Upscaling and enhancing biological corridors for the conservation of *Abronia campbelli*, through research and capacity building

The Rufford Foundation

FUNDESGUA

FINAL REPORT

For the conservation of *Abronia campbelli* we have focused on reconciliation of agricultural production activities with forest protection, creation, and connectivity by establishing habitat restoration areas, including biological corridors. This strategy serves to counteract and compensate for habitat loss caused by unsustainable agricultural practices, which are the main threat to the species. Take a look at how we are making this happen through habitat restoration,

INTRODUCTION

Campbell's alligator lizard is an arboreal species that is critically endangered due mainly to extensive habitat loss. The extremely limited distribution of the species coincides with an area rich in natural resources that is highly attractive and lucrative for floriculture, forestry, livestock and agriculture. This has given us two monumental tasks: rebuilding viable habitat for *A. campbelli* and forging unlikely allies to achieve the species conservation.

To ensure the viability of the species, we have focused on integrating biodiversity conservation into productive practices in the region; creating strategies that make harboring existing habitat and creating new habitat compatible with the livelihoods on which local human settlements depend. This has resulted in the creation of energetic (fast growing) forests for human use, and the successful establishment of biological corridors on private family plots and farms to increase and augment the habitat.

The discovery of new distribution areas for *A. campbelli* over the past few years, has prompted us to expand our conservation efforts to cover new areas and partner with more local communities, this translates into producing more native key forest trees. Furthermore, the successful involvement of key stake holders and their adoption of our habitat restoration efforts have recently reached a point where annual demand for trees for farms and small landholders exceeded the production capacity of our main nursery driving us to multiply and enhance habitat restoration efforts.

The need for broadening current habitat restoration efforts, ignited by new scientific data, matches the increased demand for trees for private farms and families. This situation has created a momentous turning point and opportunity for the program to scale up habitat restoration efforts to fulfill the conservation needs for *A. campbelli* faster and mirror the increased buy in by the local communities.

This project is centered on multiplying and enhancing nurseries of key native forest species through a network of trained conservation-committed farms and research to upscale habitat restoration. Ensuring the magnitude, quality, and sustainability of habitat restoration efforts required for the conservation of *A. campbelli.*

ACHIEVEMENTS

Development of habitat restoration plans for five key farms, strategically targeting the recovery of **100 hectares** of land for *A. campbelli* conservation over the next 3 years (2023-2025).

Research efforts lead to valuable insights into tree nursery care techniques. The findings empower us to refine our methodologies and **optimize our conservation actions** or enhanced effectiveness.

Implementation of the first phase of the habitat restoration plans through the planting of 15,000 trees. This **tangible manifestation of the commitment** of local farms to the conservation of *A. campbelli.*

Establishment of 5 satellite nurseries, each dedicated to providing native key tree species for the farms. This strategic initiative has effectively **doubled our annual habitat restoration impact,** increasing from 20,000 to an impressive 40,000 trees.

RESULTS & DISCUSSION

Habitat restoration planning

This project represents a significant step in our overarching conservation plan for *A. campbelli*, cementing our collaboration with five local farms in pursuit of ambitious habitat restoration objectives.

Through this partnership, these farms are assuming a heightened responsibility for safeguarding natural resources and biodiversity for their intrinsic value and for the sake of future human generations. Empowering local actors into taking responsibility and control over conservation actions on their land.

