UNIVERSITY OF OREGON LANDSCAPE ARCHITECTURE HANNAH CHAPIN

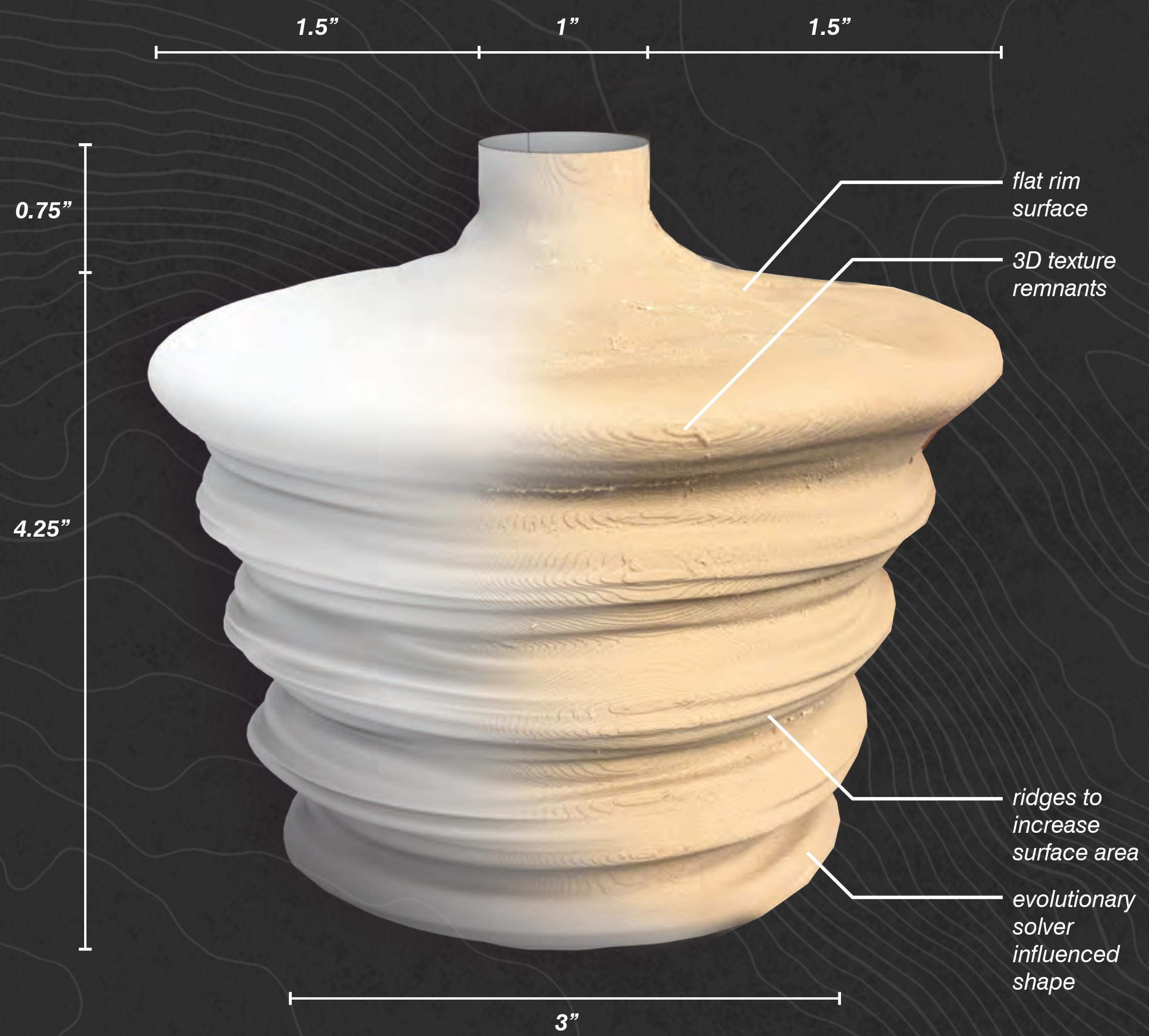
Unearthing Water Efficiency

CLAY POT IRRIGATION DESIGN THROUGH DIGITAL FABRICATION

How to design using an **EVOLUTIONARY SOLVER**

How to fabricate using **SLIP CASTING**

Super efficient irrigation for **PLANT ESTABLISHMENT**



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Special thanks to...

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PREFACE

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HOW CLAY POT IRRIGATION SYSTEMS WORK

CLAY POTS, OLLAS, PITCHERS

Clay pot irrigation, in its simplest form, utilizes unglazed baked porous clay pots buried in the ground near the root system of a plant and is filled with water. As the water slowly seeps out through the clay wall, it provides controlled irrigation for plants. These self-regulating systems are highly efficient due to the water flow rate varing with the plants' water demand.

HISTORY OF CLAY POTS

"Make 530 pits per hectare, each pit 70 cm across and 12 cm deep. To each pit add 18 kg of manure. Mix the manure well with an equal amount of earth. Bury an earthen jar of 61...." - 2000 year old text from Fan Sheng-chih Shu

Clay pot irrigation, also known as olla irrigation, has a rich and extensive history that spans centuries. Buried clay pots have been used in many dry climates worldwide including India, Iran, Africa and South American countries. While the exact origins of olla irrigation are difficult to pinpoint, the technique has been practiced in various regions around the world.

Today, clay pot irrigation continues to be practiced in both small-scale home gardens and larger agricultural operations. Its long history and enduring presence highlight its effectiveness as a water-conserving and plant-friendly irrigation technique.

TIMELINE

~4000 BCE

Ancient Mesopotamia: Clay vessels and terracotta pots were used for irrigation in the fertile lands of Mesopotamia, now present-day Iraq.

~3000 BCE

Ancient China: Chinese farmers used unglazed clay pots buried in the ground to provide a slow and steady water supply to their crops.

~150 BCE

Ancient Rome: The Romans adopted the olla irrigation method and employed it in their extensive agricultural practices.

1000 - 1500 CE

Mesoamerica: Indigenous civilizations, such as the Aztecs and Mayans, utilized olla irrigation as a fundamental technique for their agricultural systems. They created intricate irrigation networks and implemented clay pot irrigation to support the growth of crops.

8th - 15th century

Moorish Spain: During the Islamic rule in Spain, the Moors introduced advanced irrigation systems, including the use of ollas. They utilized clay pots to irrigate gardens, orchards, and agricultural fields.

14th -17th century

Renaissance Europe: Clay pot irrigation gained popularity in Europe during the Renaissance period. Italian and French gardeners incorporated clay pot irrigation into their ornamental gardens.

20th century to present

Modern Era: Olla irrigation has persisted as a traditional and sustainable irrigation method in various parts of the world. It has gained renewed attention in recent years due to its eco-friendly nature and water-saving benefits, particularly in arid and water-stressed regions.

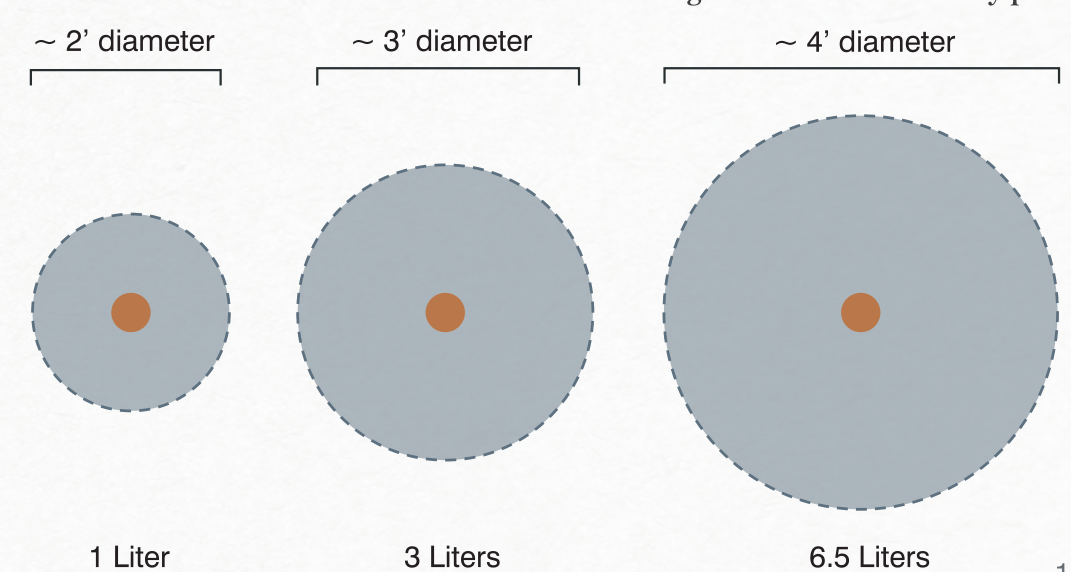
https://www.thecaliforniapotcompany.com/aboutirrigationpots

Pitcher irrigation promotes accelerated plant establishment and enhanced growth rates.

EXPLORING ROOT INTERACTIONS WITH CLAY POTS *and selecting suitable plants.*

https://www.thecaliforniapotcompany.com/aboutirrigationpots

Watering diameter based on clay pot size.



Irrigation pots ranging from 80 to 148 ounces have the capacity to effectively irrigate an area slightly larger than a 36-inch diameter. Smaller pots, around 22 ounces, can cover approximately a 24-inch diameter area. It's important to note that the specific characteristics of the soil can influence these radius measurements. Soils with a higher proportion of sand may result in a slightly reduced effective radius, while soils with a higher clay content may allow for a larger radius of coverage.

clay pot

APPLICATIONS

Irrigation pots have a wide range of applications, serving various purposes in farms, gardens, restoration sites, and propagation. They prove particularly valuable in challenging environments characterized by high salinity, extreme aridity, limited water supply, and scarce resources. Clay pot irrigation offers substantial water-saving benefits, and further exploration of pot porosity, including clay-to-sand composition, wall thickness, and firing temperature, holds potential for optimizing irrigation efficiency with different vegetable crops. Ongoing research into effective irrigation systems, like clay pots, is essential for equipping us with the necessary tools to combat future droughts and ensure sustainable water management practices.

Clay pots reduce the cost and improve the success of environmental restoration, landscaping, and re-vegetation projects.

clay pots for

HOUSE PLANTS

The concept of clay pot irrigation remains the same whether the plant is inside or outside - the porous clay pot is buried in the soil near the root system of the plant, and filled with water. The water slowly seeps out through the pores in the clay, providing a steady supply of moisture to the plant's roots. When using a clay pot for indoor plants, it is important to select a pot that is appropriately sized for the plant and the container it is growing in.

The olla should be buried in the soil near the root system, but not so deep that it interferes with the growth of the plant. One advantage of using an olla for houseplants is that it can help maintain a consistent level of moisture in the soil, which can be difficult to achieve with traditional watering methods.

Clay pots for house plants.

Exploring the latest offerings on Etsy's marketplace.

clay pots for

LANDSCAPING

In the present day, an array of diverse designs has emerged for both indoor and outdoor clay pot irrigation systems. Innovations range from extending the neck length of the pots to selectively glazing specific areas or even incorporating hose attachments, enabling further exploration of the system's efficiency. These advancements provide ample opportunities to enhance and customize the performance of clay pot irrigation, making it a versatile and adaptable option for various watering needs.

UTILIZING CLAY POTS FOR DIFFERENT LANDSCAPES.

Exploring efficiency: innovations in clay pots for house plants.

While the shape of clay pots has received more extensive research regarding plant growth, it is important to also explore the role of surface area and texture in maximizing root interactions with clay pots. Increasing the surface area can be achieved through various methods, such as incorporating ridges, grooves, or perforations on the pot's walls. This enables the root system to establish a more extensive contact with the porous clay surface. Additionally, incorporating textures that promote root adhesion, such as slightly rough or uneven surfaces, can further enhance the root-pot interaction. These strategies not only encourage better water uptake but could also stimulate root branching and overall plant growth.

INNOVATING SURFACE TEXTURE

and designing for root interactions

INTRODUCTION

02

INTRODUCTION TO PROJECT

MULTI-FOLD PROCESS

My project focuses on utilizing digital technologies to evolve the design and application of clay pots for irrigation purposes. Through research and experimentation, the aim was to gain a deeper understanding of how these digital tools can be utilized to enhance irrigation performance, reduce water consumption, and improve land management.

DESIGN & MANUFACTURING EVOLUTION

of clay pots

Hand-building → Pottery Wheel Throwing → Slip Casting → Slip Casting + Digital Design + 3D Printing

	Hand-building	Pottery Wheel Throwing	Slip Casting	Slip Casting + Digital Design + 3D Printing
Skills & Tools Needed:	Pinching Coiling Slab Construction Hand-eye Coordination	Pottery Wheel Mastery of Many Techniques: Centering Shaping Pulling	Mold Making & Preparation Slip Preparation	3D Printer Software Knowledge
Outcome of Pot:	Organic & Irregular Shape Variations in Size & Thickness Requires more time	Symmetrical & Consistent Forms Smooth & Refined Surfaces Efficiency & Reproducibility	Reproducibility & Precision Complex & Intricate Designs Smooth & Uniform Surfaces	Rapid Prototyping Design Freedom Customization & Personalization Manufacturing Complexity Iterative Design Reduce Cost & Waste Decentralized Process

TIMELINE

Hand Building | Pottery Wheel | Slip Casting | 3D Printing + Digital Design + Slip Casting

~4000 BCE — *Ancient Mesopotamia: Clay vessels and terracotta pots were used for irrigation in the fertile lands of Mesopotamia, now present-day Iraq.*

