A Parametric Design Methodology for a Novel Ecosystem

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Abstract: A literature recognizes the ecological value of biodiverse "novel ecosystems" that arise from an interplay of anthropogenic and independent ecosystem processes. Several factors influence the creation of these novel ecosystems and there is no shortage of data acquisition methods for, or complexity of descriptive data about them. However, there is a need to articulate and contextualize tools and methods for formal design iteration that can make sense of this complexity and facilitate its translation into functional and meaningful landscape form. This paper describes a method for abstracting ecosystem processes into a simple parametric model, presented in the context of a riverbed mining operation in southern Georgia. The results of this initial methodology reveal the potential of parametric models to mediate between digital models of formal proposals and abstract models of ecosystem process. Separating and recombining parametric site models, abstract ecosystem models, and landscape photomontages reveals possibilities for a more facile methodology for iteration of design interventions. A parametric model also serves as a site for negotiation between project goals and constraints. Finally, the generation of a digital parametric site model allows for subsequent visualisation and editing of more specific digital models for design development and construction.

Keywords: Geomorphological diversity, geodiversity, parametric modeling, novel ecosystems

1 Introduction

Aggregate Mining Landscapes as "Novel Ecosystems"

Aggregate mining landscapes are widely understood as sites of chronic ecosystem degradation and destruction. However, there is a growing consensus that recognizes the ecological value of chronically degraded but "novel" ecosystems in supporting biodiversity and providing ecosystem services. A "novel ecosystem" is understood here broadly as a "new species combination that arises spontaneously and irreversibly in response to anthropogenic land-use changes" (MURCIA 2011). While significant debate surrounds the "irreversibility" of these changes, the "restoration" of sites with a high degree of anthropogenic disturbance can improve biodiversity and ecosystem services. Rather than allow descriptions of "novel ecosystems" to simplify the project of ecological restoration, designers' engagement with these sites should focus on relationships between anthropogenic disturbance, ecosystem services, and complexity (MURCIA 2011).

Restoration research in riverbed aggregate mining contexts suggests that disturbed mining sites provide new ecological niches that support overall site biodiversity, and that restoration efforts could benefit from a focus on "near-natural" restoration rather than more resource-intensive planting approaches (ŘEHOUNKOVÁ 2011). Similar approaches advocate for designing ecological processes and functions to allow for plants to "develop a measure of control [themselves]" (DEL TREDICI 2007) or "intervene and leave room" (GROSSE-BACHLE 2005).

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This paper expands and applies this approach to ecosystem restoration to explore the role of geodiversity in parametric modeling and redesign of aggregate mining operations. An active open riverbed mining site in the south of Georgia provides the case study for the project, presenting opportunities to explore a design methodology that attempts to engage and alter an existing process of anthropogenic geomorphological change. Restoration is here understood as amplification and diversification of remaining landscape qualities.

From Geodiversity to Geomorphological Diversity

Where geodiversity is a result of a broader collection of factors including mineral, paleontological, and structural/ tectonic factors, *geomorphological diversity* describes that subset of factors encompassed by surface processes. While variations in surface processes like differential weathering lead to increased geomorphic diversity, these same processes can also lead to reduced geomorphic diversity (THOMAS 2011). In the shifting landscape of an active aggregate mining operation, geodiversity can be understood not only as geo-determinism but also as an effect of the existence of multiple states of succession within a given ecosystem. Altering the mining process can lead to coordination and amplification of a wider range of ecosystem successional states.

Parametric Modeling and Scenario-based Design

Ashari et al. note that "Key academics and practitioners of landscape architecture are implementing parametric design as part of their design process in generating various design scenarios" (ASHARI et al. 2022). The goal of the methodology is *incorporating* the context of the design work into a formal parametric model from which to generate proposed scenarios. Thus, the project is an attempt to situate parametric modeling within a broader definition of design scenarios (SHEARER 2022). The method should allow the model to facilitate a formal dialectic between given and proposed formal scenarios that is open to interpretation by designers. Additional parameters can facilitate landscape designers, planners, quarry operators, scientists documenting biodiversity, and the interests of laypersons living near and visiting the site. The methodology elaborated in this article proposes modifications to a traditional Analysis/Concept/Design/Evaluation workflow. The aim was to use parametric modeling to encode simple formal models of observed ecological processes and begin to visualize formal interventions in these processes.

2 Methodology + Case Study

2.1 Site-based Research + Analysis

Interview

The design team kicked off the project with a semi-formal site visit and workshop to identify formal parameters and key system concepts of the mining operation. We invited architecture students from a local university to work with the design team to interview on-site excavators, operations managers, and ecologists.

The interviews revealed that excavators control the shifting landscape by creating "dambas" (roughly translated as "dams"), which allow them to direct the river and its powerful floods.

