytechnic’s Landscape Architecture program (Cal Poly 2021). Students in both studios and specialty interest courses were given design tasks by author KC over three quarters. Students were challenged to create landscapes based on scientific bee research provided by author KC. The project prompts were very focused to help students. For example, author KC provided consolidated data on bee foraging radii, bee foraging preferences, bee nesting type, and special bee anatomical features and/or life histories. This degree of specificity was very helpful for getting past the research portion of their designs quickly and allowed for more concentration on creative implementation.

The student illustrations and work help to exemplify KC’s vision of designing bee habitat in a thorough ecological, but also provocative and engaging ways. KC’s design ideas for bees are rooted in scientific knowledge and aim to tackle bee pollinator conservation as a multi-prong approach. Students were provided with the ecological information needed for each assignment. Assignments were designed to focus on particular aspects of bee ecology and biology. This case study highlights how designers can do very well if working from accurate scientific foundations. Designs focus around the biological and ecological aspects of bees (see section 6.3 for specific bee design ideas and descriptions). Author KC evaluated student submissions for their ability to implement design ideas from the project prompts for focal bees. The best designs look to celebrate what is unique or interesting about each focal bee. In addition to habitat creation, maximization, and conservation, landscape designers can help to show how bees’ stories can be shared.

4.2.5 Seed Library

A single prototype was made to gauge neighborhood interest in improving residential bee habitats. A seed library network has potential to provide opportunities for improved neighborhood pollinator habitat. Moreover, seed library patrons would be empowered to make positive changes within their vicinities with minimal physical labor and intrusion into private land spaces which are otherwise often inaccessible. Participation in seed library usage would be entirely voluntary for users. A network of seed libraries will act as a system of structural resiliency for urban pollinators. By using geographic analysis, mapping techniques could help to shed light into where seeds are being planted and also where important pollinator plants exist.
With the help of citizen science data, areas of low pollinator plantings can be targeted for future landscape design for pollinators.

### 4.3 FIGURES

**Figure 1.** Show site visitors about special bees. Image: Alrawi (2021). Reproduced with Permission of Alrawi.

**Figure 2.** “See like a Xylocopa bee”. Image: Pasurishvili (2021); (Adobe 2021a,c). Reproduced with Permission of Pasurishvili.
Figure 3. “See like a Megachile bee”. Image: Hensen (2021); (Adobe 2021b,c). 3D Image (Rhino 2021). Reproduced with Permission of Hensen.
5 DESIGNING FOR BEES RESULTS

Student work was impressive due to receiving specific instructions to aid their designs despite being novices in the subject matter. These design studio classes were a great place to test how design quality and values can vary depending on the foundation designers are given. The full list of design prompts is listed in section 6.3. In current practice there are no parameters for what constitutes a “good” or “bad” bee habitat. Designers are sometimes limited for time and research, however, if sources of good design ideas were compiled it is clear the resulting designs would be much improved. For example, if landscape architecture groups would compile teachings such as below it seems there would be a very positive impact on bee habitat today.

5.1 SHOW SITE VISITORS ABOUT SPECIAL BEES

Students were asked to show site visitors about special bees. Figure 1 shows how one student envisioned providing nesting habitat for *Megachile* bees in a sculptural way, conveying meaning to site visitors (Alrawi 2021). This clever solution helps people to gain landscape literacy about these fascinating cavity nesting bees. Mutualism exists here, presenting opportunity for both bees and humans. Design mutualism is an opportunity for multiple species to benefit from a landscape change (Orff 2016; Orff 2021). In this case, bees benefit from habitat design for nesting and foraging, while people benefit from gaining landscape literacy (Spirn 2000) about the pollination world around them.

Another wonderful design (Figure included in presentation only) focused on endangered *Hylaeus* bees in Hawaii. As it turns out the student lives on Oahu, the same island where the endangered *Hylaeus* species are found. By researching the foraging preferences and last sighting locations of these rare bees, a plan was made to help both conserve and celebrate these now rare bees. Interestingly, the possible conservation area overlapped with an already existing botanical arboretum. Adding an installation to highlight the special traits of endangered *Hylaeus* appears to be an opportunity for public education. The student was able to research the face patterns of the local *Hylaeus* bees and designed an interactive walking tour which would appeal to a large age range of visitors. This project was serendipitous, and holds potential for implementation.

5.2 SEE LIKE A BEE

Students were challenged to envision and demonstrate what a vegetated landscape looks like from a bee’s point of view, focusing on the valued elements. This project forces students to look at the landscape from their organism’s value system, which is an essential part of good ecological design. Figure 2 shows how *Xylocopa* favors some forage plants over others in this residential landscape. This student shows clearly which plants have ecological value to *Xylocopa* with the use of color, in contrast to the colorless (ecologically valueless) portions of the image. This image is particularly good at transmitting meaning to human viewers, helping people to understand this organism’s preferences and landscape opportunities or limitations.

Another intelligent “see like a bee” design solution (Figure 3) shaped the ear pieces of glasses to look like tubular *Megachile* nests. The work was completed with an annotated design plan with callouts to highlight favorite foraging plants. The idea of ecologically based ‘bee glasses’ seems like an opportunity for helping capture the imagination of children and with educational presentations. There are many aspects of the bee’s biology, ecology and foraging preferences which could be highlighted and made possibly more memorable with the help of glasses props, for example.

5.3 DESIGNING BEE “BOXES”

An aspect of bee biology which has potential for design is for bees which cavity nest above ground. It is possible for designers to create cavity nesting areas on any vertical surface. The form of these sorts of projects is limitless. One of the best student work’s shows a concept for spelling the desired nesting bee’s genus name (*Osmia*, for example). A design like this is fairly simple, yet demonstrates much more knowledge and information than a standard bee box from a standard retailer. Other students looked to maximize wall design space. One student created a huge silhouette of *Megachile* and planned drilled holes of the correct diameter all over the entire surface. It is conceivable to imagine that design as both striking and memorable. Other students strove for more abstract geometric patterns, which though artistic in nature, were not effective at communicating as much information about the bees.
5.4 FREE POLLINATOR SEED LIBRARIES

Author KC has envisioned a new way to help achieve higher quality pollinator habitat in neighborhoods via the installation of free seed libraries. A prototype pollinator seed library was made from a repurposed windowed cabinet and painted to advertise its contents. Since pollinators are suffering from habitat fragmentation and degradation due to human land use activities, habitat design (plant selection and placement) is critical to solving these connectivity issues today. Improvements to habitat networks are on the forefront of research and design by urban and landscape ecologists.

Seed libraries, a grass roots phenomenon, aid in accessibility for people to start their own seeds. These cabinets originated in effort to provide free resource availability and seem like an opportunity for growing pollinator habitat. Seed libraries are small outdoor cabinets which can be curated to a palette of the provider’s choice. The seeds contained within are available free to whoever accesses them. Seed library users are also encouraged to leave seeds for others as well. Seed libraries are a “spin-off” of the popular “Free Little Libraries” program for exchanging books. Cabinet-style libraries are hyper local in design scale, often with one every few blocks in a neighborhood. Designs are often creative, attractive and fun to elicit usage. Specializing seed libraries to help meet the needs of local pollinators has great mutual potential, both for humans, and also pollinators.

So far, author KC’s “Free Pollinator Seed Library” has been extremely popular. Well over 800 hundred seed packets have already been exchanged in the months of its existence thus far. The reception of the Grover Beach, California surrounding neighbors and users has been extremely positive. Efforts have been made to create a ‘buzz’ online. Basic information about the project can be found at author KC’s personal website, (beelandscapes.com) and it even has its own Facebook (free pollinator seed library, 2021) page, titled, “Free Pollinator Seed Libraries where author KC can post updates. However, the highest interest occurred by posting on the Nextdoor (social media website to connect geographic neighbors, allowing online communication and posts) (Nextdoor, 2021). Seventy-four people within the immediate neighborhood liked the post and twenty took the time to post comments, all with positive words about the project. Of the commenters, all were within a maximum 12.5 km (7.8 mi) radius from the seed library. The average distance of a commenter to the seed library was 6.3 km (3.9 mi) and the median was 3.4 km and 2.1 mi. Commenters show which neighborhood area they are posting from, which are defined by local’s sense of geographic area, in this containing the following regions: Corbett Canyon, Edge of San Luis Obispo (SLO), Fair Oaks-Grand, Grover Heights, Horned Toad Trail, Huasna Valley and Huasna Corridor, Just Off The Pike, Lopez Drive, Oak Park Streets, Oceano, Ocean South, Old Oak Park, S. Oak Park and Trilogy. Most recently a Google Business listing was also made (Google Business 2021), which has further increased page views and visits. For example, in mid-January 2022 there have been over 1,100 visits to the Google page, which has increased exposure significantly.

Therefore, the seed library captured the attention of people in the general geographic area as well as in the local neighborhood. There is a lot of enthusiasm among the neighborhood to help bees. Designing pollinator seed libraries seems to hold a great potential for making the largest positive changes in short amounts of time with limited budgets.

