

Executive Summary

Prairie Restoration as Ecological Mitigation: Trait-Informed Design of Upland Prairie Communities in the Willamette Valley

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Purpose and Context

Upland prairies in the Willamette Valley have been significantly reduced due to agricultural conversion and urban development, resulting in habitat loss, fragmentation, and declining ecological function. As development pressures continue, environmental planning frameworks such as the National Environmental Policy Act (NEPA) require Environmental Assessments (EAs) to evaluate impacts and identify mitigation strategies. In many cases, restoration is used to offset habitat loss, yet these restoration plans often remain conceptual and lack clear connections to ecological performance and implementation feasibility.

This project was conducted at the North Willamette Research and Extension Center (NWREC) and was designed to address this gap by developing a trait-informed restoration framework grounded in empirical data. Using a hypothetical EA scenario in which a 100-acre development requires 20% mitigation through upland prairie restoration, this work translates ecological principles into a quantitatively defined and spatially explicit planting design that is both ecologically grounded and operationally feasible.

Scope, Data, and Methods

Dataset and Variables

This study integrates greenhouse propagation data with ecological trait data to evaluate early establishment dynamics of nine native upland prairie species. A controlled greenhouse experiment conducted at NWREC monitored germination timing, cumulative germination, seedling growth, root development, and transplant readiness over a nine-week period. These variables were paired with functional traits including germination rate, time to emergence, seed mass, root morphology, growth rate, and phenology timing to represent both establishment potential and ecological function.

Analytical Approach

Trait values were standardized and combined using a weighted ecological framework to

generate composite species scores. Functional complementarity between species was calculated to incorporate biodiversity considerations into the design. These outputs were translated into proportional representation and applied to a one-meter spatial grid across a 20-acre restoration site, resulting in approximately 80,000 planting locations. A rule-based spatial allocation approach was used to maintain species proportions while promoting local heterogeneity and reducing clustering.

Germination Rates of North Willamette Valley Upland Prairie Species

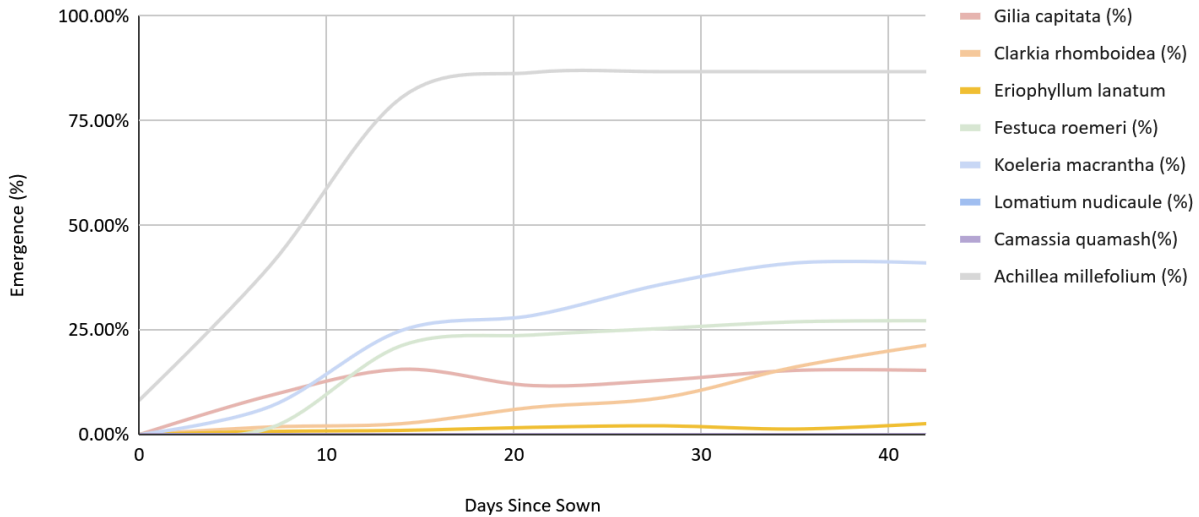


Figure 1. Germination and establishment patterns across species.