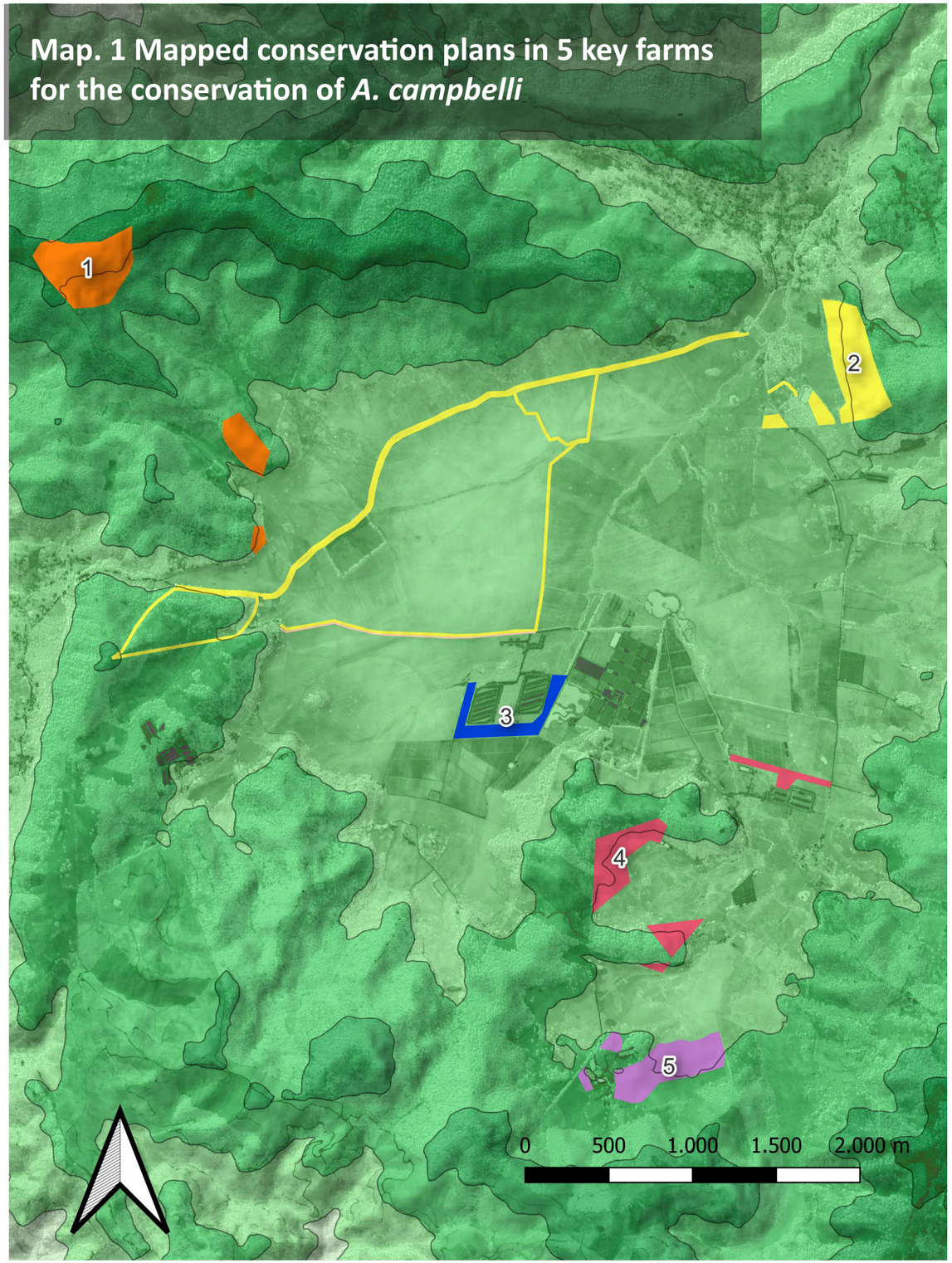
The resultant plans, collaboratively devised and tailored for each farm, have been mapped (Map 1). This map illustrates the areas that will undergo recovery for species conservation, serving as a blueprint for collaborative efforts in the upcoming years.

By incorporating the collective area of all five farms, encompassing both production zones and conservation/ restoration zones, this comprehensive strategy will oversee the execution of conservation tactics that will influence the stewardship of over 1,000 hectares. Every square meter depicted on this map signifies a substantial triumph for the conservation of *Abronia campbelli.* Given that this land embodies a premium level of productivity highly esteemed in the market, these farms have made the admirable decision to dedicate these land sections exclusively for conservation purposes.

Among these five farms, their combined commitment to conserving *A. campbelli* culminates in an impressive total of 100 hectares of land dedicated to conservation. This encompasses the incorporation of biological corridors, linearly extending to a remarkable span of 16,370 meters. The plan for each farm will be described below and will be carried out in the next 3 years.