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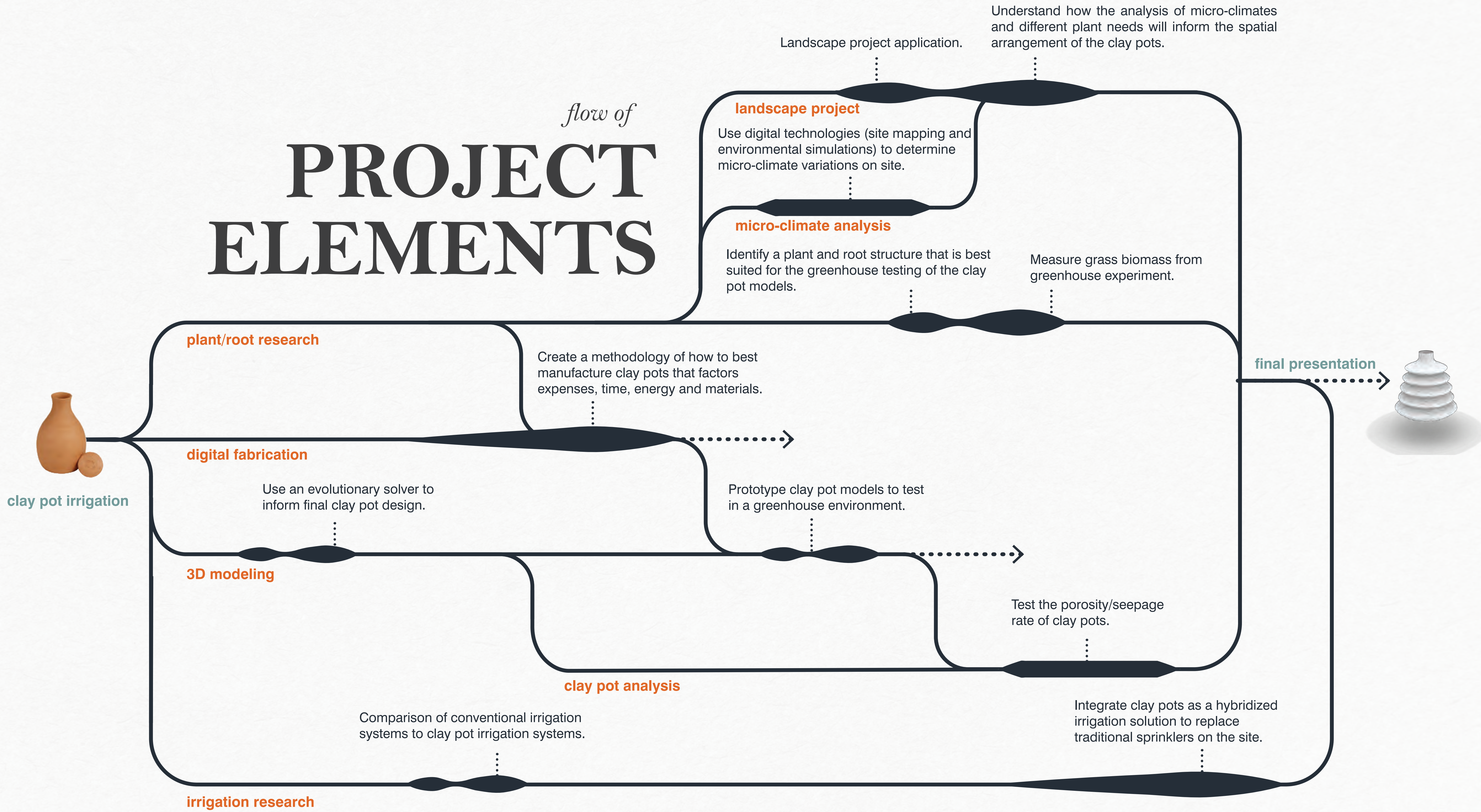
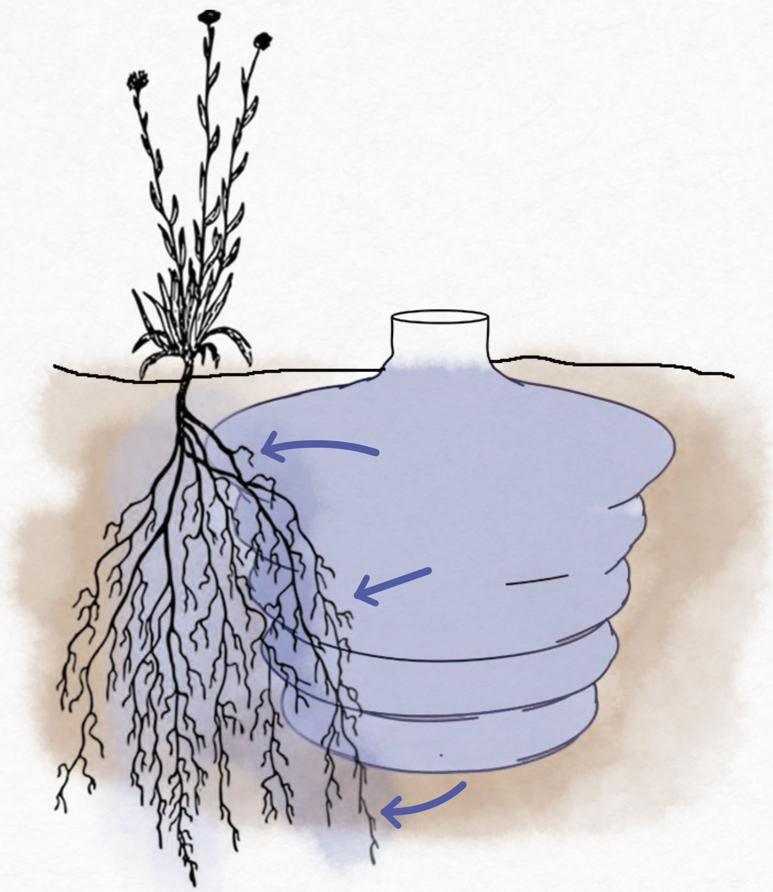
flow of

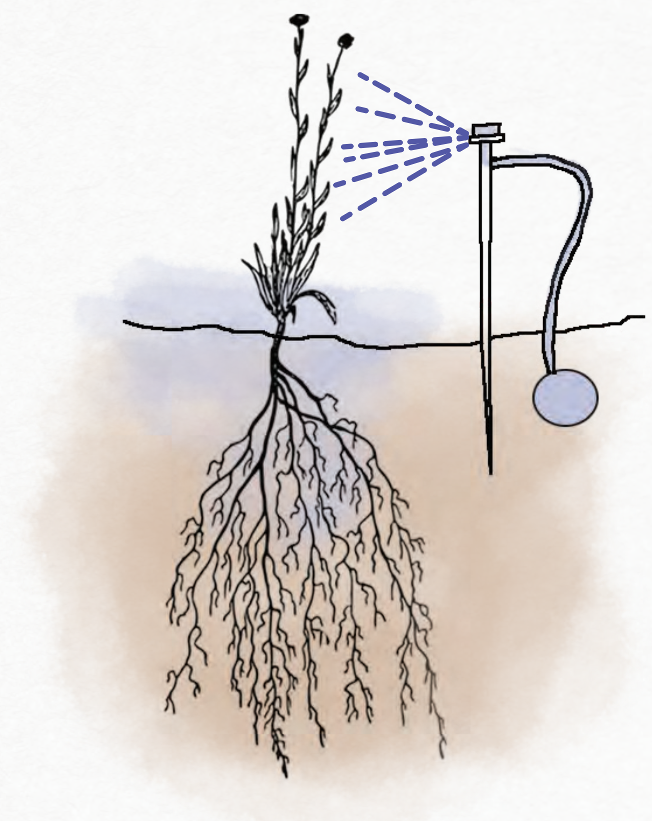
PROJECT ELEMENTS



COMPARING CONVENTIONAL IRRIGATION SYSTEMS TO CLAY POT IRRIGATION

at a small scale

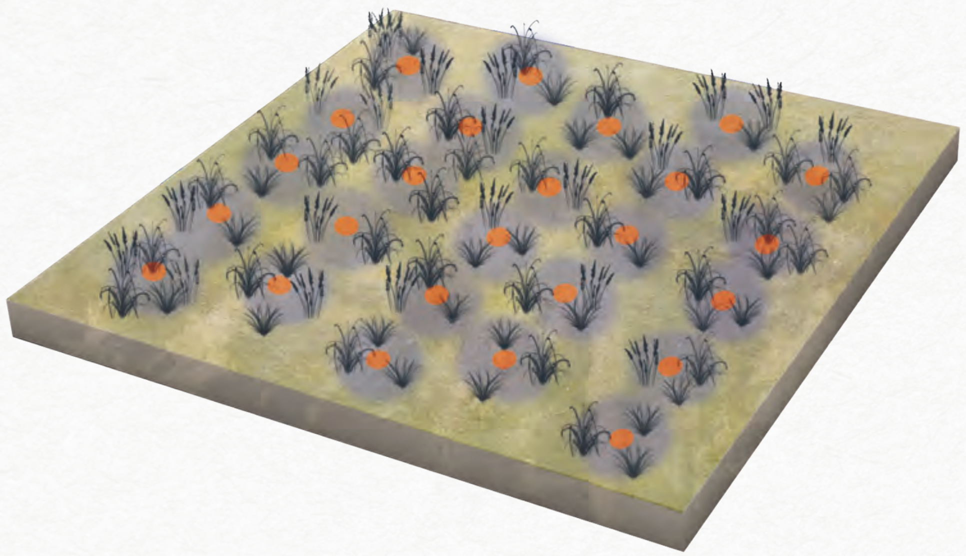


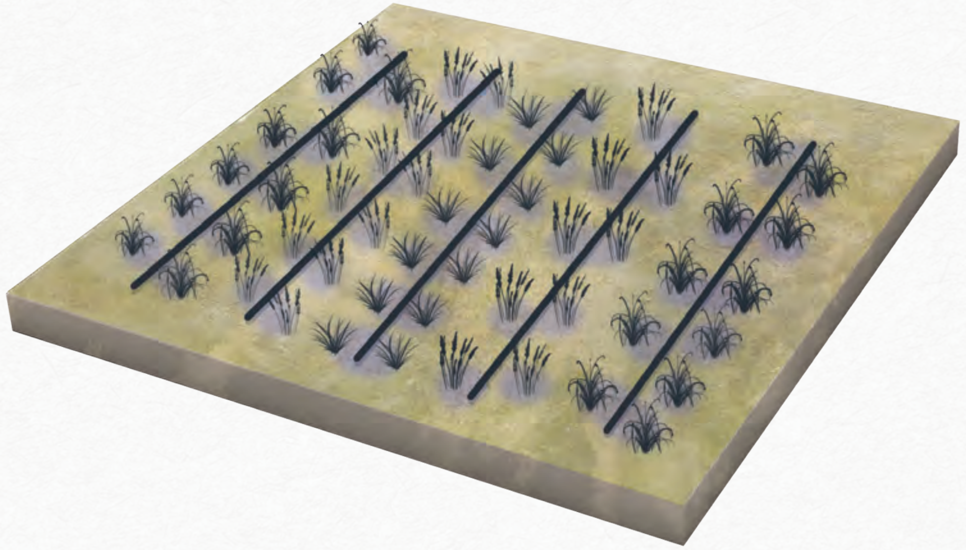


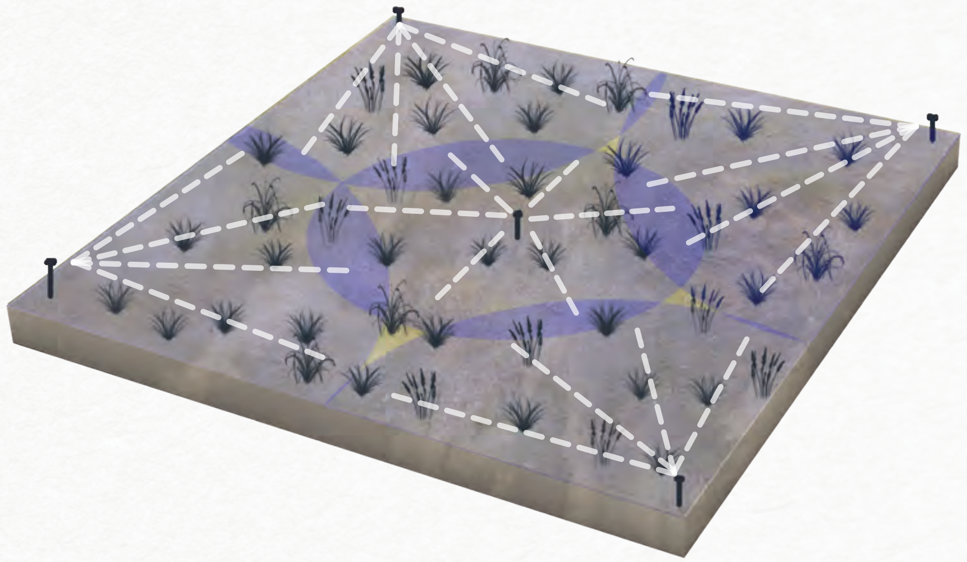
CLAY POT IRRIGATION	DRIP IRRIGATION	SPRAY IRRIGATION
Water directed to roots	Provides targeted watering	Water sprayed through air
No evaporation	Minimal evaporation	Heavy evaporation
Roots control water amount	Pre-determined water amount	Pre-determined water amount
Provides a constant water supply	Automated water supply	Automated water supply
Reduces disease risks: ideal for water-sensitive plants	Reduces disease risks	Can damage leaves

COMPARING CONVENTIONAL IRRIGATION SYSTEMS TO CLAY POT IRRIGATION

at a large scale





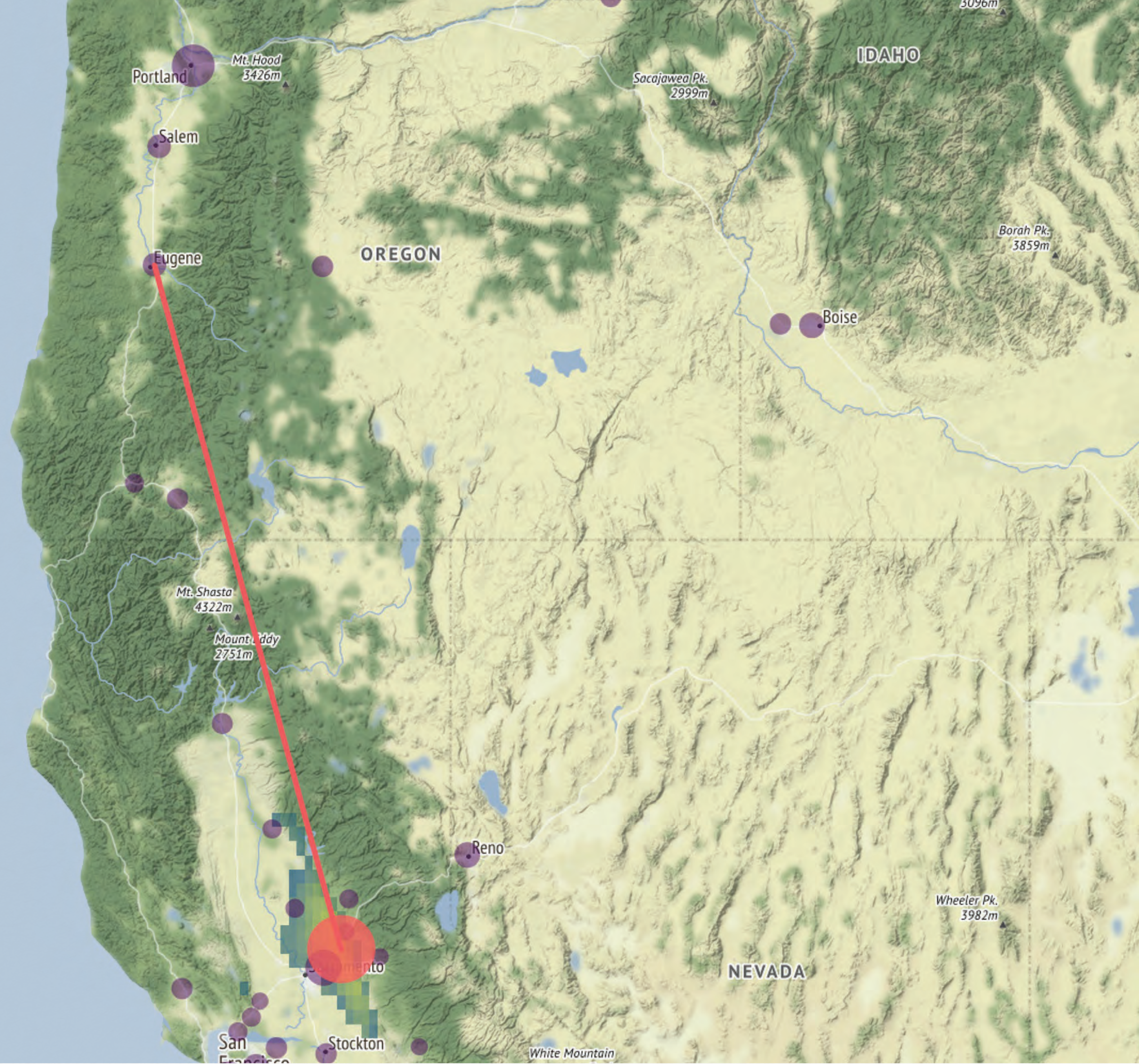


CLAY POT IRRIGATION	***DRIP IRRIGATION***	***SPRAY IRRIGATION***
Cost effective	Demands special materials	Demands special materials
No electricity	Requires electricity	Requires electricity
Easily Implemented for small-scale projects	Either small or large scale	Suitable for large areas
Improved production efficiency	Sophisticated manufacturing	Sophisticated manufacturing
DIY potential	Requires careful planning & installation	Requires careful planning & installation
Requires minimal maintenance	Requires regular maintenance: easily blocked w/ sediment	Requires regular maintenance