Key Findings

1) Early establishment variability

Species exhibited substantial differences in germination and establishment success. *Achillea millefolium* demonstrated rapid and high germination (~86%), while *Koeleria macrantha* and *Festuca roemerii* showed moderate but consistent establishment. In contrast, *Eriophyllum lanatum* exhibited low germination, and *Camassia* spp. and *Lomatium nudicaule* did not emerge within the monitoring period. These patterns highlight the importance of early establishment traits in determining species feasibility within mitigation timelines.

2) Trait-based scoring as a decision framework

The ecological weighting framework synthesizes greenhouse-derived performance metrics with functional trait data to generate standardized composite scores, facilitating rigorous cross-species evaluation. In doing so, it grounds restoration design decisions in explicitly defined, quantifiable ecological parameters rather than subjective or heuristic-based selection.

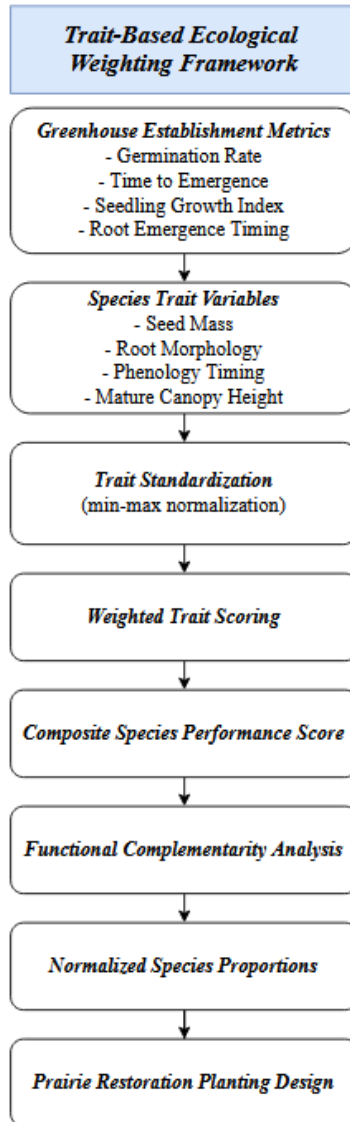


Figure 2. Trait-based ecological weighting framework.

3) Translation to spatial design

Composite scores and functional complementarity metrics were converted into proportional species representation and systematically applied within a spatially explicit grid framework. These quantified outputs informed both species distribution and relative abundance across the restoration site, ensuring alignment with ecological performance criteria while preserving functional diversity. This approach demonstrates that restoration planning can be directly translated from conceptual design into quantitatively informed, spatially resolved,

implementation-ready configurations that are ecologically grounded and operationally actionable.

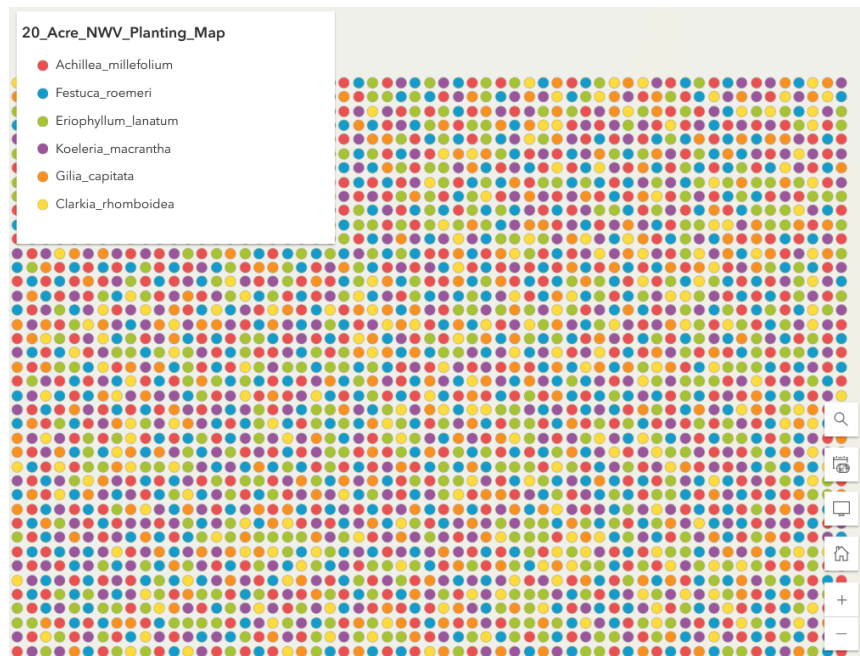


Figure 3. Spatially explicit planting design (GIS output).