All the farms included in this project are situated within one of the three distribution areas of the species, which had been initially assumed to encompass the sole distribution range of *A. campbelli.* Farms have been numbered from one to five to facilitate clear referencing throughout this document.

Map. 1 Mapped conservation plans in 5 key farms for the conservation of *A. campbelli*



Farm number one delineated in orange on the map, holds notable scientific and conservation importance due to several factors, including it being the type locality where *A. campbelli* was originally documented and described.

Positioned at an elevation exceeding 2,000 meters above sea level, this farm occupies one of the highest points within the entirety of *A. campbelli's* distribution range. This altitude is second only to that of the volcano Jumay, which remains situated in a different and still disconnected distribution zone.

The high elevation creates an optimal microclimate that supports the growth and propagation of epiphytic vegetation such as bromeliads and orchids within the canopy, a microhabitat integral to the species' ecological niche. Given *A. campbelli's* specific habitat preferences and the scarcity of these high-altitude forests, this site holds great conservation value.

Additionally, as the next phase of our habitat restoration initiative focuses on enhancing the presence of epiphytic plants on host trees, this site assumes added significance for our canopy characterization studies. The area is also characterized by natural regeneration patches of pine and oak forests, that although currently having very low forest density and low connectivity they will be crucial for the species' viability when preserved and linked with broader habitat networks.

This habitat restoration site, once a forested landscape, now comprises isolated mature trees in a considerably degraded condition (Map 2). The area had pronounced vegetation that had reached the height of an adult human. This has severely hindered natural regeneration due to limited light penetration, resulting in inhibition of seedling growth. To address this issue, proactive measures have been implemented to prepare the site for restoration.

Farm number one predominantly centers around pine forest trade. However, due to the farm's considerable extent, not all sectors are used for this specific purpose. In a laudable demonstration of dedication to the conservation of *A. campbelli,* the farm will dedicate a total of 25.8 hectares for habitat restoration. This will be partitioned into three habitat patches, measuring 18.8 hectares, 5.9 hectares, and 1.1 hectares, respectively. Notably, the habitat patch spanning 18.8 hectares is strategically positioned within the high-altitude zone.

Farm number 2 represented in yellow on the map, encompasses the majority of the entire valley and it is the biggest a substantial segment of the original distribution area that was initially regarded as the sole range of the species. After enduring extensive forest destruction over half a century ago, this farm had maintained a moderate operational profile in recent decades. Incorporating various activities such as small and medium-scale agricultural endeavors, cultivation of corn to meet the sustenance needs of local families, and small-scale flora-culture enterprises.

Regrettably, within the past two years, a substantial portion of the farm has undergone significant modification. Notably, this tract of land has been extensively transformed and subsequently leased to a corporate entity specializing in the large-scale production of export-oriented vegetables, operating at an industrial scale. This land use shift has catalyzed notable repercussions, significantly impacting the area.

This upheaval arises from a shift in farm management prompted by a familial transition. The individual who had overseen farm operations for over five decades with whom we worked closely, unfortunately passed away. This event precipitated the emergence of a new management team from within the family that owns this farm, resulting in the decision to lease the farm to the vegetable production company.

This circumstance positioned us in a new negotiation context with the family. Although the initial interactions were marked by challenges, the ensuing course of events has yielded substantial benefits. In the grand scheme, this development has fortified our relationship with the family, particularly with the conservation-oriented younger generations. Furthermore, this scenario has opened up fresh prospects, which will be expounded upon in the subsequent sections.

The polygon marked with the number 2 in the map corresponds to a small mountain featuring young forest cover, this area will be enhanced, and preserved to foster its maturation. Adjacent to this small mountain lies a polygon positioned to the west, characterized by seasonal flooding during winter, rendering it of limited practical utility for the farm. This specific tract will undergo restoration employing the native forest species *Liquidambar styraciflua*, which naturally thrives in swamp zones.

Continuing westward from the previously mentioned polygon is yet another area designated for habitat restoration. Here, the restoration will be conducted utilizing native oak species. This area holds notable significance as it will serve as the site for the installation

of several research plots. These plots will facilitate the observation and analysis of tree growth and development over the forthcoming decade. This research aims to discern the enduring impacts of distinct treatments executed in the nursery setting.