FUTURE CLIMATE CONDITIONS

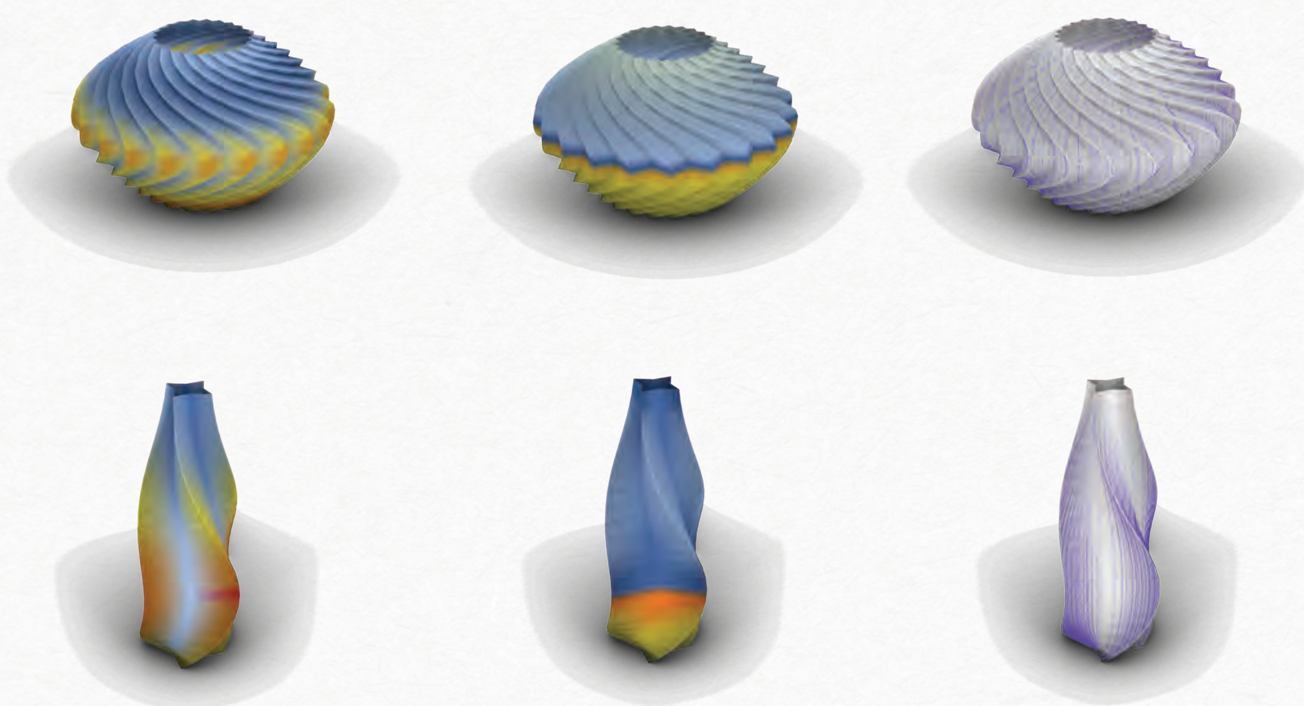
of Eugene in 2080

By 2080, the climate in Eugene is projected to resemble the current climate in Granite Bay, California. In Granite Bay, summers are typically 13.8°F hotter and 86.2% drier than in Eugene. This anticipated shift in summer drought and heat will have significant implications for growing conditions and will require ongoing adaptation of irrigation practices.

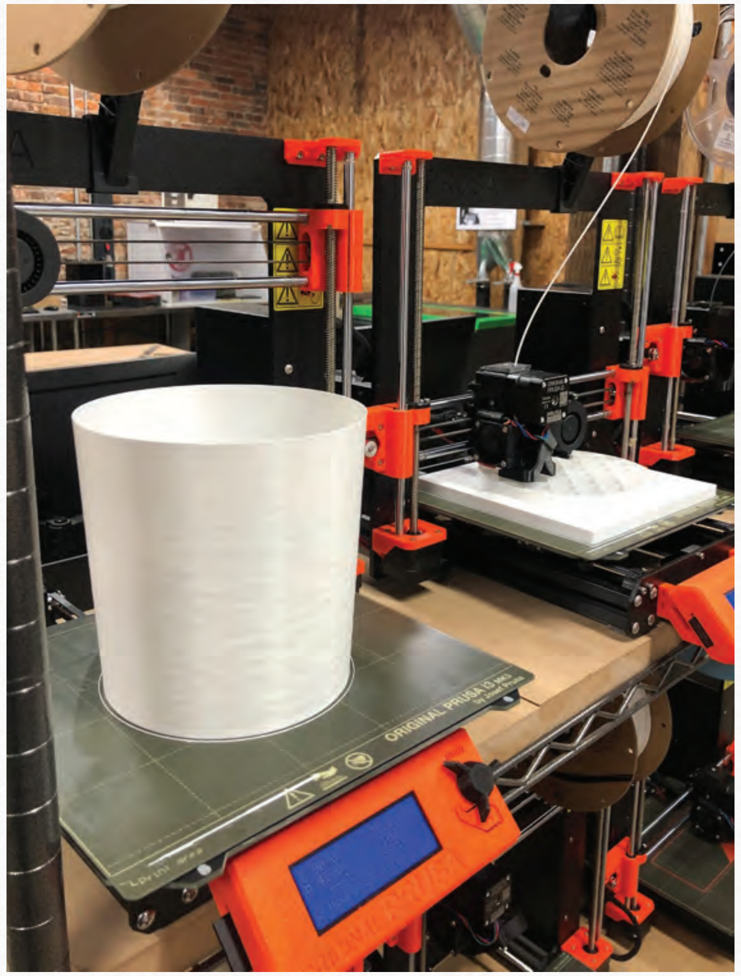


DIGITAL TECHNOLOGIES

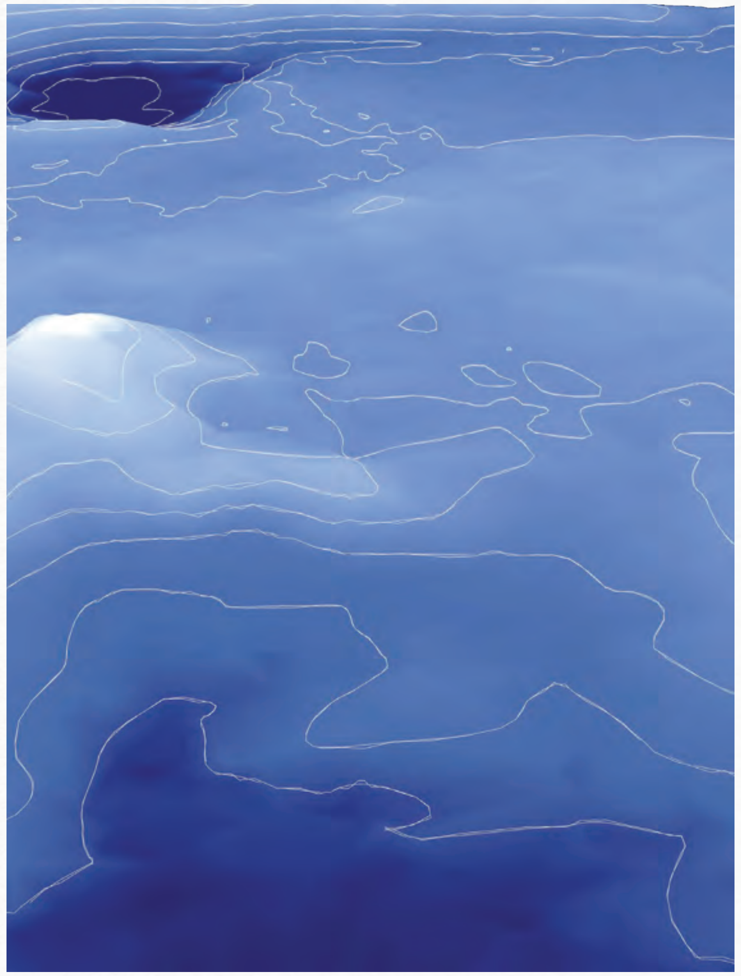
algorithmic design, digital fabrication, and micro-climate analysis



While clay pots are readily available for purchase at garden stores, the utilization of 3D printers presents a range of advantages when it comes to exploring clay pot design and efficiency. 3D printers provide enhanced customization and precision, allowing for greater design flexibility and intricate details. Additionally, they offer accessibility and efficiency in the manufacturing process, enabling individuals without specialized wheel-throwing skills to engage in clay pot production. The integration of digital design with 3D printing has revolutionized product development, offering designers unprecedented freedom to create complex and customized objects. With 3D printing, digital designs can be translated into physical objects by adding material layer by layer, opening up new possibilities that were previously challenging or impossible with traditional methods. This innovation enables iterative prototyping, allowing designers to modify digital models and print new iterations quickly and cost-effectively. Forexample, in fields like healthcare, the combination of digital design and 3D printing allows for extensive customization, addressing individual needs. Design optimization algorithms further enhance the process, fostering lightweight and efficient designs that minimize waste and enhance product functionality. Additionally, digital technologies and computational modeling can help assess micro-climate variations on-site, guiding the layout of clay pot irrigation systems by analyzing factors such as water flow patterns, sunlight exposure, shading influences, and wind direction.



3D printing one-part master mold to use for fabrication process.

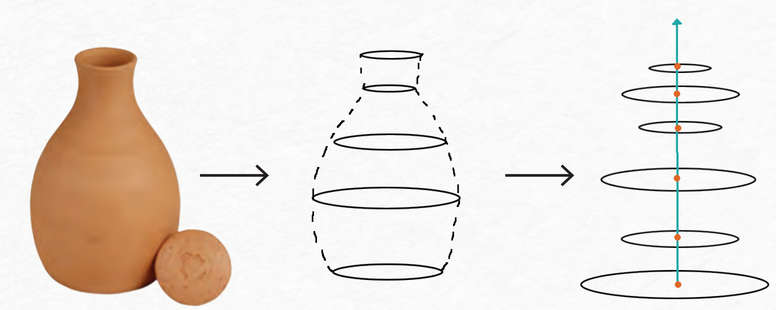


Beginning steps of learning how to 3D print for the fabrication phase.

METHODS

03

HOW TO DESIGN CLAY POTS

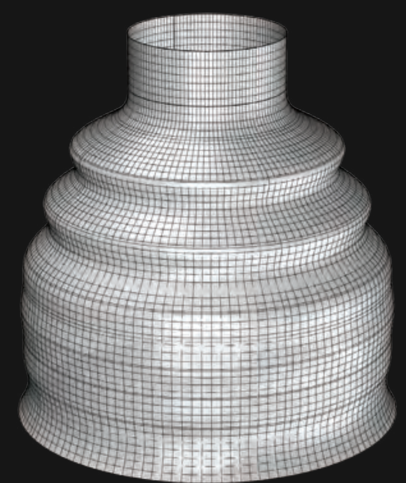


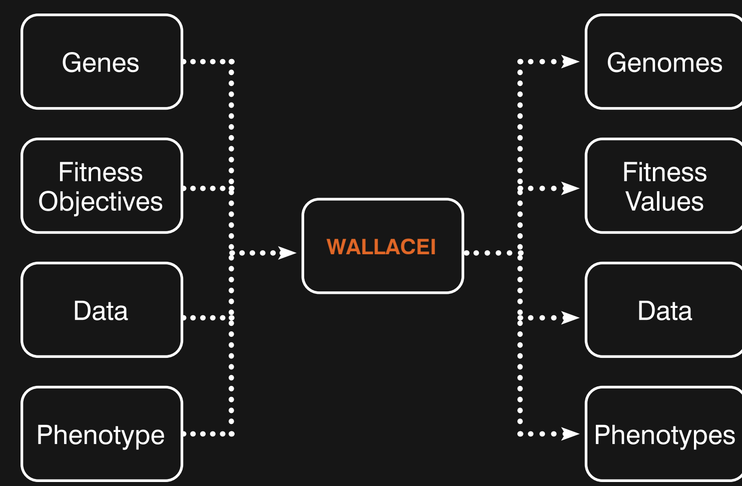
DECONSTRUCTING GEOMETRIES

Exploring different clay pot shapes and surface areas is crucial because the form directly impacts water distribution, evaporation rate, root growth patterns, aesthetic appeal, and space optimization. When considering the use of algorithmic solvers to aid in design solutions, it was important to deconstruct and analyze the pot geometries in order to create a definition in Grasshopper.

Generation Size: 100
Generation Count: 100
Population Size: 10000

Evolutionary Solvers



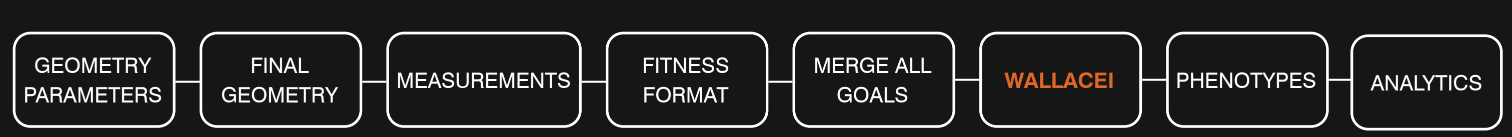


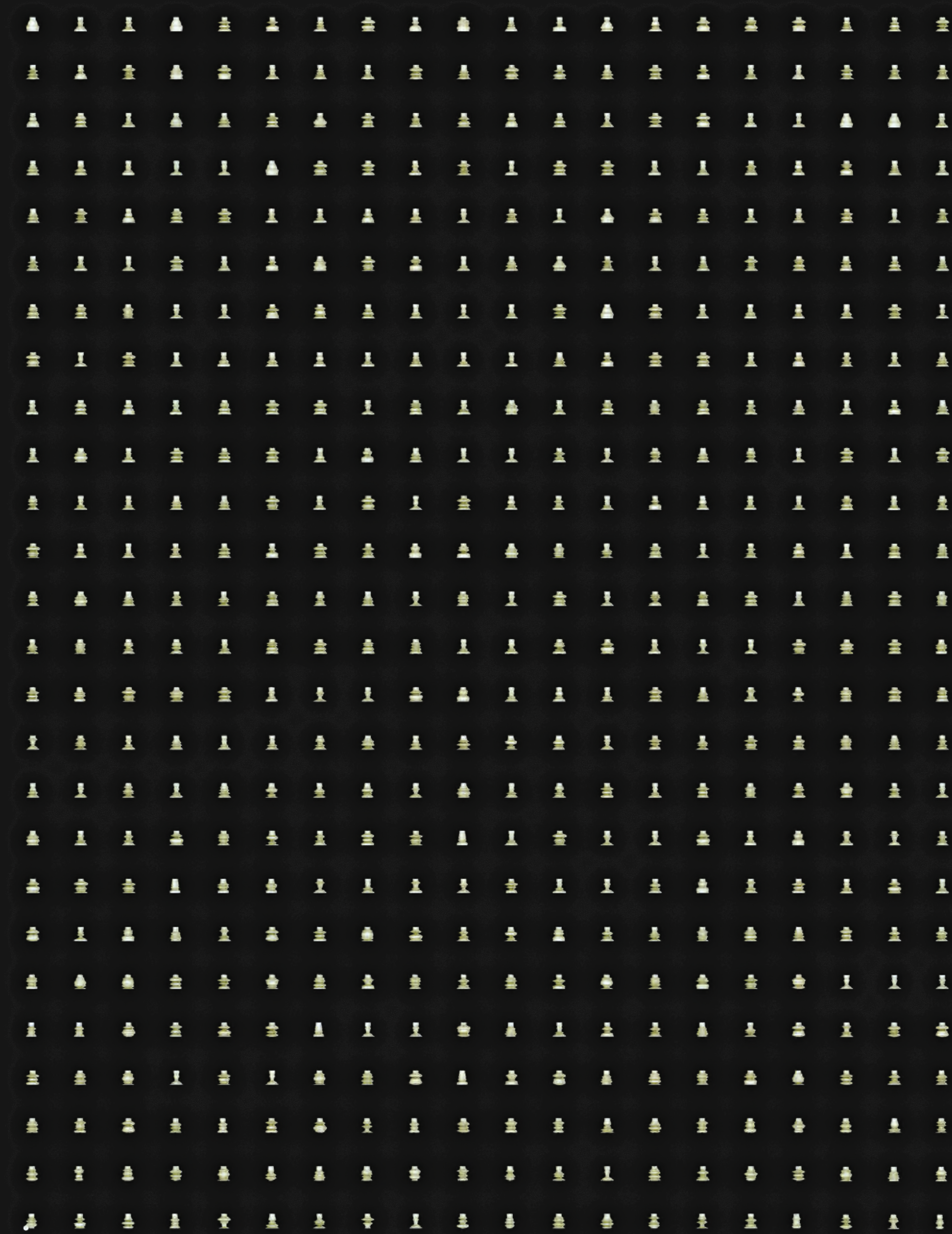
Input values required for Wallacei and the corresponding output data.