5.5 PLAYING WITH CONTRASTING BEES THROUGH DESIGN

One of the most engaging potential design themes explores the contrasting nature of various bee genera. One student came up with a particularly interesting sculpture idea to celebrate two very different native bees. The student was keen enough to focus on the materials for each bee, wood for Xylocopa, and soil/ceramics for Andrena. The project (not pictured) shows two large (about 4 meters tall) bees of contrasting colors diving into the ground with their paths dynamically crossing. This work helps to demonstrate the various nesting substrates each bee would use. Furthermore, the student carefully imagined the body size and shape of each bee. (Note: the Xylocopa design could be improved by showing the nesting hole above the bee or on its side. Xylocopa does not ordinarily enter their nest holes from the top). It would be an impressive sight to see this design implemented. Different bees could be chosen at geographically different places to highlight locally special bees.

Other well thought out contrasting bee designs included, showcasing different bee nesting styles or foraging preferences. Some students juxtaposed different style nesters along a human walkway. Others used a human path to separate two very different foraging habitats on each side, for bees with extremely different foraging preferences. Overall, these themes have a lot of potential and should be explored more. Particularly, displaying uniqueness of bees and/or local adaptations seems like an excellent way to support local bee populations.
5.6 RETROFITS OF YARDS (AND OTHER COMMON LANDSCAPE TYPES)

Designing for bees over large areas of human dominated landscapes will require renovation of landscaping with little to no ecological value. Learning to maximize bee habitat with small planting areas is very important. When added together, these small snippets of micro-habitats contribute to pollinator habitat networks, which are essential for resilient landscapes. One of the best submitted images shows one student’s attempt to maximize bee habitat foraging area in their family home. This student wisely recommends more pollinator plantings on the ground level, but also imagines creating more foraging area by utilizing vertical wall space for habitat.

Some students were bolder with their designs. They thought through how to maximize the area of foraging plants for bees, whether that was on the roof, walls, driveway, getting rid of grass or paving. Students were urged to think about a design they would like to look at every day, thus, in this way, it was easier for them to imagine if it was their own home or property. Since much of the human-built environment is already in existence, it is very important that we strive to update and augment the ecological functionality of such places for bees and other pollinators.

5.7 CONNECT THE COGNITIVE DISCONNECT, INCREASE LANDSCAPE LITERACY

A particular area for improvement among bee habitat designs is the level of literacy they allow the public to understand. Designs such as shown in Figures 1-3 show how large-scale demonstrations, featuring sculpture(s) and murals can have a strong impact on the designed landscapes and are an opportunity to transmit information (Spinn 2000); to educate whomever can view them. In this way, the entire landscape is a canvas, just waiting to share its meaning. Designers can help “interpret” what the landscape is doing; how it is functioning ecologically.

5.8 HABITAT MAPPING, INTERMEDIATE

Students tackled the bee habitat map categorization in a variety of ways, each producing effective graphics to demonstrate habitat patchiness of bees in human-dominated environments. Figure 4 shows an attempt at classifying landscape in Oakland, California from *Bombus*’ perspective. This is a somewhat typical classification of open space, park land, street and sidewalk vegetation. Looking at the landscape with spatial distances between habitat is essential to better understand how bee habitat fragmentation patterns play out for bees at a city-wide scale. Figure 4 was made quickly by using an extension of ArcMap (ESRI 2021) within Illustrator (Adobe 2021a), a more illustrative software. This method was quite quick and accurate, creating quite effective results. Other students tried to streamline the tracing task by utilizing Photoshop’s (Adobe 2021a) select by color tool which was perhaps the fastest method, but also lacking in accuracy. More mapping technique results are described below.

Other mappers strove to add more detailed information, with varied categories for example, including: natural landscapes, parks, redwood tree dominated areas. This categorization scheme made more sense for the student working out of Mill Valley, California. Some students missed the opportunity to demonstrate human residential areas as possible habitat for native bees. The best projects, also show well the possible geographic connections between denoted patches. The main correction for this type of mapping project would showing suburban and residential areas do have some ecological habitat value for bees. However, showing how much habitat value a residential parcel has is not simple, but subsequent student designers tried with other techniques shown in section 5.9, below.

5.9 HABITAT MAPPING, ADVANCED

The goal for the studio students was to create an extensive poster emphasizing designing for bees in a city of their choice. The final project had them concentrate at the scale of up to a few kilometers or miles maximum. One of the best projects include Figure 5, which shows a regional bee habitat design for the SLO area. This student was careful to use both GIS (ESRI 2021) land cover data for more precise habitat mapping as well as mapping information (Google 2021b). In their map titled, “The Network Map”, they were able to precisely prescribe where to place new habitat for “pollinator usability” which in ecological terms relates to ensuring foraging habitats are close enough together for continuity between pollinator patches. This student also does a wonderful job demonstrating three simple design techniques in their category “Pollinator Pockets” (or best management practices) which could be implemented at various landscape types. So, for example, with major streets, slim narrow planters could be installed; with residential areas, seed packet programs could be implemented; and finally with parks, suitable foraging
flowers could be planted in groups. All three of these design techniques add together for the desired result of increased pollinator habitat circuitry and connectivity. This design solution is akin to adding sunflowers throughout a town to bolster bee network connectivity, as seen in The Great Sunflower Project (LeBuhn 2021) in Sonoma, California, which was very well received. Overall, Roa’s (2021) project is an outstanding example of assessing a city’s pollinator habitat and offering design solutions. This is the sort of spatial resolution landscape designers should be striving for to create bee habitat network plans. This project is a shining example of how bee or pollinator habitat analysis and design could be accomplished.

Another final project worth discussing is a pollinator habitat project for densely urban, Glendora, California. This student opted to trace every portion of vegetation from an aerial imagery (Google 2021c) map using Illustrator (Adobe 2021b). This process, at this scale was painstaking and took several days, but the results are fascinating. They were able to capture the distribution of vegetation through this highly urbanized area. We realized that even the proportion of green spaces were visible between neighborhoods at this scale (further studies should be done to inspect the degree to which this could affect pollinator availability between different density greenspace neighborhoods). Moreover, this project helps to show the proportion of vegetated space versus hardscape in very urbanized areas. This is an important factor for how much area could even be potentially converted to pollinator habitat. This project could have been stronger by identifying how far their focal bee could travel and/or possibly occupy habitat patches within this map. Additionally, this project lacks a vision that the previous one, Figure 5, showed for implementation in typical design situations. However, the attention to detail in mapping green space was outstanding and should not be overshadowed by these constructive criticisms. Finally, this sort of mapping technique, if used in GIS could be very helpful for improving the urban pollinator network and quantifying existing conditions as well as potential habitat modifications.

By applying landscape categorizations to real landscapes, it was possible to graphically demonstrate how bees perceive the greater landscape. Only then, once habitat deficiencies are identified can designers go about fixing habitat short-falls. How different bee genera experience the same landscape will also be important to understand and see spatially, as dynamic landscapes create geographic isolation or continuity depending on bee genera. Future studies should work to untangle how urban habitat performs; provides habitat for various focal bees.

6 DISCUSSION

This research focuses on developing the field of landscape architecture to better aid in bee conservation design at multiple scales. My goal is to build resilient pollination landscapes for the future. Every time a landscape is designed there is potential for bee habitat. However, designers need help making adequate bee designs. As a profession we must invest in helping stabilize landscapes and their functionality or the effects climate change could be much worse. Climate change is causing ecological stress for bees, both in terms of environmental, including phenological, mismatches (Barthomeus et al., 2011; Beard et al., 2019), but also in terms of increased physiological issues, including bee body temperature. Bees are keystone species and conserving them, saves so much more than just bees. Pollination functionality underlines the very basis for nearly all terrestrial ecosystems on Earth. Every day, landscape architects and designers create plans to change Earth’s lands and with every plant they choose, they either provide foraging habitat for a bee… or not. These landscape changes are replicated across the broader landscape with scaled results. Planting designs need to serve functional pollination purpose, to feed the local (micro)fauna. Landscape designers, should put an emphasis on bee conservation now to hopefully preserve and prioritize pollination ecosystem services. Strategic solutions to habitat deficiencies, education and also raising public awareness are all important for resilient landscapes. Now is the time to act. Its time to make great strides in educating not only the new generations of designers, but also, with the greater public. Through implementing designs that celebrate local pollinator diversity, biology, and ecology, we can help to support nature’s and our own, human, future as well.

6.1 POLLINATOR PLANT PALETTES

For the last decade or so, horticultural and landscape researchers have been developing sustainable California plant varieties and palettes. Most research on sustainable themes has been completed on low water use landscape plants, but more recently, wildlife friendly too. Field trials for future suitable plants have been completed to help identify, promote and produce climate suitable plantings (Reid and Oki 2008; UC Davis Arboretum 2018; Hartin et al., 2018). For over a decade the UC Davis Arboretum
and Public Garden has placed a strong emphasis on using drought tolerant plants, regardless of their geographic origin, the published list being called “The Arboretum All-Stars.” Notably, many of these plants, of non-California origin exhibit traits which this research project has found are also attractive to and functional for foraging native bees. Importantly, this plant palette (i.e., the All-Stars) has been carefully crafted to first prioritize low water use, which is an essential quality facing California’s Central Valley future facing climate change (Houlton and Lund 2018).