The remaining marked sections in yellow within farm number 2 encompass a sequence of corridors along the valley, which will play a pivotal role in fostering habitat connectivity (Map 2). These corridors primarily coincide with existing live fences, with plans in place to transform these fences through the substitution of eucalyptus trees, an exotic species lacking ecological significance in the area. This change aims to replace a historical live fence along the highway, which was originally established using *Eucalyptus* trees several decades ago.

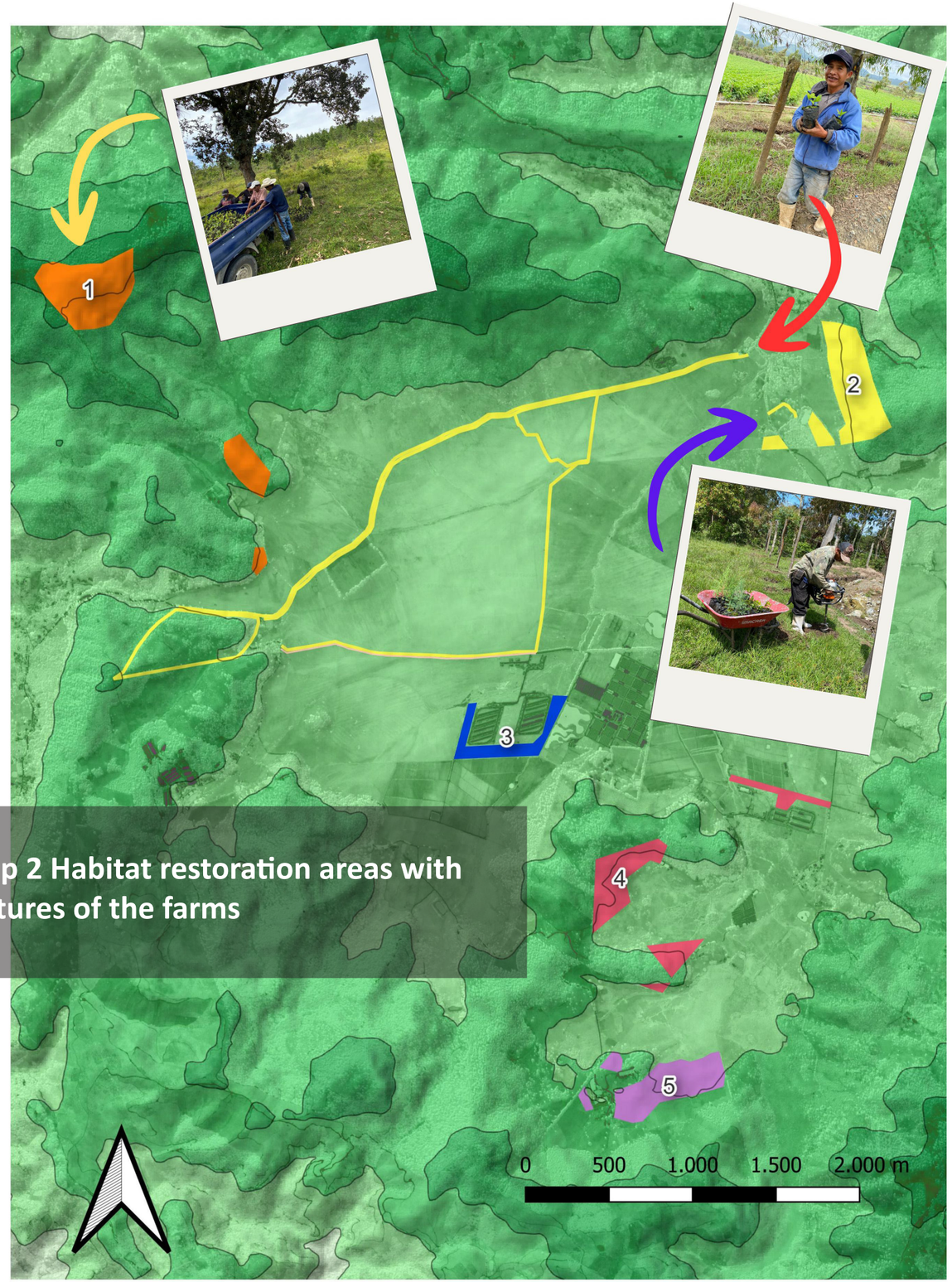
These new corridors will be built with native key tree species that hold significant ecological value, contributing to enhanced connectivity within the landscape. In addition, other fences within this farm serve the purpose of delineating divisions between distinct vegetable crops in the area.