WALLACEI

Wallacei is a powerful evolutionary engine integrated with Grasshopper 3D, enabling users to conduct evolutionary simulations. It combines advanced analytics, comprehensive selection methods, and detailed tools to enhance users' understanding of their evolutionary runs. From setting up the design problem to analyzing results and selecting optimal solutions, Wallacei allowed the clay pot design decisions to be informed throughout the simulation process. Furthermore, it offered the flexibility to select, reconstruct, and output desired phenotypes from the population, providing a robust framework for achieving the desired final output to help inform the clay pot design.

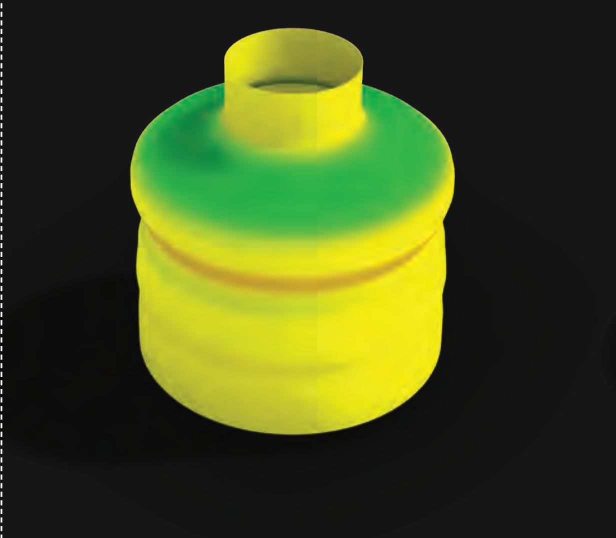
A condensed grasshopper definition utilizing Wallacei.

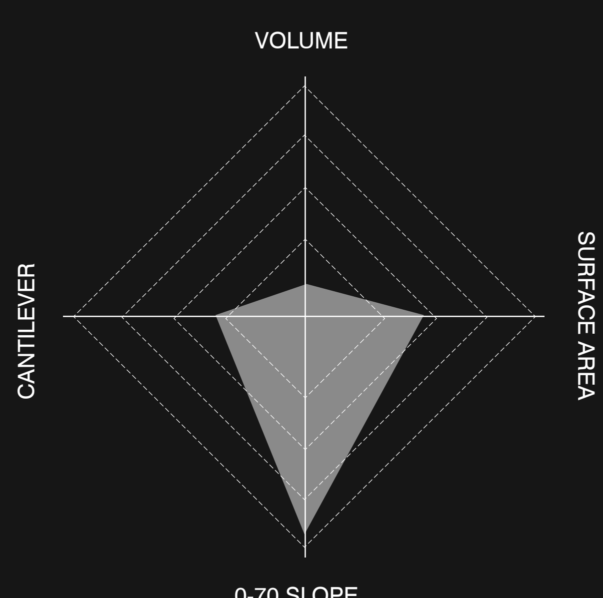




Objective 1: Maximize Volume

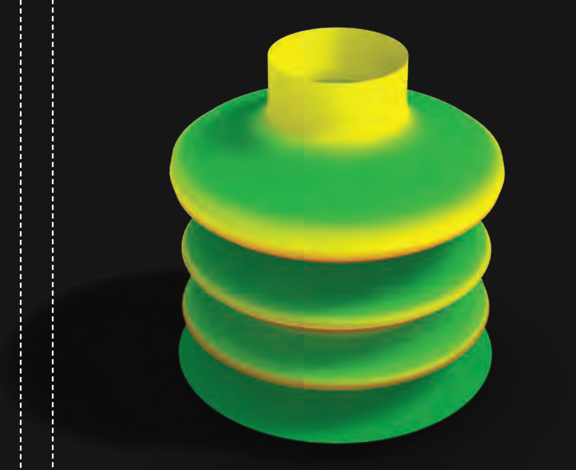
Increase Volume: To expand water storage for plants.

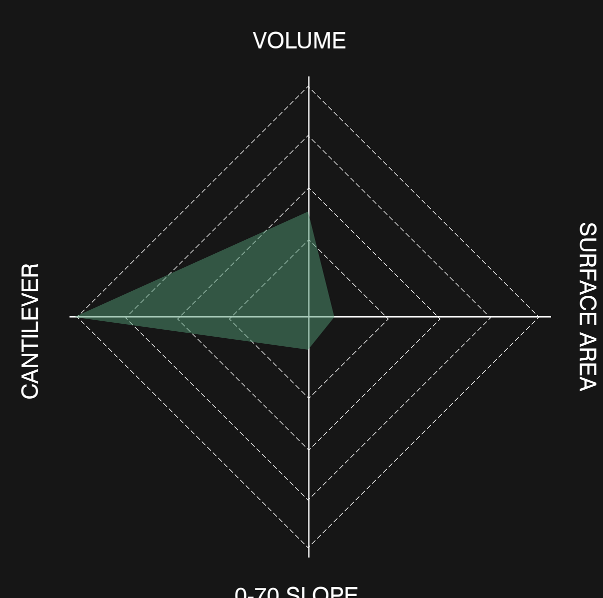




Objective 2: Maximize Surface Area

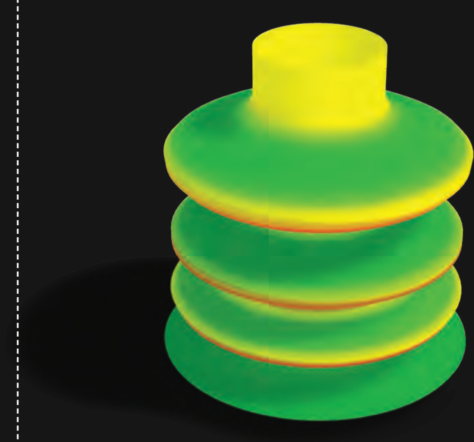
Increase Surface Area: Enhancing root-pot interactions.

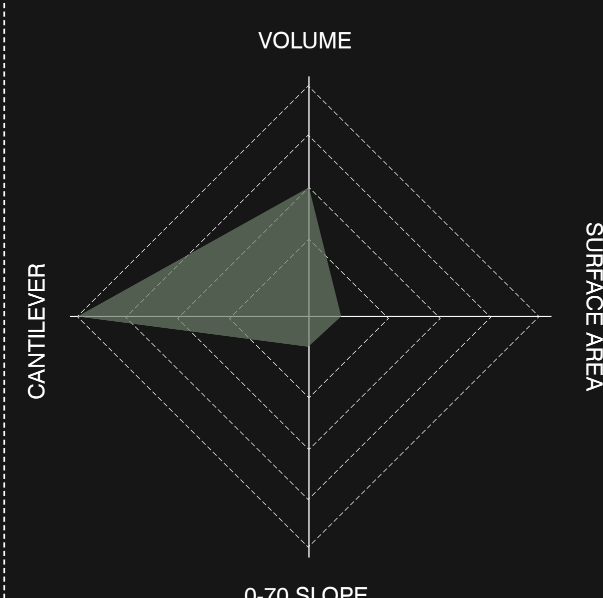




Objective 3: Maximize10-70 Slope

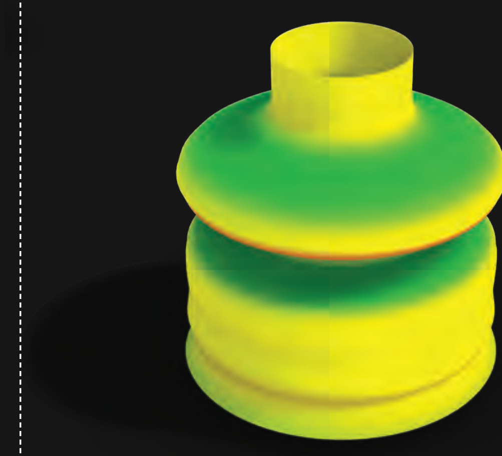
Increase Slope 10- 70: Expand surface area and root-pot interactions.

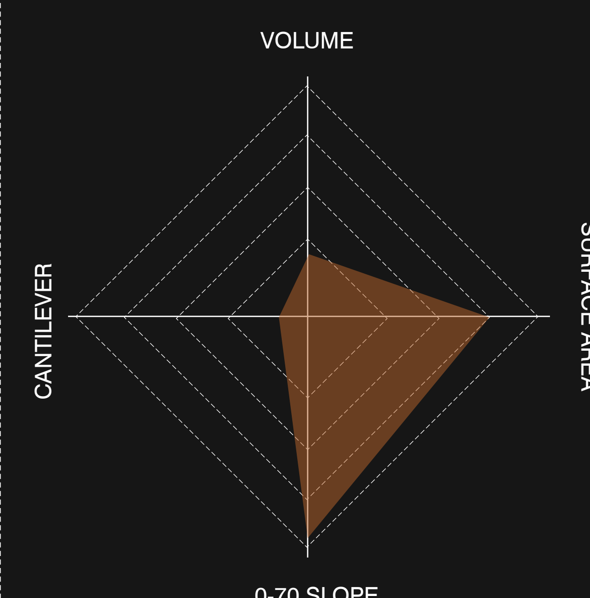




Objective 4: Minimize Cantilever

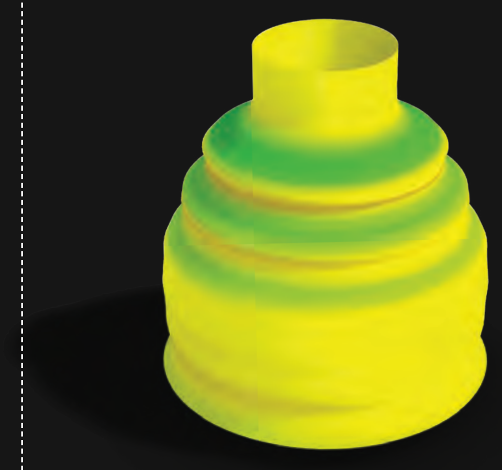
Decrease Cantilever: Allows structure to maintain durability.

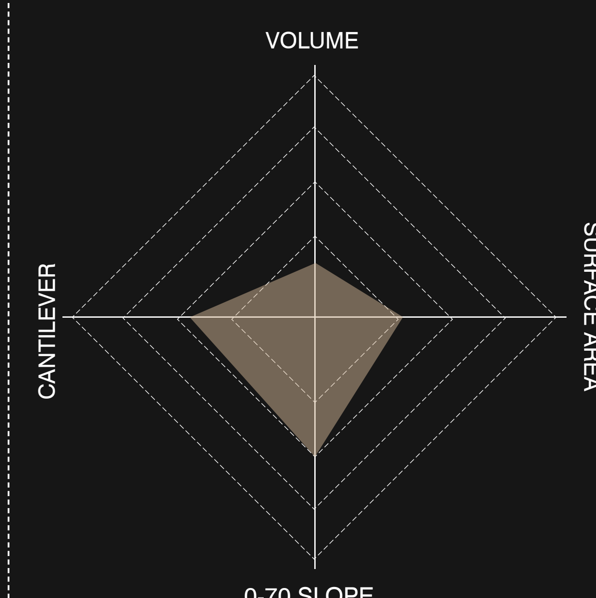




Average of Fitness Ranks

This phenotype shows the average of fitness ranks for over 10,000 iterations.