Consider that in similar urban butterfly studies, it is estimated that around 40% of native host plants which once existed in the California Central Valley habitat areas no longer exist where they once grew and exotic species now provide essential host plant habitat (Shapiro 2002). Thus, it is inappropriate to attempt to eradicate all non-native plants, as many are currently native bee foraging resources. The non-invasive exotic plants that native bees currently use may provide important habitat resources in the future if native plants cannot survive extreme climate change, while the exotic species may be more resilient.

6.2 CONSERVING POLLINATION FOR RESILIENT LANDSCAPES

Preserving and enhancing pollination ecosystem services are extremely important in landscapes facing great uncertainties with climate change such as California’s drought-stricken landscapes. Ecosystem services are a tool which can be used to help buffer the negative effects of drought, extreme storms, increased or decreased precipitation.

Pollination ecosystem services are infrastructure and essential not only for conservation, nature and biodiversity, but also for much of the food humans depend on (MEA 2003). Between one-third (USDA 2021) and two-thirds (Xerces Society 2011) of the food we eat is the result of insect pollination. Aside from that, the next top priority in California should be water conservation. While pollinator plant lists exist, it is important to explore their success in a real-world setting and examine which ecological aspects could still be improved upon. Ecologically, landscape design can be used to provide and promote bee habitat and connectivity of habitat.

6.3 LANDSCAPE DESIGN IDEAS FOR BEES

The main goals are to create and enhance bee habitat in anthropocentric landscapes. These are summaries of project prompts students were given. It was important to isolate very specific design ideas to attain adequate design results. In this way, students were pushed to think very carefully and creatively about the design problems they were trying to solve.

6.3.1 SHOW AND EDUCATE SITE VISITORS ABOUT SPECIAL BEES (Figures 1).
Showcase an interesting aspect of their life cycle or physical structure (i.e., biological, ecological, morphological). Make learning accessible to a variety of humans across a ‘mixed life’ gradient. This is a potential opportunity for botanic garden display application.

6.3.2 “SEE LIKE A BEE” MICRO-SITE DESIGNS (Figures 3 and 4).
Graphically showing examples of how various bee genera would value aspects of a site and its plantings is another way to increase landscape literacy. For example, perhaps a bee has preferred plantings, but paved areas, skyscrapers and water bodies offer little to no habitat value from a bee’s perspective. Help educate project viewers on how bees look at the landscape.

6.3.3 DESIGNING BEE “BOXES” FOR CAVITY NESTING BEES.
Explore educational, exciting designs in for a botanic garden setting (some something similar, for example a school or community garden sites). Showcase the unique, fascinating, and/or amazing nesting habits.

6.3.4 DESIGN A SEED LIBRARY.
Alone, each seed library has the potential to affect the surrounding habitat value for bees. Extrapolating the network of seed libraries has the potential for improving pollinator habitat in otherwise difficult (or impossible) land cover. In this way, healthy pollinator metapopulations can overlap with human populations for resilient landscapes. With the aid of iNaturalist (iNaturalist 2021) identifications, neighborhood level projects could be completed with nearly all citizen science footwork. This process has already begun by author KC with bee identifications made to the species level by top bee researchers in the field (see beelandscapes 2021; Free Pollinator Seed Library 2021 for updates and current information).
6.3.5 PLAYING WITH CONTRASTING BEES THROUGH DESIGN.
Landscape designs which feature two contrasting bee genera have the potential to demonstrate the variety of local bees. Comparisons could be made between biological (feeding/nesting/travel distance), ecological (only found in certain areas? Very fine of broad niche?), or morphological (unique body feature). The experiential effect on site visitors could be fascinating and memorable.

6.3.6 RETROFITS OF YARDS AND OTHER COMMON LANDSCAPE TYPES.
Many residential and commercial land areas are dated and lacking ecological value. Updating the designs of yester-year represent a smorgasbord of opportunity for retro-fitted design integration. While design “elements” (bee ‘box’, watering area, signage, etc.) show promise for aiding in pollinator design we can do better, be more wholistic. Design to maximize bee habitat in any site would be the best, resilient plan for the future. Building roofs, walls, and land could all be tailored for bees.

6.3.7 CONNECT THE COGNITIVE DISCONNECT, INCREASE LANDSCAPE LITERACY (Figures 1 through 3). Better bee habitat designs don’t necessarily speak for themselves. To the average person, even with the best bee plants possible, the design of, say an empty lot, may look “messy” and be overlooked or even disliked. The best designs help to “tell” about themselves, to help site visitors gain landscape literacy. Sites which are experiential, share information, are memorable and/or interactive are the most desirable designs. When people understand ecology, they will value it. The contrary is also true. Recently, in East Vancouver, Canada, there was a news article titled, “Overgrown grass in an East Vancouver park meant to attract bees is attracting complaints too” (CBC 2021). Projects were marked with signs, but this was not enough. Residents do not understand or value prairie lands and are “…concerned there’s more hidden in the tall, dry grass than just butterflies and bees”. This is what we are facing as designers. This is how little ordinary citizens understand about their local environments. We need to show site visitors about their local environments. We need help the public to become stewards of nature instead of turf grass obsessed visitors, illiterate to the landscape surrounding them.

6.3.8 TACKLING POLLINATOR HABITAT FRAGMENTATION HEAD-ON, DESIGNING BEE LANDSCAPE NETWORKS (Figures 4 and 5). Designing for one garden for pollinators is good, but designing more green space is even better. How does the habitat look at the neighborhood scale? How do the patches of vegetation contribute to the area’s habitat as a whole? How does this vary between bee types?

6.4 STUDY LIMITATIONS
A portion of the student projects in this paper were completed during the Coronavirus pandemic in 2021. Unfortunately, some classes could not be held in-person due to pandemic restrictions. Thus, some lectures and coursework were done online. Students missed out on building their design ideas in-person, which would normally be a component of this type of class. All of these designs could be evaluated further to help augment a design process with iterations of improvement.

This research suggests further urban bee ecology studies could be done to examine the degree to which urban and suburban areas act as habitat for native bees, in all ecological aspects. For example, the levels to which bee predation, parasitism and other ecological and biological processes vary with urban versus wild bees. Another potential future area of study should try to determine which bee population’s genetics are affected by habitat fragmentation. Bee genera should be studied genetically over a landscape scale to help quantify how isolated habitat patches are, but that is beyond the scope of this research project.

7 CONCLUSIONS
This research project emphasizes how bees offer much in ecosystem services (Wojcik et al., 2008; Pawelek et al., 2009; Frankie et al., 2009), no matter if ‘novel’ or ‘wild.’ In the end, conservation of bee’s pollination ecosystem services is key to our own (human) quality of life and should not be an issue taken lightly. Bee habitat design solutions will help to address the importance of focal bee target specificity, gap analysis results and what to do with that knowledge. Once spatial and temporal habitat gaps are determined, strategic plant solutions can be determined. Design alternatives should focus on selecting the best possible plants to maximize floral resource improvement. Stand-alone singular garden designs are well meaning, but not enough on their own, they need to be linked together into a functional network.
Furthermore, protecting bees and their ecosystem services means conserving an entire suite of insects and considering their habitat requirements in the process. This is not an easy feat for landscape designers. Thus, the need for selecting promising focal species that can achieve the ecosystem services which we prefer. Selection of an umbrella species, for conservation of a suite of bees may be a viable option for conservation, as has been done with larger animals (Lambeck 1997). This research discussed this concept, however it should be studied and explored more. Landscape designers have the potential to improve bee habitat in landscapes. However, designers would benefit greatly from using good bee research, which at the time is not easy to learn about and implement quickly. The students in this study did very well when working with accurate and precise instruction. It is exciting to consider how advanced designers could positively amplify the results even further.

The amazing suite of bees found in our local landscapes each have their own perspective on what habitat is suitable or not, close enough, or too far away. This research has shown that some gardens provide bees with excellent source habitat and improvement of the greater urban habitat is necessary to improve resilient bee habitats. Current bee-plant lists have been understudied and hold an important role in regard to how bee conservation should be handled moving into the future. Humans depend greatly on the ecosystem services provided by bees. Pollination is an ecosystem service that is vital to humankind and must be protected. Informed habitat design presents an opportunity to create resilient bee landscapes for bees, humans, ecosystems, and the future of our Earth.

8 ACKNOWLEDGMENTS

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9 REFERENCES


POURED EARTH: SITE SOIL: A POETICS OF TERROIR

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1 ABSTRACT
Landscapes offer climate change solutions – functional carbon sequestration (Zinnert et al., 2021), urban forests (Brack, 2002), and interlocking building and flora systems (American Society of Landscape Architects [ASLA], 2021) to name a few. The production and use of Portland cement and material transportation to sites for landscape design contributes to climate change emissions (Ehrlich, 2020). This paper proposes Fabric Formed Poured Earth (FFPE), transforming site soils into building material without Portland cement, as another way landscapes can mitigate climate change (O’Geen & Harris, 2022; Bui, Morel, Tran, Hans, & Oggero, 2016; Gauzin-Müller & Fuchs, 2020). Using site soil to build structure, whether sculptural or functional, decreases emissions by bringing less material to a site and removing less material from a site.