In total, farm number 2 will be dedicating 36.17 hectares to the conservation of *A. campbelli,* according to the plan described in this document. These internal fencing divisions between the vegetable crops can play an important role for conservation.

It is at this point that, faced with the formidable challenge of large-scale vegetable production, new opportunities came into view. Given the projection of a future need for multiple live fences to demarcate various plantations, the potential arose for us to establish a more extensive network of corridors than we had previously considered.

Presently, we are actively engaged in planning this prospect in collaboration with the landowners. It's important to highlight that the realization of such opportunities would not have been feasible without this project. This initiative has facilitated the provision of tailored, robust support, and meticulous follow-up for each farm, enabling the identification and capitalization of such unique possibilities.

Farm number 3 marked with blue on the map, pertains to a farm engaged in chicken production. This area stands as a site of complete disturbance, characterized by the absence of any form of forest cover. This farm belongs to the “Corporación Multi Inversiones” also known as CMI and it is an entity esteemed as one of the largest and most important corporations in Guatemala.



Map 2 Habitat restoration areas with pictures of the farms

Given the considerable scale of this corporation, it places a robust emphasis on sustainability, driven by the imperative to uphold its distinguished reputation. The plan for this farm includes the habitat restoration of 7-hectare plot within their farm.

Farm number 4 marked with red in the map, is a pork production farm, constituting another of the companies encompassed by the CMI corporation. This farm has undertaken the commitment to allocate four distinct sections, collectively amounting to 15.9 hectares, for the explicit purpose of conserving *A. campbelli.* These areas will be restored with native oak trees, that eventually will connect with various small parcels of maturing pine-oak forest.

Farm number 5 marked by the color purple on the map, epitomizes a new collaborative venture with a landowner within the region. The landowner's aspiration revolves around getting forestry incentives. While national incentives prioritize forest coverage, it is paradoxical that local species often take a backseat. In this context, our involvement becomes pivotal, infusing ecological value into these areas.

Within this farm, habitat restoration will encompass three distinct zones, collectively spanning 16.2 hectares; these areas are characterized by complete degradation. The restoration process on this farm will entail the utilization of native tree species.

Notably, this farm is situated precisely on the outskirts of what we presently regard as the species' most crucial conservation zone. This zone encompasses the majority of the remaining and largest habitat patches of forest within the region. These patches epitomize the highest habitat quality within the meager 3% of remaining forest habitat across the entire distribution range of the species.

The forthcoming maturation of the habitat restoration areas of the five farms holds the promise of a profound transformation: the establishment of an impressive 40,000 essential native key trees.

Through a conservative assessment, factoring that each tree can potentially sustain four adult individuals, the initiatives undertaken within this project will sculpt an environment with the capacity to support a remarkable population of over 160,000 *A. campbelli* individuals. This calculation underscores the potential magnitude of our conservation efforts in fostering the survival and proliferation of this critically endangered species.

Satellite nurseries

To support the successful implementation of the habitat restoration plans within the five farms described in the last section we have established “satellite” nurseries on each farm.

The satellite nurseries have been successfully constructed and are ready to start their first reproduction cycle. Each nursery has the capacity to house 3,000 native trees that will be used to establish conservation zones and biological corridors.

This way we transfer our knowledge and skills to multiply the number of trees we produce each year. The farms will have the supply of trees that they are demanding for the creation of biological corridors and forest patches within their farms.

If five farms supply an average of 15,000 trees each year for their own use, our main nursery can supply trees for smallholders, automatically doubling our impact in the area.

The design of the nurseries has as its main feature an irrigation system that, depending on accessibility to electricity, is automatic or semi-automatic. Standardizing and alleviating the need for manual irrigation, which is the most time-consuming part of nursery care, turning tree production on farms into a task that can be accomplished and sustained by farm staff.