According to the on-site operations manager, dambas are built for a variety of reasons, including protecting machinery from periodic flooding, reducing sediment flow, and allowing for truck access from extraction points to processing sites. After a certain area is excavated, dambas are eventually removed to allow larger floods to "replenish excavated material", a process which can take as few as five years.

After collecting the qualitative description of the mining process and ecological diversity, the team compiled satellite imagery, reviewed drone footage, and composed diagrams describing the mining process and its extent. While the drone footage from the February visit shows a sparse winter landscape, satellite imagery shows a river in constant flux, coming to life each spring as a new layer of vegetation spreads over the bed of silt and rocks freshly deposited by winter flooding. The imagery serves as a partial record of the last decade and reveals the impact of mining activities on the riverbed over time. Aggregate mining disturbs the riverbed on a timeline of weeks to months, but this impact is superseded by spring floods that occur yearly.

In response to these conditions, we hypothesized that the mining and damba-building processes could be harnessed to increase the geomorphological diversity of the mining site. Processes of excavation, damba building, and periodic flooding have the potential to create a wide range of microhabitats that support increased species biodiversity.

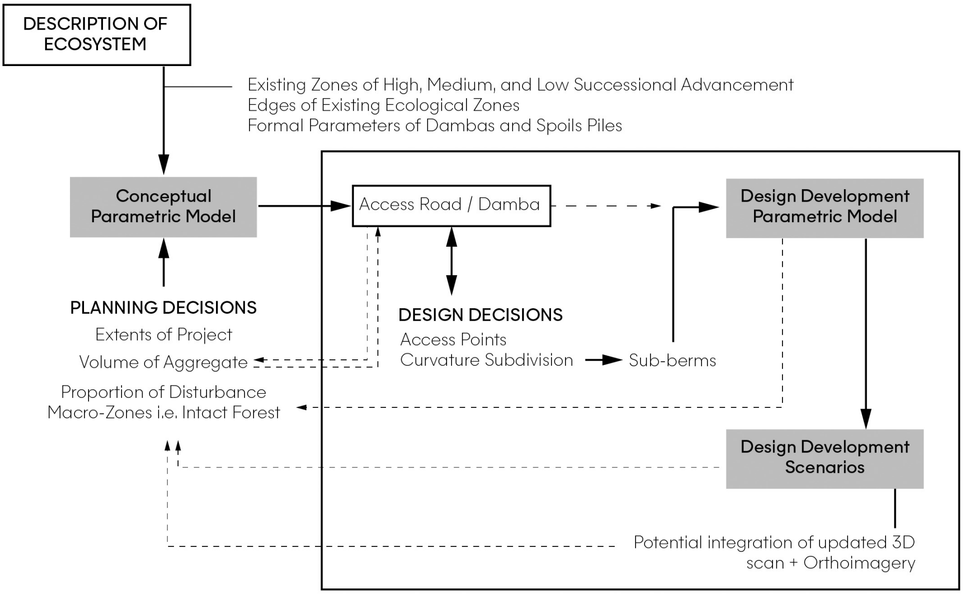

Fig. 1: Diagram of nested parametric models and feedbacks. Solid lines denote design decisions and dashed lines denote iterative feedback loops that integrate parametric decisions into the formal model.

2.2 Definition of Ecosystem

Grasshopper Definition of Formal Ecosystem Drivers

A secondary step of analysis involved the translation of the narrative context of the site into formal parameters that respond to existing ecological conditions and planned works on the site. To create a tool for quick formal iteration with respect to site-scale decisions ("Planning Decisions" in Fig. 1), we needed to identify and abstract the appropriate metrics and formal parameters of the mining operation and larger landscape ecological dynamics and forms.

Table 1: Metrics and Parameters

Feature	Specs	Analysis Metric	Grasshopper component
Damba	1-2 m above zero	Cubic meters of fill	[(Section Curve) * (Plan Curve)] +- Existing topo surface where available
Spoils Pile	1-2 m above surface	# of truckloads	Offset from (Damba/Road Plan Curve)
Intact Bosque	3-4 m above surface	Square meters	Curve / Region / Surface + 3D Canopy generated from color selection
Early Successional Bosque	1-2m above zero	Square meters	Curve / Region / Surface
Less Active / Previous Mining Zone	1-2m below zero	Square meters	Curve / Region / Surface from Orthophoto
Active Mining Zone	3-4m below zero	Square meters, cubic meters of fill	Curve / Region / Surface

Identifying Macro- and Micro-ecosystems

The abstraction of landscape ecological features was accomplished by comparing areas of similar vegetation cover to the topographical surface to define boundary conditions on a broad site-scale. As observed on site and through sectional analysis in Google Earth, the edge of the "Intact Bosque" follows the scoured edge of the riverbed, providing a sharp boundary at the site scale. A lighter shade of vegetation composes an intermediary edge zone that has allowed for the development of an early successional bosque, which exists at 1-2m above the apparent limit of flooding. The floodplain is defined by a zone of high-frequency scouring evidenced by the limited presence of shrubs. Scattered across the floodplain are former borrow pits, which host littoral micro-ecosystems similar to the early successional bosque.