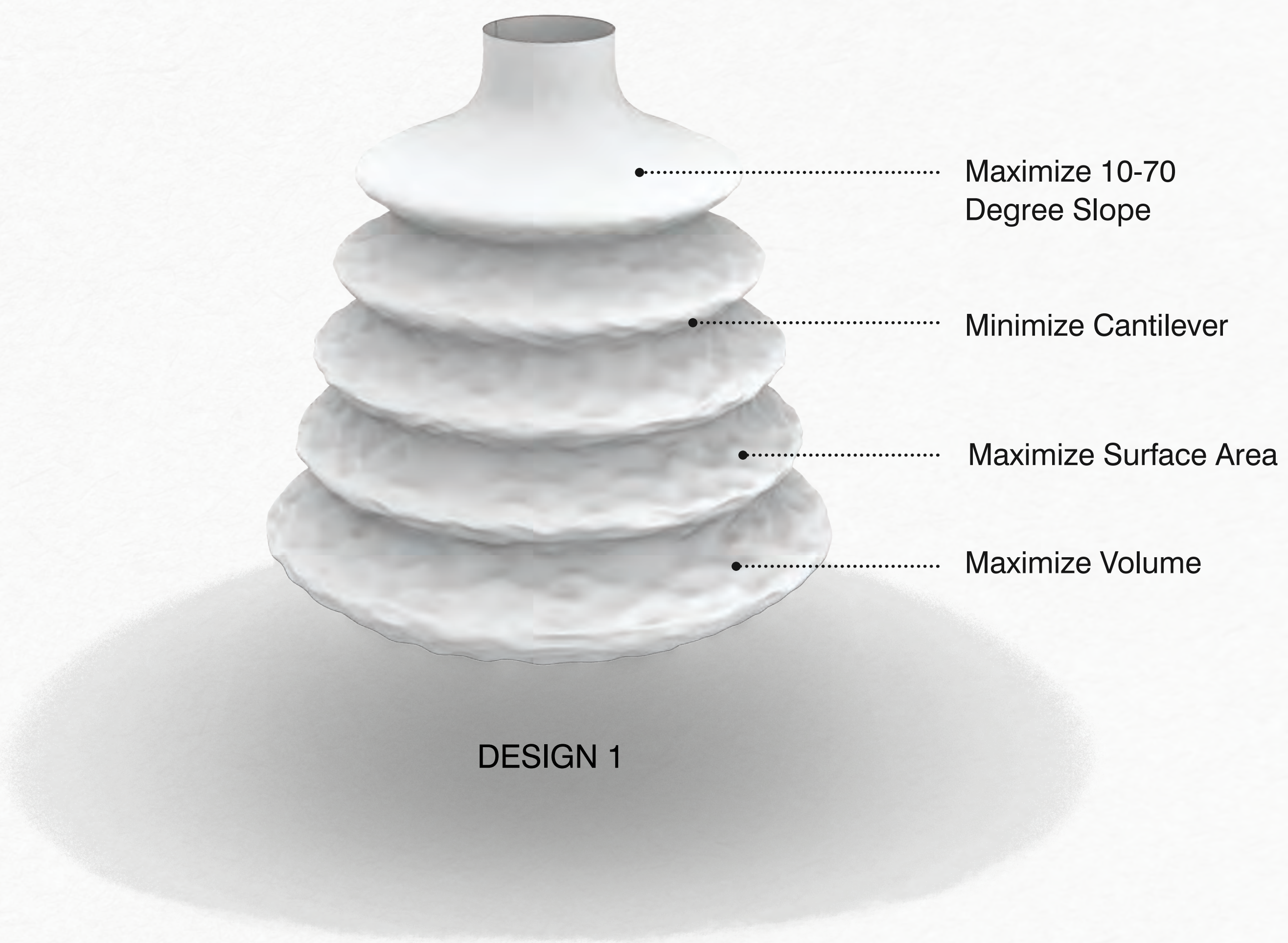




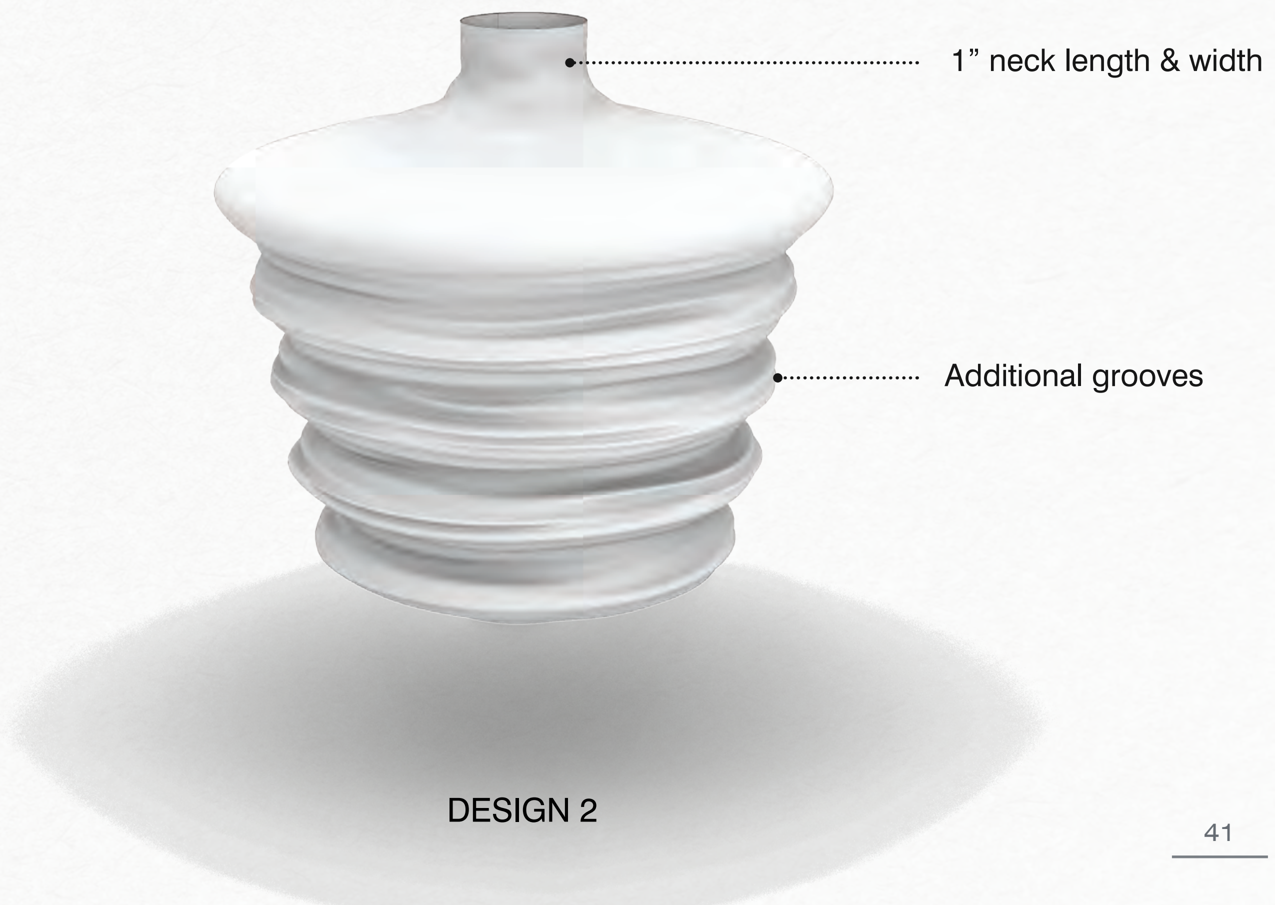
DATA INFORMED

clay pot design

While using Wallacei informed my decision-making process and facilitated the finalization of two clay pot shapes, I took over the final creative choices and added textures, inverted shapes to change the water distribution, speculated on the neck length, and adjusted the bottom of the pots to have a rounded structure.



DESIGN 1

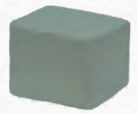


DESIGN 2

CLAY TYPE

Earthenware — REJECTED

- Uses: Sculpting, hand-building, & wheel throwing.
- Firing Temperatures: Optimum hardness at lower temps: ~1745 F and 2012 F.
- Porosity: Most porous.
- Plasticity: Highly plastic and contains iron & other mineral impurities.
- Other Facts: Oldest and most common clay. Terracotta most popular.



Ball

- Uses: Mainly used in slip casting, also used for wheel throwing.
- Firing Temperatures: Shrinks excessively. Fire to mature hardness at ~ 2336 F.
- Porosity: Semi-porous.
- Plasticity: Highly plastic and contain few impurities.
- Other Facts: High unfired strength.

Stoneware — REJECTED

- Uses: Hand-building and wheel thrown. Popular for tableware.
- Firing Temperatures: Matures between high temps. ~2,167 F to 2345 F.
- Porosity: ~~Not porous.~~
- Plasticity: Moderately plastic and hard.
- Other Facts: Very durable and dense.

Porcelain — REJECTED

- Uses: Wheel throwing & cast slipping. For tableware & vases.
- Firing Temperatures: Matures between 2381 F and 2455 F.
- Porosity: ~~Not porous.~~
- Plasticity: Least plasticity.
- Other Facts: 3 types of porcelain: hard-paste, soft-paste, & bone china.

FABRICATION METHOD

Slip Cast Mold

- 3D print PLA pot, then build cast
  - No limitations to geometry.
  - Clay pot surface can be analyzed.
  - More steps to create cast.
  - PLA is expensive.
  - Less wasteful of clay material.
- CNC/laser cut the pot, then build cast
  - Laser allows for stacking affect.
  - ~~Less accurate process.~~

3D Clay Printer — REJECTED

- Print pot using a 3D Clay Printer
  - Eliminate need to use PLA.
  - ~~Difficulty printing if clay is not properly prepared.~~
  - ~~Might create gaps in the wall.~~
  - ~~Clay printers are expensive.~~
  - ~~Shape could collapse while printing.~~

Wheel Thrown — REJECTED

- Wheel Thrown
  - ~~Need skill-set in craft.~~
  - ~~Unable to analyze pot shape.~~
  - ~~Less control over shape.~~
  - Eliminate need to use PLA.
  - Less expensive materials.

Analysis of FABRICATION METHOD & CLAY TYPE

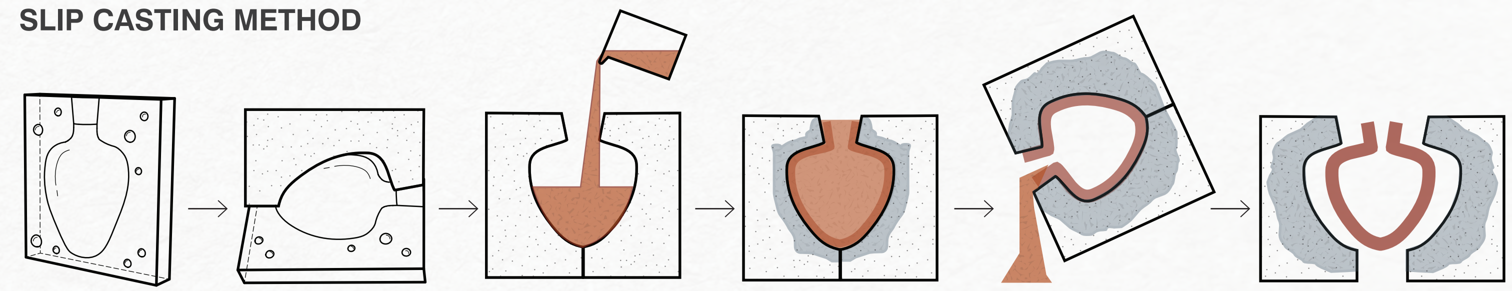
Industrial

CERAMICS

Slip casting is a widely utilized technique in the realm of industrial ceramics, offering a versatile and efficient method of shaping ceramic materials. For this method, ceramic particles are first suspended in water to form a fluid mixture known as 'slip'. The composition and viscosity of the slip can be adjusted to achieve the desired properties for casting. This slip is then carefully poured into a specially prepared plaster mold.

The plaster mold plays a crucial role in the slip casting process. The porous nature of the dry plaster allows water from the slip to be gradually absorbed, leading to the formation of a solid layer of ceramic on the inner surface of the mold. This layer starts to develop immediately upon contact with the mold, with the thickness increasing over time.

SLIP CASTING METHOD



To ensure uniform thickness and optimal casting results, the mold is rotated and tilted during the casting process. This helps distribute the slip evenly across the mold's interior, allowing for consistent ceramic deposition. As the casting progresses, the plaster mold acts as a filter, separating the liquid portion of the slip from the solid particles.

Once the desired thickness has been achieved, the mold is carefully inverted, allowing any excess liquid to drain out. The remaining ceramic layer, still in its malleable or 'green' state, retains the shape and details of the mold. The excess ceramic around the opening of the mold is trimmed, ensuring clean edges and a neat final product.

After the mold is opened, the molded ceramic object is removed and set aside for further processing. Depending on the specific requirements, the greenware may undergo additional treatments, such as drying, refining, or surface decoration, before being fired in a kiln. The firing process transforms the molded ceramic into a durable, hardened material, ready for various applications ranging from functional pottery to intricate sculptural pieces.

Slip casting offers numerous advantages in ceramic production, including the ability to reproduce intricate details, achieve consistent thickness, and create complex shapes. It is a versatile and widely utilized method that has contributed to the production of diverse ceramic objects found in everyday life, art, and design.

+

- Ideal for producing hollow ware.
- Complex forms can easily be achieved.
- Efficient use of material.
- Lends itself well to low-production runs.
- Allows for production of a lot of homogeneous clay pieces without compromising the shape.

–

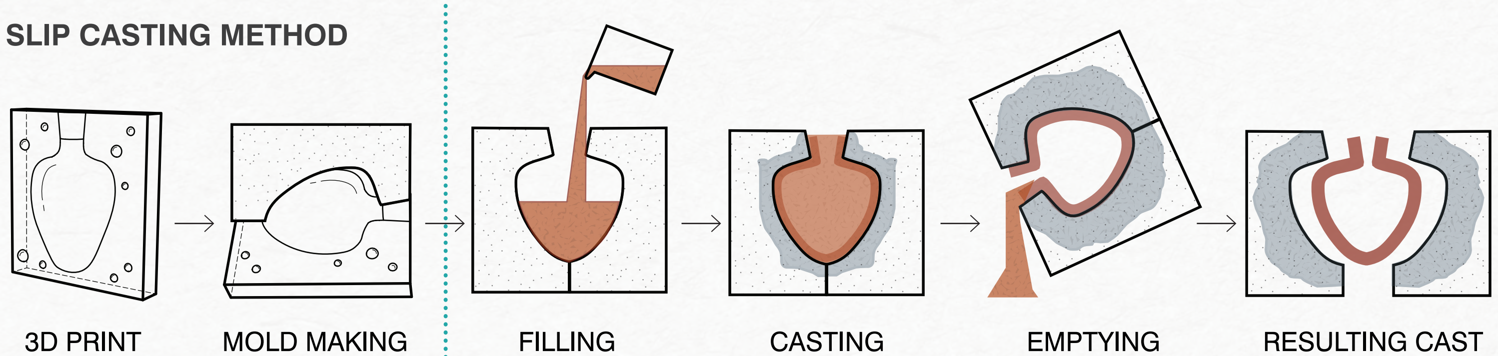
- Labor-intensive.
- Limited control over tolerances.
- Slow production rate.
- Large-scale production requires many molds.
- Larger storage space required.

3D PRINTING & MOLD MAKING

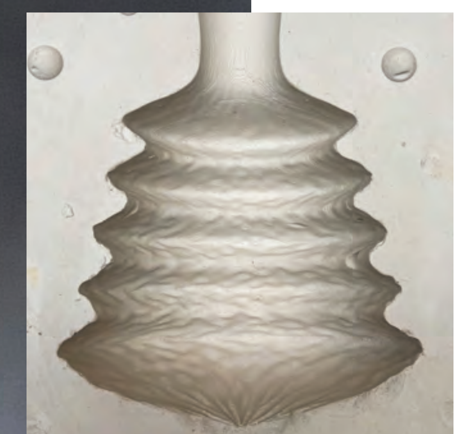
A 3D-printed pot design utilized for creating the plaster master mold.

The step-by-step process of utilizing the 3D print to create the master mold.

SLIP CASTING METHOD



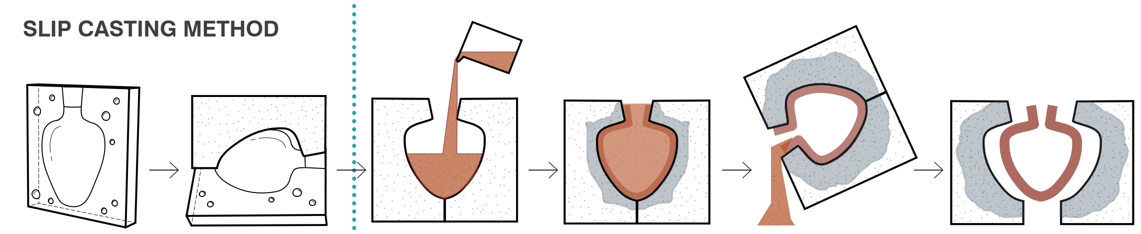
Texture remnants from the 3D print.



CASTING NOTES

1. Minimum of 4 bands is needed to hold mold together.
2. Once slip is emptied from mold, let the mold sit upside down for 15 min before flipping it to the correct orientation for the remainder of the hour.
3. The clay cast will dry from the top down, and needs to be cleaned within the day.
4. Optimal Casting times: wall thickness (55 min), drying in cast (60 min), drying before clean up (60 min), and drying before firing (24 hr).

SLIP CASTING METHOD



ONE VS TWO PIECE

master molds

1

Ideal for simple, solid shapes without undercuts

Offers a quick and easy method for creating ceramic objects with one-piece molds

Enables straightforward and efficient production

2

Suitable for forms with undercuts or complex shapes

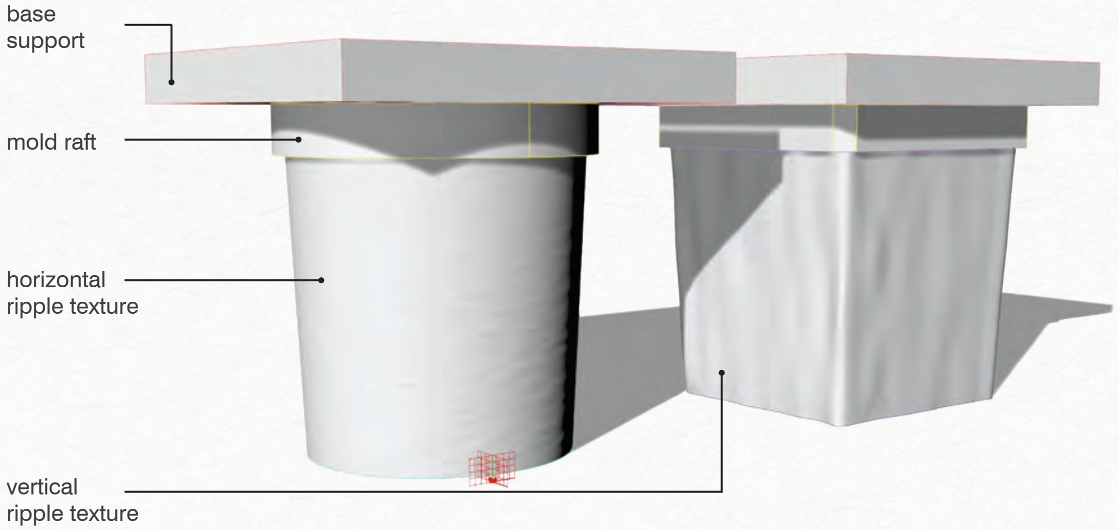
Enables the production of ceramic objects with intricate details and varied geometries

Mold parts are more difficult to produce

Require keys

3D Print and Mold Making Notes:

1. Draft angle (3%), height of print (7.5 in.), diameter of print (7 in.), height of pot (6 in.), diameter of pot (5.5 in.), texture (ripple), pot volume (56 oz.), and no keys
2. Once slip is emptied from mold, let the mold sit upside down for 15 min before flipping it to the correct orientation for another hour.
3. The clay cast will dry from the top down, and needs to be cleaned within the day.
4. Optimal Casting times: wall thickness (65 min), drying in cast (75 min), drying before clean up (60 min), and drying before firing (24 hr).