4) Propagation feasibility and cost constraints

Per-acre greenhouse production costs were estimated at approximately \$3,240, based on modeled input requirements for the propagation of approximately 4,000 plants per acre under controlled conditions. These projections assume consistently high germination and establishment success and incorporate minimal contingency for interspecific variability and production inefficiencies. This constraint emphasizes the need to embed feasibility, uncertainty, and cost responsiveness within restoration planning frameworks to ensure alignment between ecological design and implementation capacity.

Case Study: 20-Acre Upland Prairie Mitigation Scenario

Project Overview:

A theoretical 100-acre development scenario in the Willamette Valley was developed to simulate mitigation requirements under an Environmental Assessment framework, with 20 percent of the project area allocated to upland prairie restoration on former grazing land. This context requires the development of a restoration design that meets ecological suitability criteria

while also demonstrating feasibility in terms of implementation logistics, production capacity, and cost, consistent with regulatory expectations for defensible mitigation planning.

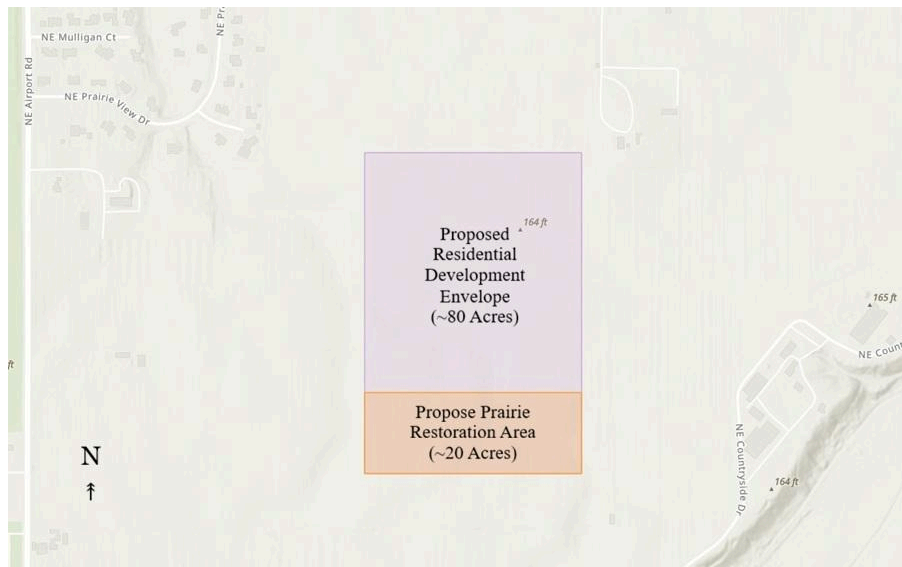


Figure 4. Conceptual restoration site map.

1) Restoration Design Approach

The integrated framework was operationalized to produce a spatially explicit planting design informed by greenhouse-derived performance data and trait-based ecological weighting. The site was modeled at an approximate density of 4,047 plants per acre, resulting in more than 80,000 spatially distributed planting locations across the mitigation area, structured according to proportional species representation.

2) Species Composition and Structure

Species composition was determined using establishment performance derived from greenhouse and trait-based metrics, balanced against requirements for functional and compositional diversity. High-performing taxa, including *Achillea millefolium* and *Koeleria macrantha*, were allocated greater proportional representation, while lower-performing or non-emergent species were included at reduced frequencies to maintain functional diversity and structural heterogeneity within the restoration design.

3) Implementation considerations and outcomes

Key considerations included greenhouse production capacity, seasonal constraints governing establishment timing, and variability in species-specific establishment success. The

resulting design illustrates that restoration planning can be systematically aligned with ecological objectives and operational constraints, resulting in a mitigation strategy that is both well-substantiated in its design and feasible to implement.