FFPE uses geotextile fabrics as formwork for earthen infill wall structures, poured from soils tested and augmented to an optimal ratio of aggregates and clay. This project tests FFPE by building a prototype sculptural wall form; sorting site soils by particle sizes; testing traditional Puebloan clay harvesting; modifying site soils for an optimal range of grain sizes of clay, sand, and small rocks; and considering the aesthetic effects of fabric formwork in the landscape. FFPE uses the site itself as a construction material and reforms traditional methods with a workflow more like contemporary concrete construction and the aesthetics of experimental architectures (West, 2008; Gauzin-Müller & Fuchs, 2020).

Building on O’Geen & Harris’ prior tests completed with optimal soil mixes of purchased materials and a previous site soil test in Albuquerque, NM (O’Geen & Harris 2022), this project separates site soil by particle size sieve and then uses traditional Puebloan clay harvesting techniques to ascertain the proportion of clay to aggregates in the native soil. To create a structurally sound and durable mix, the test mix is matched to optimal mix by adding clay or aggregates to create optimal percentages. The poured wall sculpture is paired with an excavation void sealed with ⅜” acrylic. This paper develops an aesthetics of climate change resilience and response through examining a site and building a prototype FFPE intervention at a site at the Open Space Visitor’s Center in Albuquerque. Translating the ground into upright forms reveals the site in built form, a poetics of terroir. Terroir is multiple elements of a site, not just the soil or the climate or the vegetation or the microbial life or the social context of a building method. FFPE seeks to unite these into a physical form.

1.1 Keywords
Poured earth, Site soil, Fabric formwork, Climate change, Terroir
2 BACKGROUND:

Earthen construction reifies the site itself. It articulates places where soils are good for such construction, containing the right proportions of clay, sand, and aggregates (earthenarchitecture.org). The conditions of the site determine opportunities for construction. In sculptural terms, earthen construction is subtractive, or re-forming present material, and conventional construction is additive, or bringing material to a site. Graeber and Wengrow in “The Dawn of Everything” describe the regular rituals of rebuilding and building of a Mesopotamian city as “corvée” (tithe) where “Even the most powerful Mesopotamian rulers… had to heave a basket of clay to the construction site. The Sumerian word for corvée (dubsig) refers to this basket of earth…. “ (Graeber, 2020) In Graeber and Wengrow’s writing of urban history, political systems are choices, and those choices often are as often made in the direction of personal freedom and determination as they are in hierarchy or slavery. Arguably, the use of a ubiquitous site-based material would allow and nurture self-determination by being freely available. Mud brick technology (Mesopotamia, Moorish buildings, contemporary adobe), rammed earth technology (China, Northern Europe, and in contemporary times across the world), cob, poured or slumped earth (North America, North Africa, Northern Europe), all develop a relationship with site through engaging with the particularities of soil particles. Investigating site soils reveals that not all soils create an optimal mix. Soils high in organic matter, silt, or aggregate, that lack a significant proportion of clay binder, require amendment with clay.

Thus, earthen construction does not work everywhere as a subtractive process or as purely site based. In many earth types, the addition of clay or aggregates is necessary to balance a soil and resist tendencies to cracking and shrinkage to create an optimal mix. “New Deal homes designed by Thomas Hibben in Mt. Olive, Alabama…were constructed with dirt, taken from the site, which was mixed with red-rock aggregate and tamped between wooden forms. The homes were built as part of a New Deal Resettlement Administration homestead community” (earthankitecture.org). Built in 1930, these rammed earth homes from site materials are still being used today. Whether indigenous people would have imported materials to add to earthen construction, or simply found sites where the soil particle sizes and distribution matched their needs, needs further study and is not in the scope of this project.

3 INTRODUCTION: Landscape Materials as a Climate Solution

Landscapes commonly are opportunities for biochemical carbon sequestration – plant and microbial actions that move carbon out of the atmosphere and into soils or plant material. Landscapes can also provide the materials for their own transformation. On site material harvesting happens in native plant restoration, where projects save seeds to start plants for replanting after the disturbances of construction, or in recycling and repurposing paving materials, as happened with DIRT studio’s design for Urban Outfitters Headquarters in Philadelphia. This paper proposes Fabric Formed Poured Earth (FFPE), transforming site soils into building material without Portland cement, as another way landscapes can mitigate climate change. While poured earth does not provide structure for retaining walls or load bearing walls without post and beam support, it is an efficient way to use excavation material as infill and provides a strong connection to place, moving the horizontal site to the vertical spatial division or wall. This project seeks to investigate precedents for one specific earthen building method - poured earth paired with fabric formwork, the latter generally used for concrete forms. Fabric formwork has its own beneficial properties for reducing climate carbon impacts. It is light and therefore requires less embodied energy to move to a site. Building with fabric formwork does involve form ties, like conventional concrete formwork, but the fabric’s flexible nature removes the need for a Portland cement stabilizer in the poured earth mixture, thus removing the high embodied energy input common to concrete mixtures.

4 RESEARCH OBJECTIVES

There are two research objectives of this paper. The first is to investigate site relationships as terroir or the composition of building and composition of humans in the Vitruvian, de Serresian, and Graeber/Wengrow sense. The project explores the poetics of the site through the praxis of excavating, sorting and reconstituting site soil into a building material, and thus experiencing a site in its complexity. The second is to show that making infill material for sculptural forms in the landscape from site materials with
fabric formwork is a practical answer to the drying and building constraints of substituting materials without Portland cement stabilizer for Portland cement stabilized materials. The intention is to articulate the building process of a material that optimizes site materials, not relying on conventionally mass-produced materials that are resource- and ozone-depleting.

5   METHODS: Mixed

5.1 Research and Literature Review: Concrete, Poured Earth, and Terroir
This research is inspired by Mark West’s work in fabric-formed cast-in-place concrete at the Center for Architectural and Structural Technology [CAST], and by the work of Alan Chandler and Remo Pedreschi from The University of East London and The University of Edinburgh respectively. A careful look at the motivations, process, and results of these projects, as well as our own physical testing as discussed in the next section, was undertaken. However, concrete depends on the binding properties of Portland cement, which significantly contributes to greenhouse gas emissions. In considering earthen construction, we first looked at classic adobe and rammed earth, but the forming methodology seemed too rigid and heavy. We then reviewed literature of experiments with poured earth, especially Cycle Terre and later CRATerre in France, which have sponsored projects with earth similar to the process surrounding concrete construction. This work seemed to answer our intentions and major concerns in a dynamic, beautiful way. Further, our site research and related theoretical readings pushed us toward a poetics of site and form. By working directly with the site as material, a larger connection to the immediate landscape and place is made. The earthen construction process continuously reveals the unseen layers and history of the site. Sifting, sorting, soaking, and weighing soils create a method of engagement and experience of site, of terroir.

Terroir as a European concept developed over a period of roughly 2000 years, perhaps influenced by contact with other cultures, from North Africa to North America. Vitruvius in 27 BC, later championed by Renaissance thinkers, claimed buildings should be designed for the climate, and that humans are designed by the climate, positing differences in amount of blood, intelligence, stature, and hair color among humans based on the angle of the sun in mid-summer in any area. (Vitruvius, 1954 trans.) In so doing, he also delineated the sun angles and created a passive solar proposal. In 1600, Olivier de Serres, in writing about the possibility of introducing commercial silk production in France, advocated for the planting of mulberry trees to support the silkworm. In his description, he suggests that the soil is most important to influence the quality of the leaf of the mulberry and thus the quality of the silk. “…For the quantity of leaf, it is to be desired that the trees be planted in good soils, but not for the quality; because never comes out the leaf so fruitful of fat, as of meager terroir; (having this in common with wines, the most exquisite of which grow in light soil) since this terroir, there, brings back the coarse and bland leaf, and this one, delicate and savory “ (de Serres, 1600 trans. authors). The idea of terroir that de Serres clarifies here is that the content of the soil has a direct relationship to the character of the leaf, and thus its ability to nurture, in this case, silkworms.

As Graber and Wengrow point out, by 1600, European treatises would also have been influenced by the then-common interchange of ideas between indigenous thinkers and Europeans. Graeber and Wengrow are speaking directly of northern European contact with nations of the Great Lakes and Hudson River Valley region, but European contact was also going on in what is now the Southwest United States. While European contact was mostly bloody and destructive, it is possible that Acoma Sky City and Taos Pueblo architecture would have offered articulation of soil-based construction methods to Spanish mercenaries, who would have been aware of earthen construction from their European roots. Taos and Acoma display long-standing Puebloan use of site-based earth and stone as building material in pueblo settlements. Settled before Spanish colonial conquest, Taos Pueblo shows several techniques of earthen building – brick and a more cob-like tradition of layers – both covered with a clay-based plaster. The renewal of this plaster on these buildings requires a connection to seasonality and place.

5.2 Built, Physical Research: Site Soil and Non-Site Soil
Non-Site Soil: The authors experimented with optimal mix proportions of clay and aggregate to determine how best to use the fabric formwork in tandem with poured earth to create a self-supporting material without cracks. The scale was shifted from one cubic foot to a partial full-scale mockup at 6’ x 4’ x 9” thick. These experiments were undertaken in New Mexico and Detroit over a year’s time.
Site Soil: The authors then created an installation, excavating one cubic foot of material, dividing it by particle size into its constituent parts, and then augmenting the mix to be able to pour an optimal mix derived from the site material into a fabric formwork. In this paper the authors detail our experiments using sieves and traditional clay harvesting methods from the area to identify site-harvested clay particles.