BISQUE FIRING

DESIGN 1

DESIGN 2

CONTROL

By exploring various pot shapes, designers can optimize water distribution, balance evaporation for specific conditions, cater to different plant species' root systems, enhance visual appeal, and maximize space utilization.

Thin-walled structures that are both lightweight and strong

Total Pots: 26
Design 1: 11
Design 2: 12
Control: 3

DESIGN 1

DESIGN 2

CONTROL

Retained mold raft for extending neck length of the clay pot design.

Narrow neck width to decrease amount of evaporation.

Texture remnants from 3d print.

Disk-like shapes to increase the surface area.

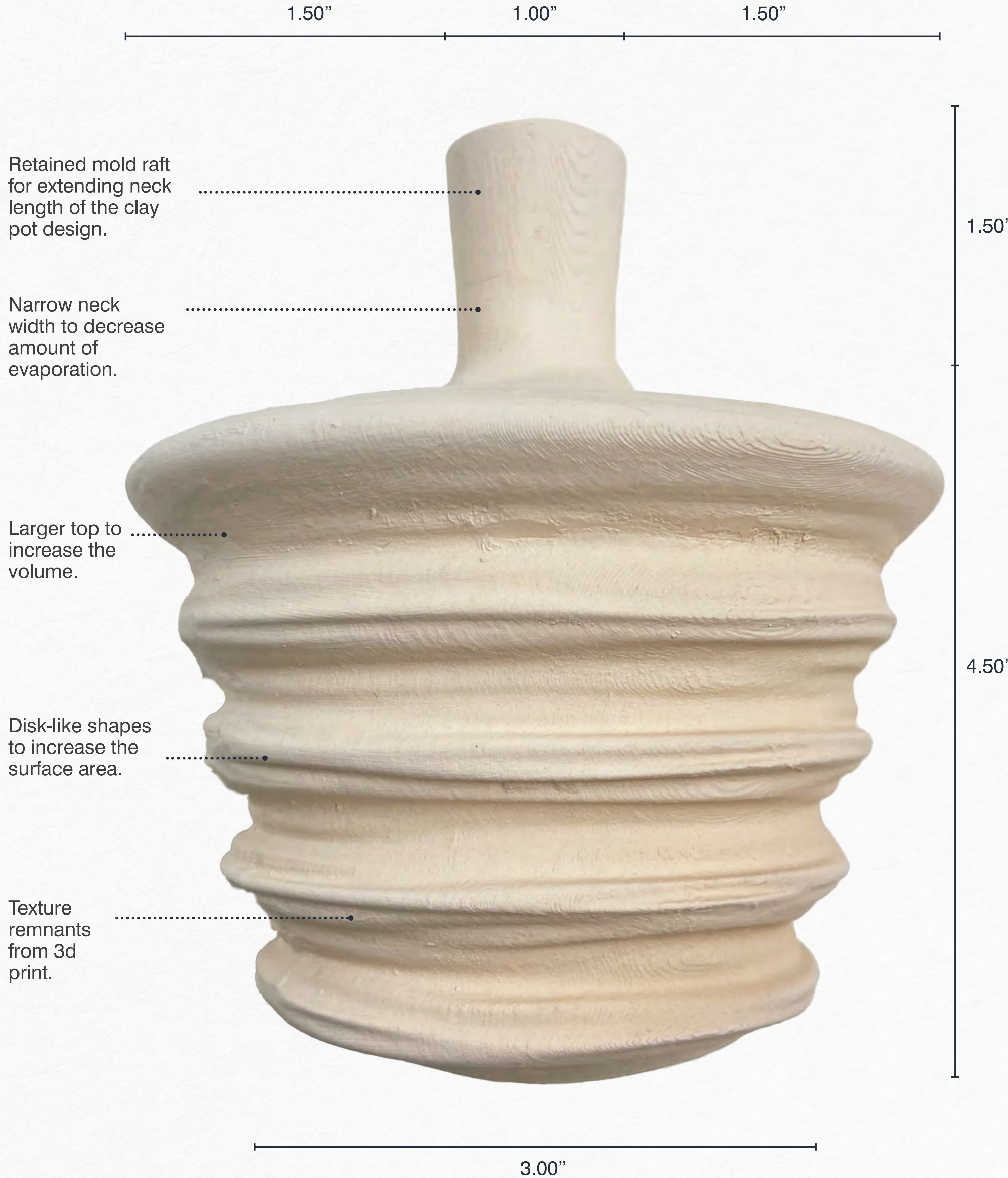
Larger base to increase the volume.

Volume: 600 mL
Watering Diameter: ~22 in.

DESIGN 1

DESIGN 2

CONTROL

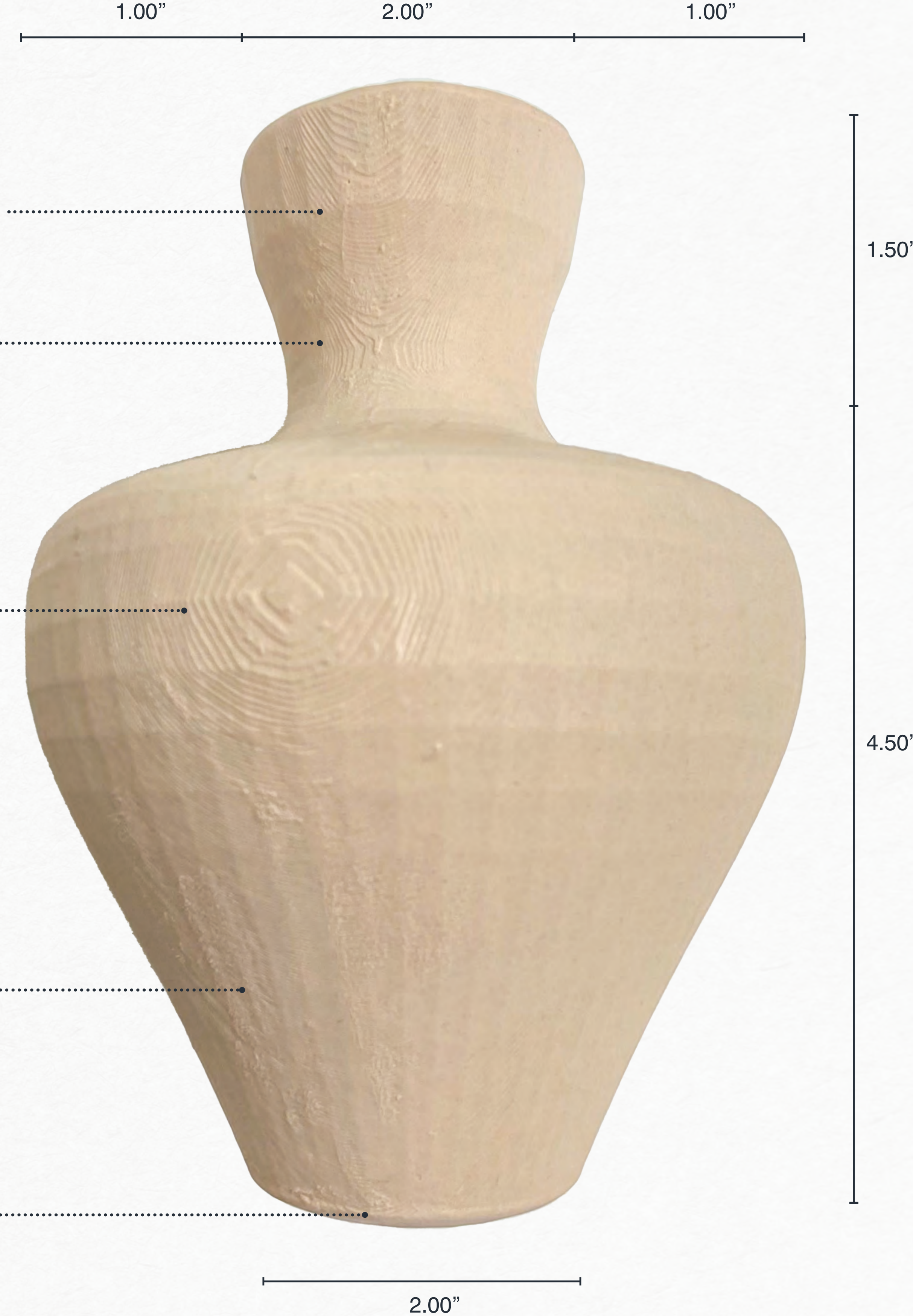


DESIGN 1

DESIGN 2

CONTROL

CONTROL



Retained mold raft for extending neck length of the clay pot design.

Traditional wider shaped neck.

Texture remnants from 3d print.

Tapered body shape to facilitate easier burial in soil.

Rounded bottom for pot durability.

Volume: 600 mL
Watering Diameter: ~22 in.

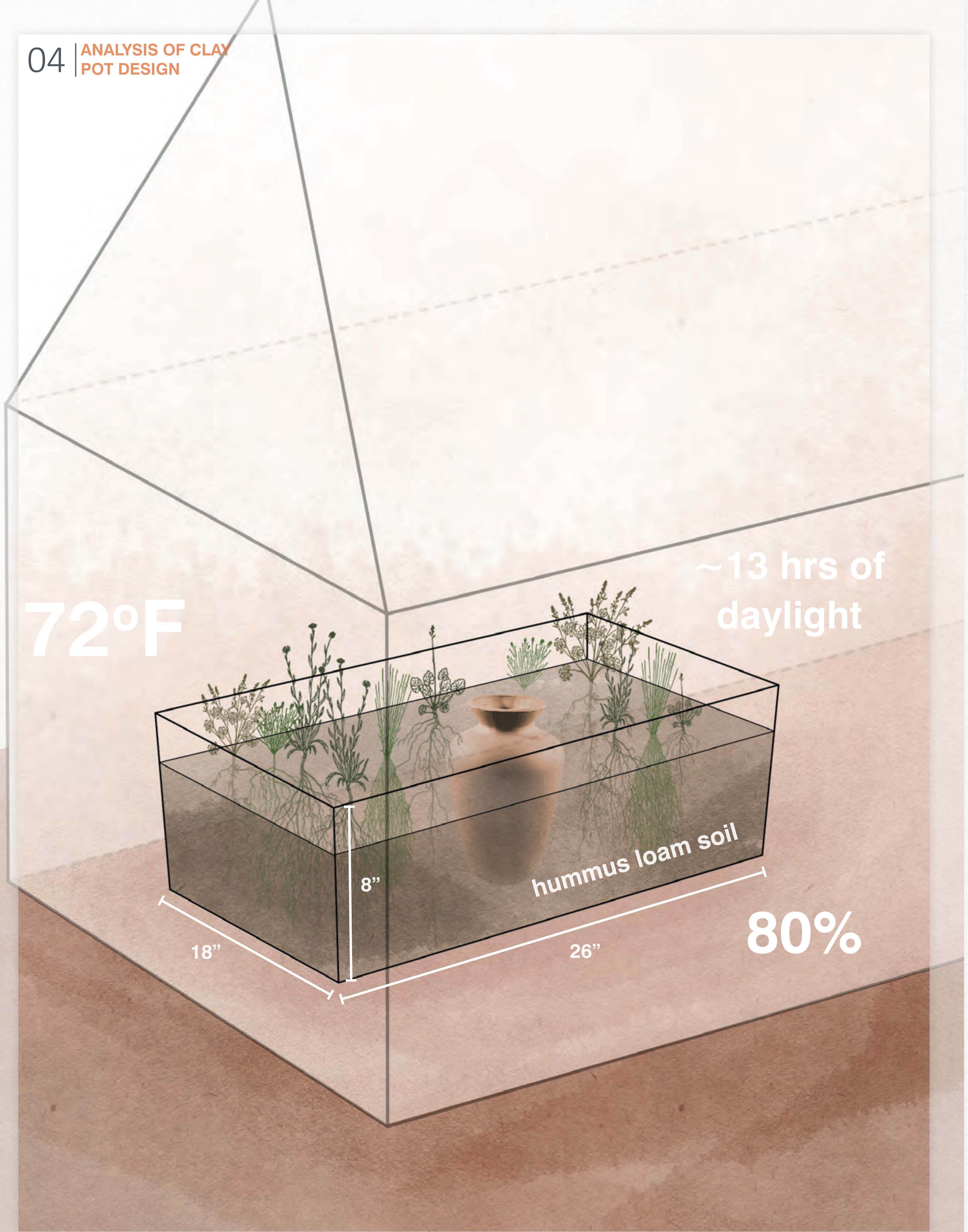
RESULTS

04

ANALYSIS OF CLAY POT DESIGN

RESEARCH QUESTION

This research aims to determine which clay pot design yields the highest biomass of the native grass, Roemer's Fescue, providing insights into the project's success.



GREENHOUSE TESTING

part 1

The original greenhouse setup was instrumental in preparing for the actual experiment. It provided insights into the optimal soil composition for measuring plant biomass and helped determine the arrangement of the pots within the container. The setup included a combination of seeds and container plants, as well as commercially purchased clay pots.