By applying Richard Forman's principles of landscape ecology, the early successional bosque can be understood as the cellular or nuclear membrane of the intact bosque, facilitating the migration and succession of species (DRAMSTAD et al. 1996). A key assumption for the model is the role of the intact bosque as a nucleus for expansion into the shifting floodplain and active mine zones (CORBIN et al. 2016). This allowed us to argue for the conservation of the bosque by shifting tipping grounds from the floor of the intact bosque to the more frequently disturbed early successional bosque. The tipping piles currently interspersed throughout the intact bosque should be redistributed as a way of amplifying the seed bank of the more frequently disturbed landscape.

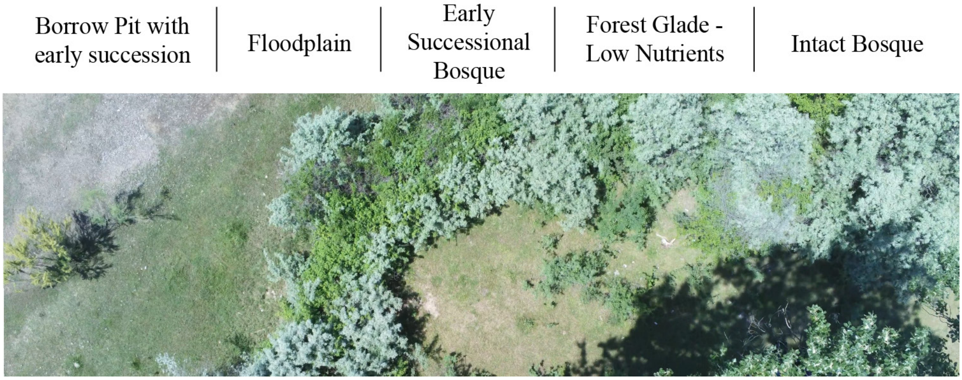

Fig. 2: Microecosystem transect – A closer look at the interface of the intact bosque, early successional bosque, floodplain, and the intact bosque reveals the movement of species between "stacked zones of succession".

2.3 Concept Development

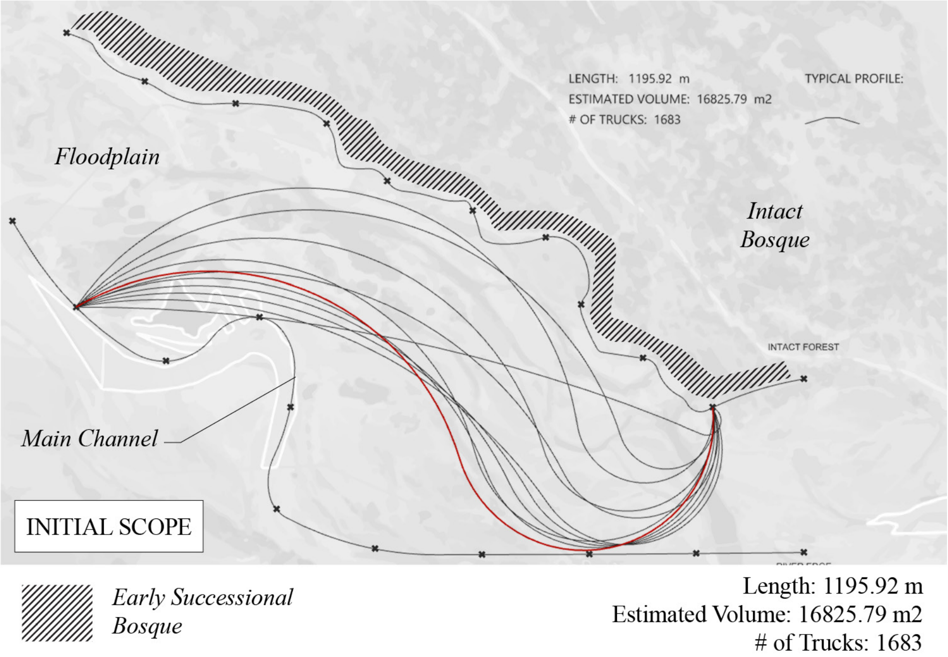

Fig. 3: Simplified parametric model in context with initial "damba" iterations. Bi-arcs are generated between two start/end points along the curves of the ecological diagram. An underlay extracted from orthoimagery provides for an overall comparison of the intervention with existing channels.