6 Poured Earth

Matthieu Fuchs – “One need not think of poured earth as a standardized product, but as the valuing of a local resource” (Gauzin-Müller & Fuchs, 2020, pg. 50 [trans. authors.]).

6.1 Contemporary Earthen Construction

Earthen construction is being pursued in many countries due to growing concerns about the impact of the building industry. Earthen construction avoids the embodied energy of concrete and its contribution to greenhouse gasses, allows the re-use of construction debris, and provides an opportunity to use materials local to a site, for instance the earth that needs to be excavated to create the foundations (American Society of Testing and Materials [ASTM], 2016). Current practices and codes in earth construction exist in New Mexico, New Zealand, Australia, Germany, France, and Spain (Pacheco-Torgal & Jalali, 2012). In France, CRATerre-EAG, founded in 1979, and supported by the French government since 1986, has pushed research in earth-based building techniques via conferences, workshops and supporting educational programs in Grenoble, France. The program has produced several architects and studios experimenting with all forms of earthen architecture. A professional organization has formed in poured earth building, “amaco,” that held a conference “Construire en terre coulée” in 2017 (amaco, 2017).

Architects Matthieu Fuchs, studios Mil Leux, atelierphilippeMadec and Nicolas Miessner published their recent projects in poured earth developed from the experiments at CRATerre and supported by the French Government’s recent project Cycle Terre (Gauzin-Müller & Fuchs, 2020). Cycle Terre incentivizes the use of raw earth as a building material by providing support “to integrate 0.025m³ (0.88 ft³) of materials into their projects from now on in raw earth mainly from (construction excavation) and without adding binders, with the exception of biobased stabilizers, per m² (10.76 ft²) of floor space” (Cycle Terre, 2021). Cycle Terre supports research in earthen building and creates building products such as compressed earth block and poured earth infill panels. CRATerre’s projects employ multiple products which minimize, but do not eliminate, Portland cement or polymers as additives. Cmaterre is a good example: “This earth-concrete is basically composed from natural soil (87%) that can be amended with recycled concrete aggregates RCA (Kanema, Eid, & Taibi, 2016), and treated with 9% of cement and/or 3% of lime...” (Eid, 2018, pg. 1523). This figure of 9% cement is below the range (12-15%) of the composition of standard concrete -- “In standard concrete, with a density of approximately 2300 kg/m³ (145 lbs/ft³), these different ingredients are generally divided into 45% sands, 30% aggregates, 12 to 15% cement and 10% water” (Gauzin-Müller & Fuchs, 2020, p. 49). CRATerre is pursuing commercial use of poured earth, as it provides a process that is most like a normative construction process with concrete pours, and thus can be used relatively economically.

6.2 Contemporary Earthen Material Experiments

In narrowing down contemporary work on poured earth, the constituent parts of an unstabilized mix offers the most options for adopting site soils and provides a starting point for minimal stabilizer additions to preserve the low embodied energy of poured earth. Jedidiah Williamson’s master’s thesis for the University of Colorado - Denver (Williamson, 2012) provided a starting point for our material research because it tested three poured earth mixes which were unstabilized - without a Portland cement binder. Williamson thoroughly studied these three sample mixes, changing the percentages of each mix slightly to test their durability, shrinkage, and strength; the project ended with a series of brick tests. This inspired the authors to prototype poured earth for walls, using responsive formwork as a way of working with unstabilized poured earth.

In these formulations, clay is part of the natural soil, and forms a cement substitute in poured earth formulas. The French research above seeks to address the functional issues of cracking, which is created by the amount of water needed to activate the binding properties of clay (like cement) and to create a pourable slurry (Minke, 2006). “Since this technique is fairly recent, it presents several challenges to understand, among which can be cited: (i) clay-binders physico-chemical interactions (short-term and pozzolanic reactions), (ii) cracking due to desiccation, as in order to obtain a good workability (slump S3),
the water content is quite high (25%) so cracks appear during drying..." (Eid, 2018, pg. 1523). Cracking is most often addressed by adding some proportion of Portland cement or polymers in rigid formwork.

Kanema, Eid and Taibi’s work on shrinkage of raw earth articulates that “the magnitude of shrinkage depends on the amount of clay present in the soil, and that the drying process is related to the maximum radius of the pores filled with water. The soil cracks when it attains its maximum tensile stress” (Kanema, Eid, & Taibi, 2016, p. 379). This study adds super plasticizers and recycled cement aggregates to the poured earth mixture, in a rigid formwork.

The Médiathèque et maison des réfugiés project, by atelierphilippepmadec and Nicolas Miessner (Gauzin-Müller & Fuchs, 2020), supported by Cycle Terre, uses poured earth without cement or polymer additives, with cut straw as a binder, in a precast panel with an embedded formwork. These precast panels are non-structural as they were placed into frames. This is the closest precedent to our work, as it uses an unstabilized mix, a non-structural panel, and a formwork that accommodates the shrinkage of the material.

6.3 Material Tests in Rectangular Prism Form

Our material tests began with tests to determine mixes, pourability, and cracking of poured earth. Williamson’s three basic material mixes were replicated: A (78% aggregate, 8% clay, 13% water by weight), B (54% aggregate, 30% clay, and 12% water by weight) and C (24% aggregate, 55% clay, 11% water by weight). The first forms were 1’ x 1’ x 6” thick rectangular prisms made of plywood (see Figure 1A). The A and B mixes were pourable, relatively speaking. The C mix was rigid once the clay was hydrated and developed air pockets and voids as it was packed into the mold. It was determined that experiments would continue with mixes between A and B, as the A mix was easily friable on the surface, due to the greater amount of exposed aggregate and the B mix was stiffer than the pourable mix sought for the larger mockup. These initial explorations were all done with the illite clay: Hawthorne fire clay from pottery-style clay (see Table 1).

<table>
<thead>
<tr>
<th>Mix Name</th>
<th>Sand (LBS)</th>
<th>D.G. (LBS)</th>
<th>Total Agg. (LBS)</th>
<th>Clays (%)</th>
<th>H2O (LBS %)</th>
<th>Total (LBS)</th>
<th>Pourability</th>
<th>Mix Method</th>
<th>Clay Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>-</td>
<td>50.0</td>
<td>78.2%</td>
<td>5.5</td>
<td>8.4</td>
<td>63.9</td>
<td>Good</td>
<td>Hand</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>50.0</td>
<td>54.4%</td>
<td>26.7</td>
<td>15.2</td>
<td>91.9</td>
<td>Thick</td>
<td>Fire Clay</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>-</td>
<td>11.0</td>
<td>24.2%</td>
<td>25.0</td>
<td>9.5</td>
<td>45.5</td>
<td>Thick</td>
<td>Fire Clay</td>
</tr>
<tr>
<td>A1</td>
<td>-</td>
<td>-</td>
<td>50.0</td>
<td>76.3%</td>
<td>5.5</td>
<td>10.0</td>
<td>65.5</td>
<td>Good</td>
<td>Ball Clay</td>
</tr>
<tr>
<td>A2</td>
<td>-</td>
<td>-</td>
<td>50.0</td>
<td>73.5%</td>
<td>6.0</td>
<td>12.0</td>
<td>68.0</td>
<td>Good</td>
<td>Ball Clay</td>
</tr>
<tr>
<td>A3</td>
<td>-</td>
<td>-</td>
<td>40.0</td>
<td>67.6%</td>
<td>8.0</td>
<td>15.5</td>
<td>59.2</td>
<td>Wet</td>
<td>Fire / Ball</td>
</tr>
<tr>
<td>B1</td>
<td>-</td>
<td>-</td>
<td>40.0</td>
<td>48.2%</td>
<td>21.0</td>
<td>22.0</td>
<td>83.0</td>
<td>Slimy</td>
<td>Hand / Mech. Stoneware</td>
</tr>
<tr>
<td>B2</td>
<td>-</td>
<td>-</td>
<td>40.0</td>
<td>63.3%</td>
<td>12.0</td>
<td>19.0</td>
<td>63.2</td>
<td>Good</td>
<td>Hand / Mech. Fire/2lbs Stone.</td>
</tr>
<tr>
<td>B3</td>
<td>-</td>
<td>-</td>
<td>25.7</td>
<td>33.9%</td>
<td>27.5</td>
<td>22.5</td>
<td>75.7</td>
<td>Thick</td>
<td>Hand / Mech. Stoneware</td>
</tr>
<tr>
<td>B4</td>
<td>-</td>
<td>-</td>
<td>17.1</td>
<td>39.7%</td>
<td>6.5</td>
<td>15.1</td>
<td>45.2</td>
<td>Stiff</td>
<td>Hand / Mech. Bentonite</td>
</tr>
<tr>
<td>B5</td>
<td>7.0</td>
<td>17.1</td>
<td>24.1</td>
<td>45.4%</td>
<td>6.5</td>
<td>12.2</td>
<td>42.4</td>
<td>Stiff</td>
<td>Hand / Mech. Bentonite</td>
</tr>
<tr>
<td>B6</td>
<td>8.4</td>
<td>18.0</td>
<td>26.4</td>
<td>50.9%</td>
<td>7.2</td>
<td>13.9</td>
<td>35.2</td>
<td>Stiff</td>
<td>Hand / Mech. Bentonite</td>
</tr>
<tr>
<td>B7</td>
<td>14.4</td>
<td>18.0</td>
<td>32.4</td>
<td>50.3%</td>
<td>4.2</td>
<td>6.5</td>
<td>43.2</td>
<td>Stiff</td>
<td>Hand / Mech. Bentonite</td>
</tr>
<tr>
<td>B8</td>
<td>8.0</td>
<td>15.0</td>
<td>23.0</td>
<td>46.9%</td>
<td>6.0</td>
<td>12.2</td>
<td>40.8</td>
<td>Stiff</td>
<td>Hand / Mech. Bentonite</td>
</tr>
<tr>
<td>B9</td>
<td>8.0</td>
<td>15.0</td>
<td>23.0</td>
<td>46.9%</td>
<td>6.0</td>
<td>12.2</td>
<td>40.8</td>
<td>Stiff</td>
<td>Hand / Mech. Fire / Ben.</td>
</tr>
<tr>
<td>B10</td>
<td>15.0</td>
<td>8.0</td>
<td>23.0</td>
<td>50.0%</td>
<td>3.0</td>
<td>6.5</td>
<td>43.5</td>
<td>Stiff</td>
<td>Hand / Mech. Bentonite</td>
</tr>
<tr>
<td>B11</td>
<td>8.4</td>
<td>18.0</td>
<td>26.4</td>
<td>50.4%</td>
<td>6.0</td>
<td>11.5</td>
<td>36.2</td>
<td>Stiff</td>
<td>Hand / Mech. Bentonite</td>
</tr>
</tbody>
</table>