SHOWER
STREAM

GREENHOUSE TESTING

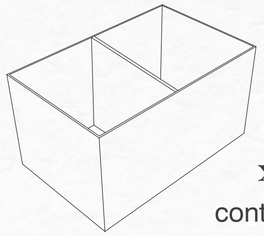
part 2

Materials

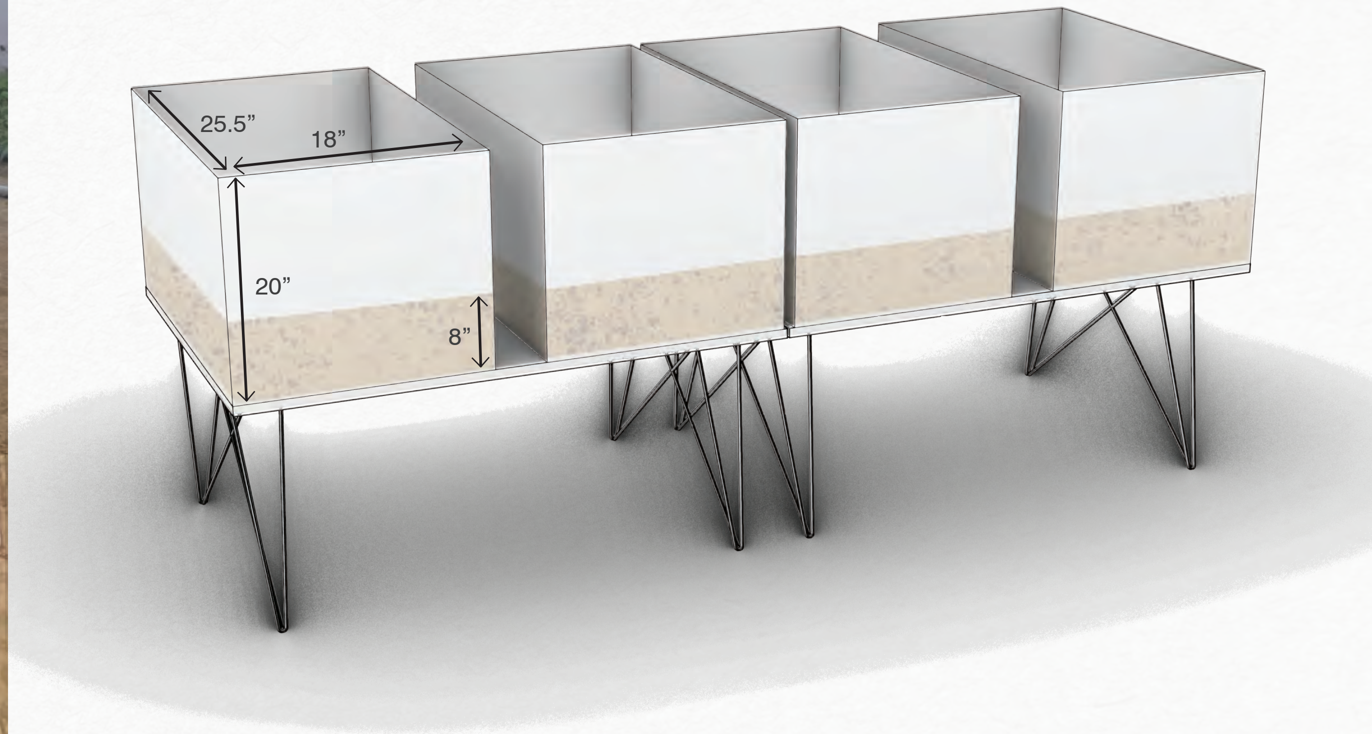
x 6
clay pots

x 6
sand bags

x 300
grass seeds



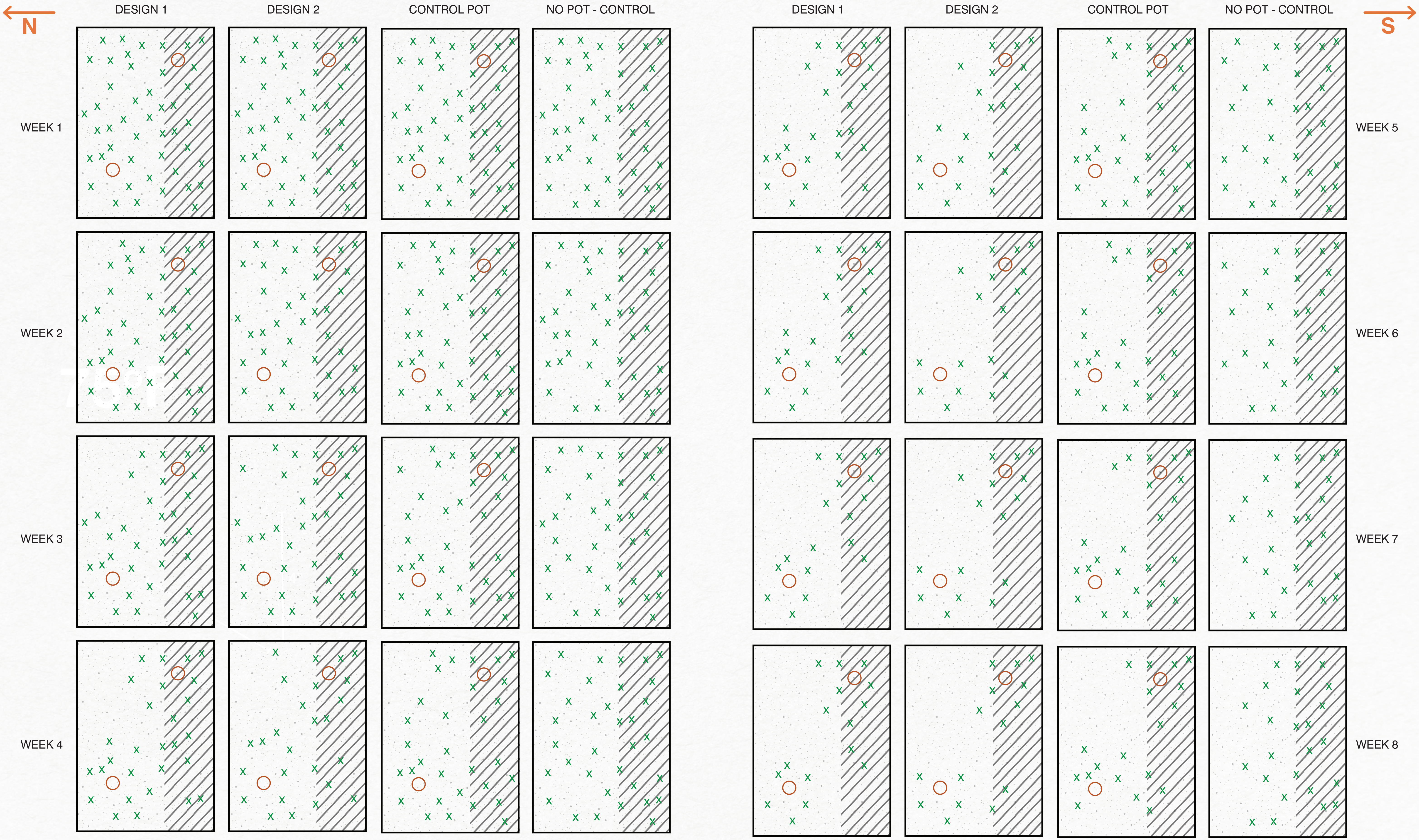
x 4
containers

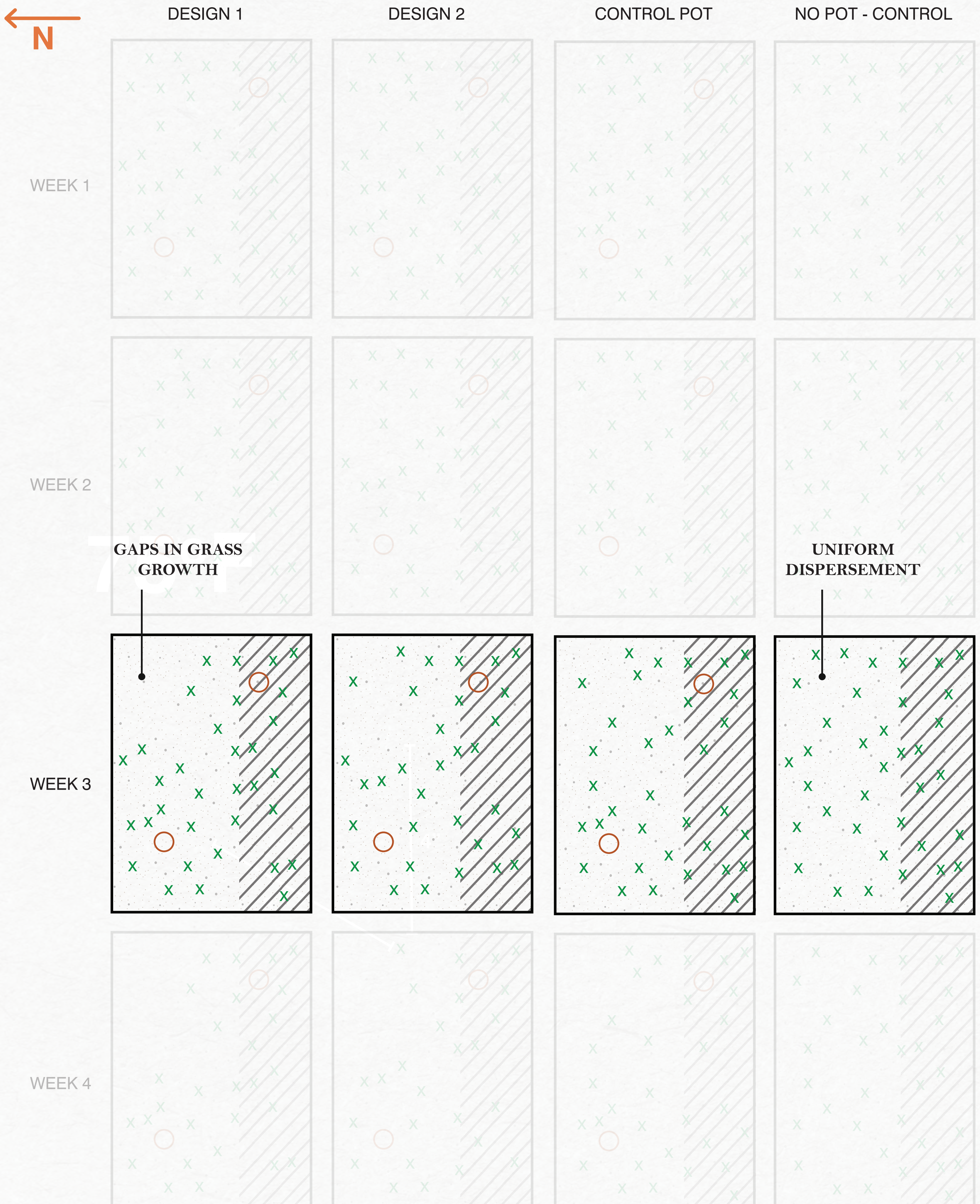


This research aims to determine which pot design yields the highest biomass of native grass, providing insights into the project's success.

The greenhouse experiment utilized four containers filled with sand and seeded with roemer's fescue grass to evaluate the different pot designs. Two pots from each design were allocated to three containers, while the fourth container served as a control without a clay pot. The containers were uniformly watered twice a week by pouring water into the pots or by spraying the same amount of water into the control container. The watering procedure and grass documentation has been carried on for 8 weeks.

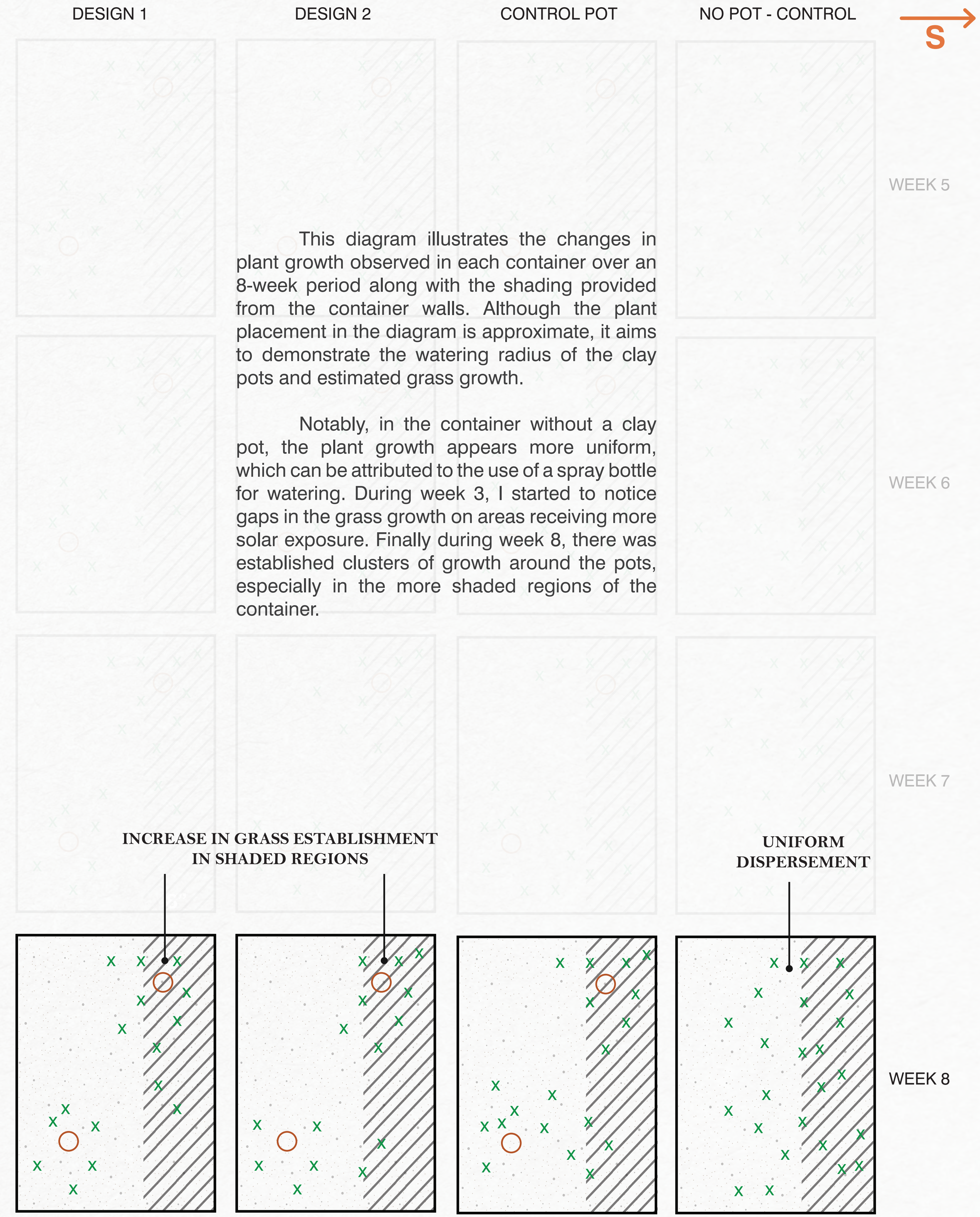
Note: The roemer's fescue grass was selected for its faster growing rates and fibrous root systems.


N
S
DESIGN 1
DESIGN 2
CONTROL POT
NO POT - CONTROL
DESIGN 1
DESIGN 2
CONTROL POT
NO POT - CONTROL
WEEK 1
WEEK 2
WEEK 3
WEEK 4
WEEK 5
WEEK 6
WEEK 7
WEEK 8

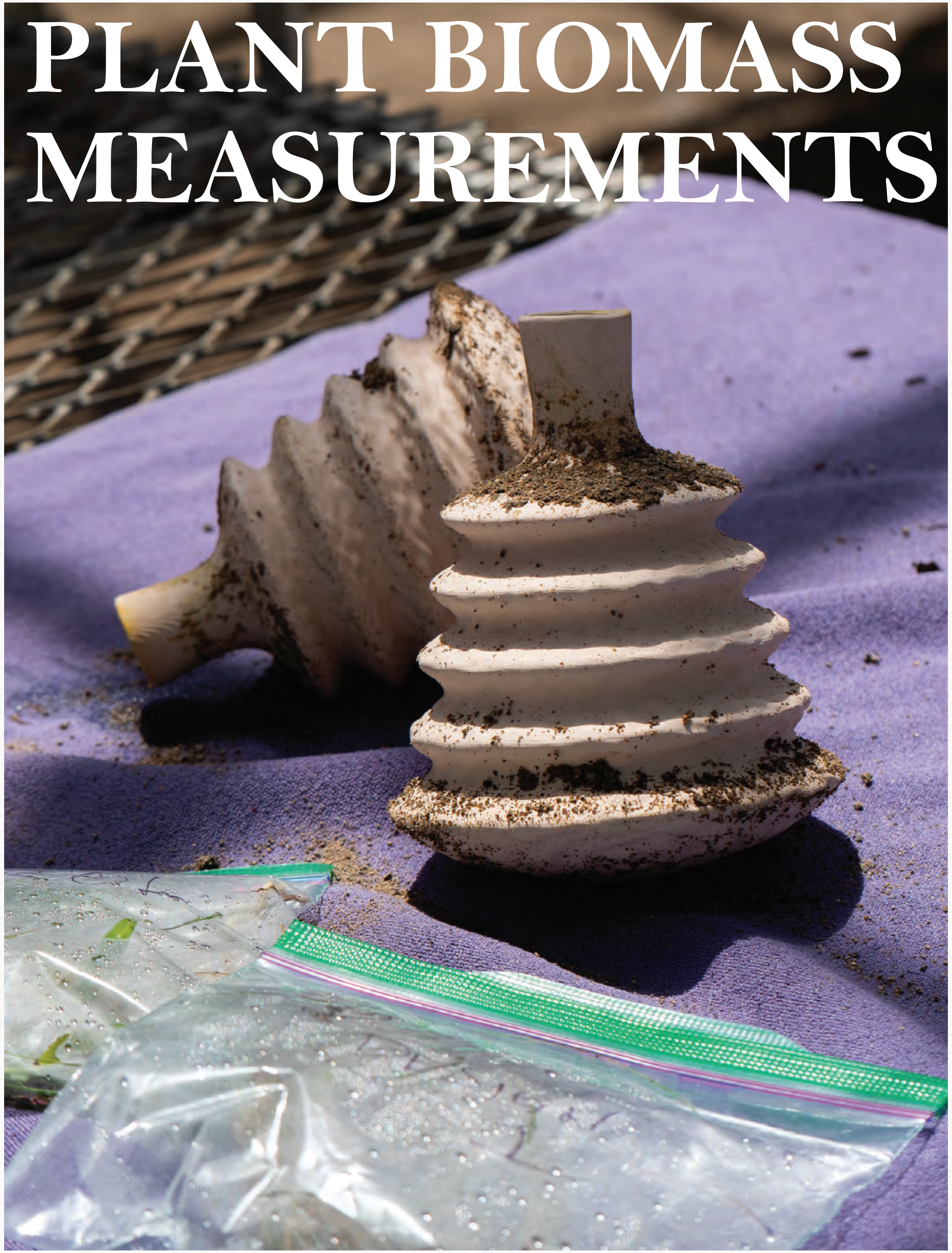


This diagram illustrates the changes in plant growth observed in each container over an 8-week period along with the shading provided from the container walls. Although the plant placement in the diagram is approximate, it aims to demonstrate the watering radius of the clay pots and estimated grass growth.