Business Implications

This framework has direct implications for environmental planning and restoration practice. By integrating empirical data into restoration design, it increases transparency and methodological clarity within Environmental Assessment processes, reduces uncertainty in species selection, and improves the precision of cost and labor forecasting. For practitioners, this approach supports the development of mitigation plans that align ecological performance with operational constraints, improving implementation reliability and project outcomes.

Recommendations

1) Integrate Propagation Data Early in Planning Workflows

Restoration planning benefits from incorporating greenhouse and field-based establishment data at the earliest stages of project development, rather than after design decisions have been finalized. Early integration enables identification of species that are both ecologically suitable and capable of consistent establishment within project timelines. This reduces the likelihood of redesign, improves alignment with mitigation requirements, and supports more predictable implementation outcomes.

2) Adopt Standardized Trait-Based Frameworks for Species Selection

Trait-based ecological frameworks should be used to evaluate species suitability through weighted, standardized criteria. Linking species selection to measurable attributes such as germination rate, emergence timing, and growth performance increases transparency and repeatability in restoration design. This approach is particularly relevant within Environmental Assessment processes, where ecological decisions must be clearly articulated and justified to regulatory agencies and stakeholders.

3) Develop Spatially Explicit, Implementation-Ready Restoration Plans

Restoration design should extend beyond species lists to include spatially explicit planting configurations that capture both proportional composition and site-level heterogeneity. Spatial allocation of species across a defined grid enhances installation coordination, improves contractor communication, and supports structured monitoring and adaptive management frameworks. Collectively, these outputs establish a direct translation between design intent and field implementation.

4) Integrate Feasibility, Cost, and Production Constraints Into Design Decisions

Greenhouse production capacity, labor requirements, and material costs should be explicitly considered when determining species composition and planting density. Incorporating these constraints during design development reduces uncertainty and improves cost estimation accuracy. Planning should also include reasonable buffers to account for variability in germination and establishment success under field conditions.

5) Plan for Variability and Environmental Uncertainty

Given inherent variability in establishment success and environmental conditions, restoration designs should incorporate flexibility to accommodate uncertainty. Strategies may include diversified species assemblages, redundancy in planting density, and contingency allowances for lower-performing or less predictable species. Accounting for variability in this way strengthens system resilience and reduces the likelihood of performance deficits under changing conditions.

6) Align Restoration Design with Regulatory Timelines and Ecological Windows

Restoration planning should account for seasonal establishment windows, species-specific dormancy requirements, and regulatory timelines associated with Environmental Assessment processes. Early alignment of these factors helps minimize implementation delays, reduces the need for design revisions, and ensures that field activities occur under conditions conducive to successful establishment.

Limitations and Future Work

Limitations

Greenhouse conditions may not fully replicate field-based environmental variability, and the nine-week monitoring period reflects only early-stage establishment dynamics rather than long-term demographic performance or successional trajectories. In addition, the restoration scenario presented herein is hypothetical and is intended to demonstrate the operationalization of the framework rather than represent an empirically implemented field restoration project.

Future Enhancements

Future research should prioritize field-based validation of spatial planting configurations, long-term longitudinal monitoring of species performance, and expansion of the framework across additional ecological systems and restoration contexts. Further refinement may include the integration of adaptive management protocols and the application of sensitivity analyses to

trait-weighting parameters to improve model calibration, ecological fidelity, and predictive performance under variable environmental conditions.

Conclusions

This project establishes a structured, data-driven framework for integrating ecological research into restoration design within an Environmental Assessment context. Results indicate that early establishment traits exert a primary influence on species establishment success and, by extension, on species feasibility within mitigation frameworks. Trait-based analytical approaches further demonstrate utility in guiding both species selection and spatial configuration of restoration assemblages.

By translating empirical ecological data into spatially explicit, implementation-ready design outputs, this work advances restoration planning beyond conceptual formulation toward quantitatively defined and operationally actionable strategies. The framework provides a scalable methodological pathway for improving the ecological performance, methodological transparency, and implementation feasibility of mitigation-based restoration within the Willamette Valley and comparable systems.

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