- CLAY - - 40.0 55.0 16.0 22.0 16.0 22.0 72.0 Decent Mechanics Fire Clay
+ CLAY - - 35.0 52.0 20.0 30.0 12.0 18.0 67.0 Wet Mechanics Fire Clay
++CLAY - - 20.0 48.0 14.0 33.0 8.0 19.0 42.0 Good Mechanics Fire Clay

6.4 Rectangular Prism Forms with One Fabric Side

The following tests used an aggregate/clay/water mix: 48% aggregate, 25% clay, 26% water with a 4% shrinkage rate. A wooden box form was created with one wall made of stretched fabric that allowed some give but had form ties to control the fabric deformation (see Figure 1B). Several configurations were tested, including one form-tie in the center of a 1’ x 1’ x 6” thick box, and a 3” on center triangle layout of three form-ties.
In these tests, it was discovered that the rigid nature of the back of the box interfered with the movement of the material with the form-tie (see Figure 1C). These movements seemed to have two sources, settling and shrinkage. The settling was due to gravity and the pressure of the material’s own weight, though the latter was not obvious until we scaled the tests up. The shrinkage was mostly expressed through observation of the finished block in comparison to the scale of the wet block. The fabric allowed us to see the shrinkage, since the fabric, which had been distended by the wet material, would stand proud of it with a void behind as the material dried. The tests uniformly cracked at the form-ties. From these observations came the idea to create a fully autonomous fabric form that would be able to move with the settling and shrinking of the clay.

Optimal pouring mixes, with few voids and air bubbles, had varying amounts of shrinkage. A larger amount of shrinkage was accepted (under 8%) than originally considered optimal, hoping that our flexible fabric formwork would allow for it or perhaps even mitigate it. For the partial full scale, we planned to pour concrete posts after the poured earth walls had been poured to make up for the shrinkage of the earth. The tests suggested that this process required an illite or granitic clay, a mix of roughly 52% aggregate, 30% clay and 18% water, and that the resulting poured earth form would shrink under 3% (see Table 1).

![Figure 1. Compiled Poured Earth Testing Images (Source: Authors)](image-url)

6.5 Test blocks

When the mix tests were close to optimal, we began casting test blocks measuring 14” x 5” x 4” tall. Blocks made of our “+ clay” mix were taken to a university laboratory for compression (see Figure 1D) and modulus of rupture tests. The testing was carried out following the standards of the 2015 New Mexico Earthen Materials Building Code. The blocks supported 464.4 pounds of force in compression and 51.6 pounds in the modulus of rupture test.

7 FABRIC FORMWORK

7.1 Contemporary Fabric Formwork

There are precedents for using fabric formwork, but all for casting concrete. Most recently are the publications coming from the previously mentioned academic research of Mark West (The Fabric Formwork Book) and the collaboration of Alan Chandler and Remo Pedreschi (Fabric Formwork). Chandler and Pedreschi write “the improbability of taming, restraining and accurately controlling a mass of liquid concrete with a textile membrane becomes a technique with multiple advantages, acting as an effective critique of conventional methods of building, working with natural forces rather than expending energy and material suppressing those forces” (Chandler & Pedreschi, 2007, pg. 2).

Japanese architect Kenzo Unno has created two novel systems for the casting of concrete with fabric sheets. The first is the “quilt-point” method. Two sheets of fabric are separated on an even grid of regularly spaced form ties. The form ties employ oversized washers to pinch the fabric to the spacers and are supported by the internal reinforcing both horizontally and vertically. An external scaffolding style tubular structure is erected to provide lateral support. After the concrete is cast between the two sheets of fabric,
the hydrostatic pressure activates a regular series of gently curving surfaces, composing a pleasing pattern on the resulting surface (West, 2017). Parallel to the "quilt-point", Unno developed the "frame-restraint" method which "...is more or less equivalent to constructing a conventional braced plywood wall mold but replacing the plywood sheets with fabric" (West, 2017, p. 162). Sticks of dimensional lumber are pre-cut and assembled much like wall framing. Fabric is laid over the top of the frame and attached, with the fabric stretched in the vertical direction while a little slack is left horizontally. Form-ties connect the two frames together at a regular grid. The result is a series of vertical curves that are held back with straight lines.

Nader Khalili’s work with SuperAdobe brings together fabric forms and earthen construction. Khalili’s system kept in mind principles of earth construction but simplified it to make it more accessible. Inspired by traditional earth dwellings in Iran, it is intended for common people to self-build. The system employs a synthetic degradable sandbag that comes in a roll and can be cut to length. Moistened earth is compacted into the bags which are coiled on top of each other. Barbed wire is laid between each layer to connect the two units into one. The coils are usually circular in plan and move in as they approach the top of the structure, like a dome. The interior and exterior surface is then covered with plaster (California Institute of Earth Architecture [CalEarth], 2021). This fabric-formed earth is hand packed and restricted to circular forms.

In addition to precedent studies, this paper benefits from the physical experience of the installation (called Re-Forum) of site-made fabric-formed concrete panels by an author of this document (see Figure 2A). A sixty-foot piece of woven geotextile was folded in half with the two sides connected by one inch form-ties. The top opening was formed by two pieces of rebar into sewn slots. The construct was carried to and tensioned into the gallery space, using the surfaces of the room to support the formwork. Three tons of concrete was cast into the formwork which was then dis-assembled and reassembled to hold the panels in a grid, still braced off the walls, revealing the efficiency and lightness of the fabric formed system.

![Figure 2. Compiled Fabric Formwork Testing Images (Source: Authors)](image)

7.2 Fully Hanging Tests - Three

1’ x 1’ x 4” thick blocks were created in fully fabric forms, using a wooden base to attach the fabric (see Figure 2B). We experimented with methods for holding the top edge of the fabric. One method used several points of tension along the top, one used a rigid bar at the top, and one used no control. We also used different form-tie patterns and styles. Even at the most controlled end of the spectrum, however, we had movement in the material which created more distortion at the base of the pour and less at the top. The rigid bar allowed us to predict where the top edge would remain, though material shrank down from the top edges. With the rigid bar, it did so in a regular manner.

7.3 Partial Full-Scale Wall

The partial full-scale experiment was built in a sculpture garden in Detroit, Michigan (see Figure 2C). The garden is designed to allow multiple planar interventions in a space at the scale of a residential lot. PEC #1 is a partial full-scale at 50’x 77” total, with a structural concrete frame keyed around the poured earth. The poured earth portion is 36” x 70” and has a roughly 12” diameter elongated elliptic void set at 48”
high on-center. The form-ties are on a diagonal grid at 4” on center, but the pressure and settling differentials cause there to be 1” more depth to the bulges in the bottom than in the top 24” of the wall.

For this experiment, we began by laying out the rebar for the final concrete frame around the poured earth wall on a concrete footing that is about 10’ long, 1’ wide and 4’ deep. We sewed and installed form-ties in a fabric form, which measured 4’ x 6’ x 7” thick. We also mechanically mixed 29 five-gallon buckets of aggregate, clay, and water to the specifications of +Clay from Table 1. The total volume was 140 gallons or 18 cubic feet, about 2 cubic feet more than the form required.

We attached an 8’ x 6’ wooden frame (like Unno’s) of reused two-by-fours to the footing to hang the fabric form. The frame allowed for room to pour the earthen mix into the top of the fabric. The form was filled by hand, bringing the buckets to the top of the formwork, and scooping the material into the form. We predict a more automated format in future tests, perhaps using a front loader to load material into the formwork. Working in the Michigan climate, we also employed dehumidifiers and heaters to approximate the humidity and temperature of the arid southwest, where the material is perhaps best suited.