The goal of the concept development phase was to create a simple iterative model of masterplan forms. At the site scale, the ecological system is represented as a "boundary model" (HILL 2005). The boundaries represented in the model (the edges of the intact forest and the edge of the main channel of the river) define the limits of the proposed berm system. These edges are subdivided to generate start and end points for the berm and distances between all possible start and end points are calculated. Each of these possible berms is then recalculated as a set of bi-arcs, or curves composed of two simple arcs. The definition incorporates In-Curve interior culling to exclude iterations that exceed the limits of the project.

Following initial iteration, a selected curve or set of curves is then used as a basis for the generation of a surface that can be intersected and compared with models of the existing surface. In this project, the lack of a high-definition surface model forced us to rely on abstracted orthoimagery to infer elevation information. In future iterations of the methodology, a context model with greater definition can add greater analytical definition to this stage.

The vertical difference in the model is developed relative to a "system zero" that can shift to any average or given waterline elevation. This allowed us to reduce the complexity of varying water levels while also retaining the ability to incorporate more complex water elevation data.

2.4 Design Development

The iterative outcomes of the concept development model form the base of a further-refined "design development" model. The development model is broken into smaller models of individual zones to generate a greater diversity of micro-ecosystems.

Manual and Parametric Cutting Operations

Berms can be cut with individual curve parameters or sets at specific intervals to introduce further porosity in the system. Varying the elevation of these cuts can generate check-dams or culverts with a range of crestline elevations.

Distribution of Varying Nutrient Levels and Soil Types

Parameters for specific soil types can be displayed by developing a key-color legend and custom material previews.

Incorporation of Environmental Simulation on Smaller Sites

The generation of a physical model allows for a range of existing Grasshopper plugins to analyze environmental factors such as hydrological saturation (Groundhog) and temperature/energy modeling (e. g. Ladybug, Honeybee).

Photomontage and Further Descriptive Visualisation

Photomontage was used not as a way of determining the fixed or final condition but as a method of representing combinations of potential project conditions to create an image open to interpretation (M'CLOSKEY 2014). The definition generates measured landscape forms that can be montaged over existing landscape conditions and textures to produce projective photomontages (Fig. 5). Such hybrid images can be used to establish metric visual parameters that facilitate systemic and systemic design decisions.

3 Discussion

Developing Facile Definitions

There is a need to balance specificity and complexity with respect to digital data inputs and outcomes when generating formal iterations. Nested, simplified models allow design teams to move efficiently between decision-making scales without carrying unnecessary complexity to the model.

Initial investigations in the design development phase revealed that the use of environmental simulation plugins such as Ladybug, Honeybee, and Groundhog (saturation) work best on smaller sub-sites, where more subtle forces of surface geology become legible. Further case studies are needed to elaborate possible applications to large-scale sites.

Designers working with parametric software must always take caution when integrating specific datasets. Beginning with an abstracted master plan model with simple geometry allows for fast and loose overlays with existing context data (orthoimagery, topography, observed vegetation, etc.).

Rules-based Experimentation

Some rules were fast and loose, aimed at experimentation and later refinement (i. e., each berm should be double-curved). Others were highly specific, (i. e., the length of the berm, the radius of the berm enclosing an area). The definitional simplicity of the model facilitates geometric iteration and pattern generation.

Representation through Hybrid Drawings

The hybrid drawings produced through this workflow operate like traditional landscape representational method of “landscape overlays” and yet add another layer of specificity and complexity. User-displayed text and annotation can further integrate metric and technical parameters of the represented form.

4 Conclusion and Outlook

This project and paper focus on the outcomes of an initial draft of a parametric methodology for engagement with novel ecosystems through geodiversity. The goal of the case study project was to bring the mining operation parameters into a model that can facilitate rapid visualisation of site-scale forms, followed by an initial investigation of smaller parameters. Creating a protocol for nested models with feedback was crucial to moving between scales and discerning between “hard” and “loose” formal design decisions.

The methodology allows the abstracted parametric model to become a site of physical and discursive negotiation and coordination between the various actors involved in the project. The next step in refining this methodology is to test the utility of this parametric model facilitating interdisciplinary data and feedback in the design process. The case study used to develop this tool aimed to establish a more intentional role for formal decision-making by facilitating decisions that incorporate aesthetic and metric-based approaches.

Further research could unfold along two strategies for further defining the surface: a more specific integration of soil types and the use of 3D scanning to incorporate temporal change of landscape form.

Eventual applications of the methodology could inform design protocols for novel and expanded riparian ecosystems. The workflow can also be applied to smaller sites and the generation of formal iterations.

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