The recently expanded capacity has facilitated the implementation of habitat restoration plans developed in this project. The initiation of restoration strategies took place through the planting of 15,000 trees, marking the onset of the first year of a three-year work plan.

VIVERO FORESTAL PARA LA PROTECCIÓN
DE ABRONIA CAMPBELLI

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SOUTH CAROLINA

OKC ZOO
+
BOTANICAL GARDEN
AQUARIUM

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Nursery research

In addition, we took advantage of the stable conditions of our nurseries to carry out applied research projects that allows us to be more efficient in our habitat restoration techniques. For this we have evaluated the following treatments:

Treatment	Description
Sun Exposure	Sun exposure was evaluated by comparing the effect of a 60% shade cloth vs total sun exposure.
Fertilizer	The use of slow-release fertilizer vs no fertilizer was evaluated
Type of container	Single cell flexible hard plastic containers featuring special walls and openings vs to the traditional polybag container of equivalent volume was evaluated
Planting	Performance of the seedlings in the field when planted in a traditional way vs when planted with the help of an earth auger will be evaluated
Soil	The effect of an enhanced soil mixture vs local ground near oak trees was evaluated.

We assessed these treatments for two native tree species, *Quercus* tristis and *Liquidambar styraciflua*, with the exception of container type, which was exclusively evaluated for the oak species. This distinction arises from the distinct behavior of native oak species, which display a unique propensity for accelerated root growth, despite exhibiting one of the slower growth rates (both in height and biomass) among native forest species. Thus, our objective is to assess the influence of container types on this particular variable.

A one-way ANOVA was conducted to ascertain the impact of each treatment outlined in the table above on the seedlings' height and biomass for each species.For the "fertilizer" and "soil" treatments, no statistically significant differences were observed in the growth or biomass of *Liquidambar styraciflua* and oak trees within the nursery. This is an encouraging finding as it suggests that utilizing costly fertilizers and undertaking extensive land preparation are not prerequisites, leading to cost savings per tree produced. Consequently, heightened tree production can be achieved with fewer resources.

Solar exposure emerged as a critical factor influencing tree growth, prompting immediate adjustments to our main nursery based on preliminary findings. Contrary to prevailing expert opinions in the country, both the native species *Liquidambar styraciflua* and *Quercus sp.* species exhibited superior responses to direct sunlight exposure rather than shade conditions.

This contrast was particularly striking for the *Liquidambar styraciflua* species; seedlings in shade conditions averaged a height of 11.35 cm, while those exposed to sunlight averaged an impressive 56 cm, yielding a statistically significant difference in seedling height (p=0.00). In terms of biomass, seedlings in shade conditions averaged 2.15 g, compared to 10.1 g for those in sunlight, similarly resulting in a significant difference (p=0.00). This underlines that direct sun exposure in the nursery is conducive to robust tree growth, both in terms of height and biomass.

In the case of oaks, the results exhibit an intriguing pattern. Seedlings in shaded conditions displayed an average height of 6.14 cm, whereas those exposed to direct sunlight showed an average height of 7.77 cm. The variation in height is minor, and according to the analysis, the difference in height is not statistically significant (p=0.06). However, it is the biomass that truly reflects the pronounced trend observed in the nursery. Despite oak's inherent characteristic of slow vertical growth, a notable difference in leaf development became evident. The average biomass of shaded oaks was 1.12 g, whereas oaks exposed to sunlight boasted a biomass of 5.43 g, representing a noteworthy and statistically significant distinction (p=0.00).

Once more, the evidence reaffirms the advantageous impact of direct sun exposure on oak trees during their seedling stage in the nursery. Notably, the germination process of oak trees also gains from direct sunlight, exhibiting a notable 10% augmentation. This shift elevates the germination rate from 80% to an impressive 90% when subjected to direct sunlight.

These discoveries hold a twofold significance, amplifying both tree growth and germination rates while concurrently yielding cost efficiencies by eliminating the need for shading investments within the nurseries. Moreover, this revelation alleviates concerns regarding the seedlings' adaptive capacity during transplantation, as they won't have to contend with an additional adjustment from shade to direct sun exposure.