This experimental mockup marked the culmination of previous studies relative to the combined optimization of poured earth mix proportions (as outlined in sections 6.3-6.5 as well as Table 1 above) and fabric formwork (as outlined in sections 7.1 and 7.2 above). Although the construct turned out well, especially considering the steep learning curve of the material science (see Figure 2D), none of the material used in the poured earth mix came from the site. At the time, unfortunately, no site materials were easily available. However, significant knowledge was gained about all other portions of the assembly and logistics which proved to be helpful in later studies. Therefore, later studies can use the fabric and assembly and logistical methods as the control while site soil can be variable.

8 SOILS FROM THE IMMEDIATE SITE

8.1 Contemporary Site-Based Soil Mixes - Mars and Earth

Along with global research on using earthen construction methods, CraTerre’s CycleTerre project, (https://www.cycle-terre.eu/en/) is a fabrication space for compressed earth block and other supports for using soils from the Greater City of Paris to fulfill a goal to use local soils in new construction to mitigate climate change causing emissions. This work points to the terrestrial possibilities of mandating the use of excavated site soils and to the utility of being able to build with material from the site.

One case where material from the site will be mandated is in off earth construction being proposed on Mars due to the expense of transporting material to Mars. In late 2017, the National Aeronautics and Space Administration (NASA), announced the 3-D Printed Habitat Challenge as part of their larger Centennial Challenge program. The goal of the Centennial Challenge was “...to generate revolutionary and innovative solutions to problems of interest to NASA and the nation” (NASA & Bradley University, 2017, pg. 3). More importantly, a focus “...on use of space-based materials and recyclables in material formations used for construction” (NASA & Bradley University, 2017, pg. 3) was one of the key stipulations for the 3-D Printed Habitat Challenge. The goal was to be able to unleash autonomous making machines to 3-D print habitats on Mars from the material of the site itself. The Mars exploration limitations offers a good metaphor for the need for technologies like FFPE to treat the Earth as if it were Mars and respect sites accordingly.

As the construction industry moves forward with alternatives to the current conventional delivery methods, site must be considered. The NASA Centennial Challenge asks how to use the site as a material for making the structure itself. By thinking through the extreme scenario of building something on another planet, we can start to apply these solutions to projects here on earth. This method could limit the embodied carbon accrued in buildings by avoiding the use of Portland cement as a binding agent, beginning to address global warming. By thinking about optimizing what is available on site, the costly effects of extraction, refinement, optimization, and transportation could be eliminated.

8.2 Site Soil from the Open Space Visitor’s Center in Albuquerque, NM

The Open Space Visitor’s Center was established on the site of the Roberson Ranch, named for a developer who worked on the west side of the Rio Grande in Albuquerque. The land was sold to the city as part of an area where archeological finds abound, as many peoples have used this area for farming, hunting, and building homes over thousands of years. The larger ranch site is an archeological site, thus digging is limited to already disturbed areas. This site has an agricultural history spanning several centuries and many
cultures. Puebloan cultures used the Rio Grande Rift Valley extensively. Spanish colonialists removed the Puebloans, confining them to land grants now named as Pueblos and settled the rich riparian habitats. Following that, the United States wrested control of the area from the newly minted Mexican Republic. The land itself remains agricultural despite the encroachment of subdivisions, malls, and roads. The Open Space Visitor’s center preserves the long drive into a compound of buildings and even continues the tradition of kitchen garden farming with a permaculture garden on site (Funk & Schmaeder, 2021).

Figure 3. Soil Survey for Open Space Visitor’s Center (Source: USDA & NCRS) and Site Soil Extraction / Sifting Process (Source: Authors).

The visitor’s center site is on Glendale Loam and Brazito silty, clay loam area at the center of the survey in Figure 3A above. The slope characteristic of the western side of the river is clear to see in the pattern of riparian deposits on the eastern side of the image and rocky soils on the western.

Through experimentation, the authors have discovered that granitic clays crack less and produce more stability than bentonite clays, which are derived from volcanic ashes and tufas. This site is a meeting site of volcanic flow on the west mesa surface, and granitic uplift in the rift valley. Clay types may vary in small radii.

8.3 Site Specific Installation

This site at the Open Space Visitor’s Center adjoins the stormwater collection pond where water is stored to provide a riparian habitat, like the pre-engineered state of the Rio Grande. Willows, tamarisk, cottonwood, and other riparian vegetation flourish at the edges, but the pond itself is scraped to provide quantifiable water storage. The site was chosen because of its proximity to other installations, previously completed through a competition run by ArtPark21 in 2018, and due to its applicability as a testing site for soil composition, being designated as a silty clay loam.

The “PEC 3” installation was accomplished by excavating an 18” x 18” x 6” thick void in the ground. The excavated material was piled onto a tarp (Figure 3B) and then field sieves used to separate the pile into its constituent parts (see Table 2 and Figure 4C). The sieves produce a range of particle size from Agg. > .2”, Sand .05-.2”, Silt .002-.05”, Clay <.002. Those piles were weighed and classified by size. One pottery
shard, roughly ¼” x ¼” x ⅛” thick was discovered in the sifting process, speaking of layered ancestral indigenous occupations of the soils of the Rio Grande Valley.

**Table 2. Proportions of components of found site-soil.**

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Sifting</th>
<th>Soaked Sifting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate 4000 Microns+</td>
<td>19 lbs 8 oz</td>
<td>Aggregate 5 oz</td>
</tr>
<tr>
<td>Sand 500 - 4000 Microns+</td>
<td>27 lbs 9 oz</td>
<td>Sand 40 lbs</td>
</tr>
<tr>
<td>Silt 63 - 500 Microns</td>
<td>7 lbs 11 oz</td>
<td>Silt 12 lbs 5 oz</td>
</tr>
<tr>
<td>Clay &lt; 63 Microns</td>
<td>6.3 oz</td>
<td>Clay 2 lbs 3 oz</td>
</tr>
<tr>
<td>Organic Materials</td>
<td>&lt; 2 oz</td>
<td>Organic Materials 6-8 oz</td>
</tr>
</tbody>
</table>

As it seemed likely that some of the particle sizes classified as aggregate were clay material adhering to some larger size object, the authors decided to pursue a traditional Pueblo pottery method of gathering clay to separate clay from other materials, as described by Clarence Cruz, Pueblo potter and Assistant Professor at The University of New Mexico. The materials were soaked for 24 hours and allowed to pass through a fine cloth sieve in a traditional clay harvesting manner to separate silt from clay (see Figure 4A). Each pile of sieved particle sizes was soaked separately and then poured through fine cloth. The fabric created a bowl-shaped form that filled with the materials that did not filter through. In most cases, those materials also separated into a fine layer of clay on the top of the sandy silty materials. As they did not filter through, the forms dried in place. Each of those forms held its own texture, due to the different particle sizes of sands and silts. Figures 4B and C show the top and bottom of one of those forms. The clay at the top shows small organic pieces that floated to the top of the material as it was in liquid form and the inherent shrinking and cracking in the clay. The fabric print on the bottom of the form speaks of the fabric formwork’s surface texture. This process required several days for each hydrated form to dry completely. Figure 4D shows the forms in final dry form on another tarp.

**Figure 4. Site Soil Soaking and Drying Process (Source: Authors).**

The material was heavy in organic matter and in silts, as befits a river deposited soil. Much more clay was harvested from the soil by soaking it. The results from initial sieving and from the soaking process are shown in Table 2. The clay was harvested from below the fine cloth and on top of the dried forms that did not drip through the cloth. The secondary processing resulted in roughly five times as much clay from the material in contrast to the original sieving process.

To create an optimal mix, once the site soil proportions were defined, off-site clay was added (see Table 3 below) to create a mix of 30% clay (see Table 1).
8.4 **Fabric Formwork Morphology**

A woven geo-textile fabric was sewn with a panel of 20" x 18" tall on the back side and 15" x 18" tall on the front side. The side panels were kept at 5" continuously and the tubing that maintains a rigid edge at the top of the fabric form was bent to a radius that allowed for a roughly 18" center. The formwork allowed the project to experiment with a curve in the final poured piece. All seams were sewn three times with a roughly 3/16" zigzag stitch and poly thread. Form ties made of ⅜" PEX tubing with 1/4" threaded rod inserts at 5" on center were laid out in a grid, with one center tie and four diagonally symmetrical ties. The form was hung from bungee cords supported by a wood and T-post structure, which was simple to erect and rigid enough for the purpose. The form was attached to the bottom piece of ⅜" acrylic with tapped holes and ¼"-20 stainless machine screws. The wooden batten holding the fabric flush to the acrylic surface was cushioned with a ⅜" neoprene layer, to prevent the material from leaking. The flexible suspension allowed the fabric to settle with the poured earth.

As the poured material dried, it shrank. The fabric and the elastic cords allowed this movement without the form ties pulling at the material and causing cracking. After two weeks of drying, the finished mass of the pour sat inside the fabric bulges and matched surfaces at the form ties (Figure 5).

9 **RESULTS**

The Open Space Visitor’s Center site clarifies key issues with the use of site soil in FFPE. The composition of riparian soils, while including clays, are quite silty in nature. The soil needs added clay to arrive at an optimal mixture. The site also produces substantial organic matter which must be excluded from the soil mix. Organic materials degenerate in anaerobic conditions, like that of soaking clay materials for building with poured earth.

Fabric formwork continues to provide a solid and non-cracking result when soil is amended with added clay to optimal mix and organic matter is minimized. The slight arc in the formwork resulted in a pleasing experiment with rigid, but non-orthogonal forms, a future direction of interest to take advantage of the flexibility of fabric formwork.

This project affirms that fabric formwork can move from Portland cement stabilized material (concrete) to non-stabilized earthen material (poured earth). Building with site materials reaffirms the builder’s connection with the site. The analysis of soils and ability to read the histories of agriculture and flooding in the soil record through excavation, allows for a time-based experience of site. Soil produces a palimpsest, which this process reframes from horizontal layers into vertical.
Soaking and sifting were both processes that allowed hours and days of engagement with site soils. During this time, migrating cranes, roadrunners, visitors to the Open Space, and Open Space employees engaged with the authors. The sifting produced a rough, but inaccurate measure of particle sizes, despite being an ASTM standard set of equipment and protocols. The soaking is similar to the ASTM hygrometer test, in using water to separate particle sizes. The process of soaking, sieving through cloth, and waiting for the particles to drip through the cloth took several weeks and resulted in a number of forms showing the sandy silt and the layers of finer clay materials, with organic matter floating on top. These materials were then broken to lift the clay off the surface, resulting in almost four times the amount of clay that leached through the cloth. The literal composition of the soil became tactile and available to the touch and to the eye. The richness of the organic matter, the granular structure of the sand, the fine dust of the silt and the even finer silken texture of the clay are all revealed in an experience of place, of terroir in the most literal sense. That terroir is compounded in the history revealed in the pottery shard, in the adjacent gardens and house, and in the patterns of sun, shade, and animal and bird life surrounding, not to mention human users of the site.

This site was not optimal for clay content in the FFPE mix. Future sites would be chosen for higher clay content and lower organic matter and silts. This site, however, did show long term occupation and likely use of earthen building methods either in pre-conquest occupation or in the uses of Spanish housing. Along the Rio Grande on the West side, construction is frequently halted for archeological excavation of sites that are then reburied, if they are indigenous, to protect the memories and history of those sites. Excavation is only done with the permission of tribal members and finds are generally not shared with the public. This is terroir with complex stories that are not always to be told.

10 CONCLUSIONS

Ultimately, the experiments that have been described in this paper support the original objective of using the material directly from the site to create a pourable building material. This research has proved that depending on the location, there is enough usable material from the ground, only sometimes relying on a small amount of a carbon contributing (transportation) additive to augment the found materials. Fabric formwork allows for climate change solutions by allowing non-Portland cement stabilized materials to dry without cracking at form ties. To deal with this, future experiments can rely on more preliminary soil scouting and testing to discover sites that already have a close to optimal mix.

Poured earth uses the site itself as a beginning and an ending rather than as a receptacle for material moved from offsite. This process allows for site material to become the building, rather than simply supporting the building. Using site materials means that the impact of the construction does not include the movement of material to the site. In addition to the environmental benefits, the time spent on the site articulating the soil into poured earth creates a connection to the site itself, uncovering the invisible components and potential energy of the landscape.
Terroir describes site engagement with the built process, and is Vitruvian, in the sense of land creating both the human and the building. It is de Serresian in the sense of that land’s characteristics being specific to its effects on people and buildings, and in the Graeber and Wenrow sense of creating a political relationship to building, to the society those people create. Terroir describes this progression from a purely functional relationship to a complex social space. Landscape is thus constructed through the granular focus on the soils of the site and then radiates out from that understanding. The landscape is a hybrid of the terroir and its effects, its relationships, its creations.

11 DISCUSSION

11.1 Poetry: Fabric Formed Poured Earth

Chandler and Pedreschi developed a poetic understanding of the relationship of fabric forms to material in their compendium of essays, *Fabric Formwork*. “The use of fluid responsive formwork is a technique of constructing which allows the behavior of material to engage with and influence the building process itself” (Chandler & Pedreschi, 2007, p. 5). This project extends these poetics by including time as a factor in the relationship between material and responsive form making. Poured earth moves with time. In the process of drying, it shrinks, settles, breathes. In this project, fabric formwork moves with the shifting material. It swells where the settling weight pushes. It breathes where the air slowly bubbles through in response to vibration. The form-ties became an ever-descending grid, marking and corralling the wall nature with the shifting material. Without the ties, the material folds, and forms through gravity’s pull on the fabric and material. The dance of time with the pattern and rhythm of the ties creates a form to answer questions posed by the requirements of enclosure and temperature modulation. With the fabric, the poured earth can be allowed to respond to clay’s movements rather than needing the rigidity of fast drying cementitious stabilization.

Even after it dries, poured earth continues to move with time. The changing wall persists in a framework of rigidity that holds it against time’s ravages. With time, the intricate surface detail of the fabric’s impression softens. The clay surfaces decay and crack with freeze-thaw. These fabric-formed walls linger between mass and detail. They are the sculptural infill of a structure, changing with the movement of time, weather, and habitation.

French and Puebloan thinkers and builders would have had the capacity to analyze and judge soils for agriculture and for construction. While the authors are not storytellers for indigenous peoples, two concepts that relate to place and to earth that are common knowledge in published works about indigenous worldview may lead to useful rumination here. The first is the concept of Turtle world, where the earth of the world rides on the back of a global turtle. This frame allows for an appreciation of earth as intelligent and alive, and in some form a space of nurture. Another commonly held origin story in southwestern indigenous nations includes layers of worlds, the first through fifth world, with mankind being born through a fissure or hole in the earth itself from the world below into each successive world. Here again, earth is a layer, not an infinite depth, but rather a shell of soil beneath which stretches in infinite time the world before. In anecdotal conversation with members of Navajo Nation protesting the legacy mining destruction of their land, the people express the idea that the yellow dirt (uranium) should have been left underground. (Hood, 2019) Its fact of being underground is not one that should change. None of these are exhaustive cosmologies, but simply details that may offer an understanding of soil as an active agent in the context of European and Indigenous thinking.

FFPE seeks to encompass the characteristics of the soil as an active agent, to allow for shrinkage, settlement, swelling, and to provide an active matrix that constrains, but doesn’t utterly control. Terroir accounts for a complex landscape from which this material, redolent of history, experience, and living beings resides.

11.2 Poetry: Terroir: Site derived material

Site derived materiality engages with the framework of terroir outlined in the background section of this paper. The obsessive sifting and soaking and cataloging particle sizes involved in this process enabled an embodied experience of place that connects with the Vitruvian, de Serresian, and Graeber and Wenrow frameworks of terroir creating the human, creating the agricultural product, and ultimately creating the political society. Jane Bennett, in her *Vibrant Matter*, posits worms as constituting a polis (Bennett, 2009),
or having political agency. In this sense, terroir is also a polis, a political agent. Soil is an intermediary state of life, the bearer of carbon, sugar, water, and numerous nutrients to plants and microbial life. Soil is a substratum, a foundation, and a network. This project allows for a form-making exercise that focuses attention on the constituent processes of soil, shrink and swell, composition and form, and location. Terroir reaches beyond the soil's own polis into the political, morphological, and social worlds of human engagement.

12 REFERENCES


Hood, Edith, 2019 conversation with author


Vitruvius, The 10 books of Architecture, Book 6, Chapter 1, Section 2. Translated by MH Morgan, published by Dover Press, 1954


LANDSCAPE RESEARCH RECORD PEER REVIEW PROCESS

The Landscape Research Record publishes top quality articles selected from manuscripts submitted to the Council of Educators in Landscape Architecture (CELA) annual conference each year. The Record serves the mission of the CELA, that is, to encourage, support and further education in the field of landscape architecture specifically related to teaching, research, scholarship, and public service. The Record contains recent research and scholarship in all aspects of landscape architecture, distributed in the following tracks:

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Peer-reviewed article publication on the Record starts from the abstract submittal to the CELA annual conference. The CELA executive office sends out Call for Abstracts around August each year.

Abstract Review: September-October
The Vice President for Research leads the track chairs in the abstract review. Double blind review is used. Each abstract is reviewed by at least two reviewers.

Paper Submittal: January 10-20
Authors of accepted abstracts receive the invitation to submit a full paper in November. The deadline is in January of the following year. The papers submitted at this time are not peer reviewed but only edited to satisfy the conference standard. Papers that do not follow the template of the conference are rejected.

The CELA Annual Conference: March-April

Paper Review: May-June
Papers that are submitted in time in January and stratify the conference standard become eligible to enter the peer review for the publication in the Record. The track chairs manage the review for their tracks and select high quality papers based on the score of abstract review, grammar, completion of study, contribution of new knowledge, format quality, etc. The track chairs then send out selected papers to at least two reviewers.

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Track chairs collect review results and make recommendations on the manuscripts. Papers that are accepted with revision requirement will be sent back to the authors in July.

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