The rapid growth rate of oak roots may reach a level that impacts the quality of seedling roots within the nursery, subsequently, negatively influencing the establishment and growth rate

of seedlings once transplanted into the field. To mitigate this effect, it is prudent to implement a natural pruning mechanism for the seedlings' roots. This phenomenon occurs when the roots encounter air, leading to a reduction in their aggressive growth.

To evaluate the root status and growth on oak trees we utilize specialized containers with single-cell flexible hard plastic design, featuring distinct walls and perforations. The core concept is that fostering this air pruning of roots helps to prevent root spiraling, eliminate root circling, encourage the development of a robust mass of healthy fibrous roots, and even increase oxygen availability to soil microbiota.

The seedlings in the conventional polybags were positioned at ground level on a plastic sheet, whereas the seedlings in the specialized containers were effectively suspended in the air due to the unique shape of these containers, which totally prevented direct contact with the ground. While the height measurements yielded no significant difference between the two treatments, the biomass measurements produced intriguing outcomes.

The average total biomass of oak seedlings in traditional containers was 5.43g, whereas for the ones in special containers was of 3.48g, showing statistical significance (p=0.00). The average root biomass for oak seedlings in traditional containers was 3.02g, while for oak seedlings in special containers was of 2.17g, showing a statistically significant difference (p=0.01). For the mean biomass of stems and leaves, oak seedlings in traditional containers displayed an average of 2.41g, whereas their counterparts in special containers showed a mean of 1.3g, once again with a statistically significant distinction (p=0.00).

The data elucidated in the preceding paragraph appears to suggest that oaks exhibit more substantial growth within traditional containers. However, upon assessing the average root percentage relative to the total biomass, a contrasting pattern emerges. For oaks within traditional containers, the average root percentage stood at 55.06%, whereas for oaks in special containers, it reached 64.37%, a statistically significant disparity (p=0.00).

This observation implies that oaks cultivated in special containers indeed possess a higher proportion of roots relative to their overall biomass than their counterparts in soil, albeit less than 10%. Notably, these seedlings exhibit reduced foliage compared to those nurtured in traditional containers. A noteworthy observation from our nursery work, one likely to

considerable influence on the outcomes, is the distinct water access pattern evident between traditional polybag oaks and those in special containers. The traditional polybag oaks, positioned at ground level, benefited from enhanced water availability.

This was due to the direct contact between the irrigation residue and the seedlings on the plastic sheet. In contrast, the special containers, designed for improved ventilation and devoid of direct soil contact, exhibited greater dryness, so their irrigation requirements were much higher. Special containers that demand greater irrigation, might prove less practical and efficient for nursery operations taking into consideration the all-year water access in the region.

Based on our observations in the nursery and the subsequent data analysis, it appears that a trade-off exists between prioritizing root development and

promoting foliage growth. An additional noteworthy factor pertains to the challenge of accurately measuring root structures. Although this nuance may not be immediately evident within the analyzed dataset, our measurements during the study indicated a noticeable presence of more fibrous roots in seedlings housed in the special containers.

In the upcoming months, we will conduct an analysis of seedling survival and growth in the field. This phase aims to shed light on whether emphasizing foliage enhancement or root development proves more advantageous.

This endeavor highlights the complexity of root and foliage dynamics, a theme that this study embarked upon. We remain committed to this monitoring initiative, extending it over the next decade within our designated research plot. Through this sustained effort, we anticipate reaching conclusive answers to the questions initially raised by this research.

This project has resulted in the multiplying and improving of our work for the conservation of *Abronia campbelli.* To achieve our habitat restoration expansion goals, it is crucial that we produce more trees, but also that we produce trees that grow faster, establish quickly after planting, and have high survival rates. The outcomes of this project ripple far beyond the surface, fundamentally shaping the future of *A. campbelli* conservation.

FINAL THOUGHTS

Through unprecedented collaboration, dedicated farms have become custodians of biodiversity, embedding sustainability in their operations. The established farm conservation plan underlines the potential for a transformed landscape capable of sustaining a thriving population of *A. campbelli.* Scientific insights generated through nursery research enhance our toolkit for efficient restoration, while adaptability in the face of challenges exemplifies the synergy between conservation and innovation.