Notably, in the container without a clay pot, the plant growth appears more uniform, which can be attributed to the use of a spray bottle for watering. During week 3, I started to notice gaps in the grass growth on areas receiving more solar exposure. Finally during week 8, there was established clusters of growth around the pots, especially in the more shaded regions of the container.



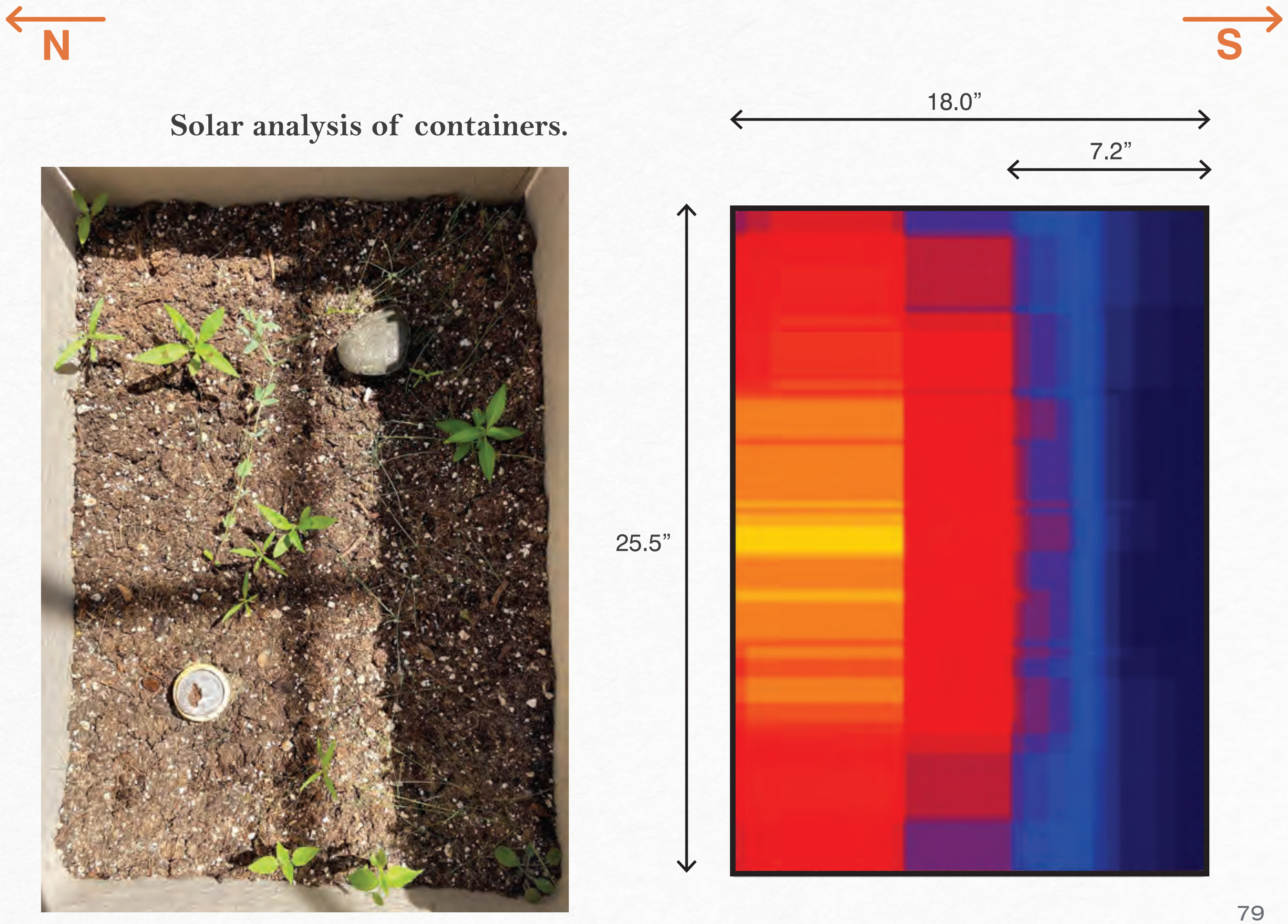
PLANT BIOMASS MEASUREMENTS



Design 1: 1.4 g
Design 2: 1.1 g
Control: 3.2 g
Spray: 2.3 g

After harvesting the plant biomass from each container, removing the sand, and drying the biomass to eliminate moisture weight, it became evident that the control pot exhibited the highest biomass at 3.2g. One possible explanation for the higher biomass in the control pot is the variation in water volume. It is important to note that the control pot, which was made by a beginner with limited experience, may have unintentionally contained a larger volume of water compared to the other pots. This difference in water content could have contributed to the observed difference in biomass between the control pot and the other experimental pots. In addition, it is important to recognize the presence of other limitations in this experiment, with one significant constraint being the influence of solar radiation and shading on grass growth within the containers. Over the course of a few weeks, it became apparent that the taller walls of the containers provided more shade to the right side of the container, resulting in increased grass growth in that area. To optimize growing conditions and facilitate a more comprehensive analysis, future studies should aim for consistent solar exposure and conduct additional sampling.

Solar analysis of containers.



EXPERIMENTAL OBSERVATIONS

While the focus of this experiment was primarily on biomass, there were several additional experimental observations made on the day of data collection. Firstly, it was observed that there was a greater density of grass within a 10-inch radius of the clay pots, indicating a potentially lower porosity than anticipated. This observation can most likely be attributed to the use of ball clay material, which is less porous compared to terracotta or the use of sand in the container. Another observation was the color retention of the pots throughout the two-month experiment, with minimal green coloration visible where the surface soil layer came into contact with the neck of the clay pots.

04 ANALYSIS OF CLAY POT DESIGN

DESIGN 1

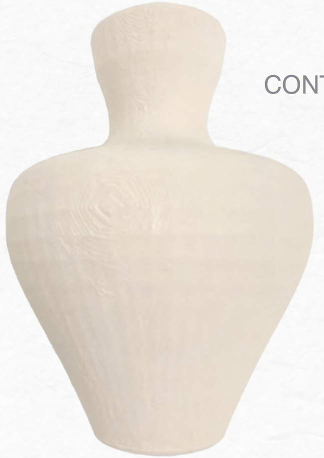
DESIGN 2

CONTROL

DESIGN 1

DESIGN 2

CONTROL



DESIGN 1

DESIGN 2

CONTROL

CONTROL

DISCUSSION

05

HOW TO APPLY TO A LANDSCAPE

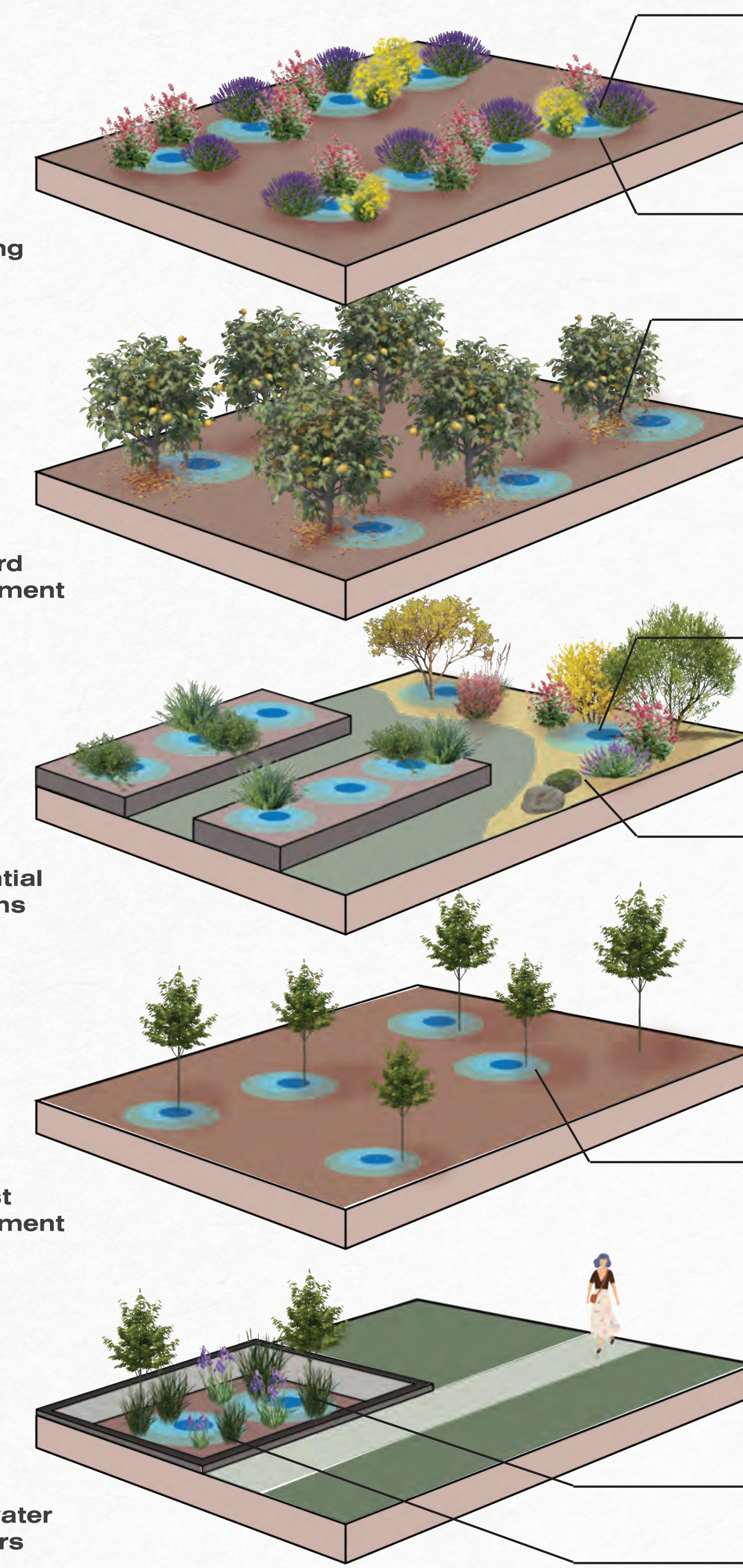
Drawing upon the research findings and the results of my experiment, I sought to apply clay pot irrigation to an existing design.

LANDSCAPE COMPARISON

Buried clay pots have proven to be highly effective in a wide range of landscape applications. They offer exceptional benefits for various purposes such as residential gardens, orchard and forest establishment, environmental restoration, farming, and propagation. How they are arranged and applied in each landscape will differ, and I wanted to begin to understand how they could be coupled with conventional irrigation to provide water to an established design.

	Buried Clay Pot	Porous Clay Pipe
Residential Gardens	Excellent	Excellent
Orchard Establishment	Good	Fair
Orchard Maintenance	Fair	Fair
Forest Establishment	Good	Fair
Environmental Restoration	Good	Fair
Container Plants	Excellent	Good
Landscapes	Excellent	Good
Farming	Excellent	Excellent
Propagation	Excellent	Good
Storm-water Planters	Unknown	Unknown

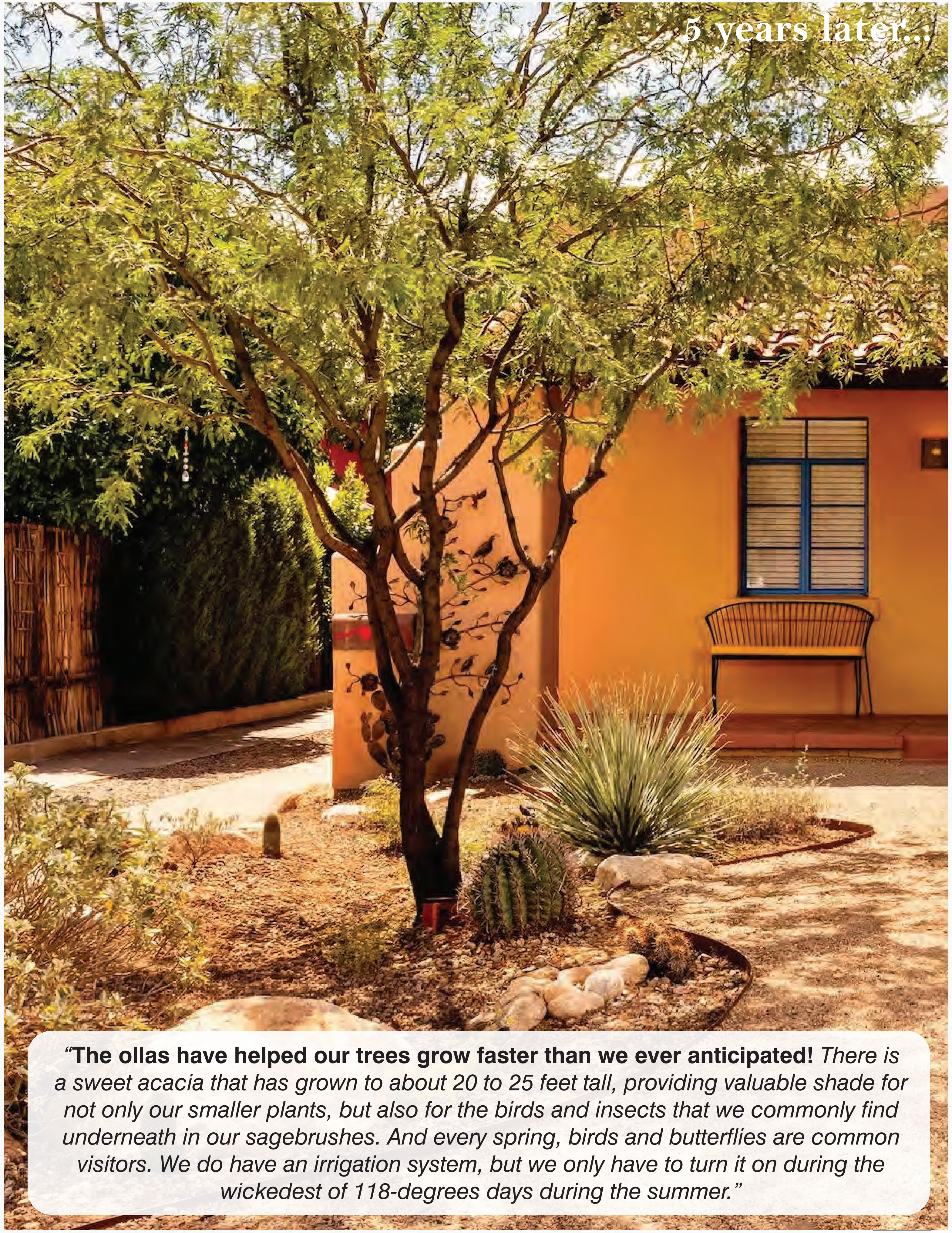
Excellent
Good
Fair
Unknown



ECOSENCE

Tucson, Arizona

"There have been conversations with many of the neighbors. **Not everyone can afford hiring someone to do this, but much of it can be done DIY.** *There has been this great movement over the past 10 years or so to regenerate our habits. And the moment one house does some sort of landscape design thing, it inspires seven other houses down the road to do the same."*



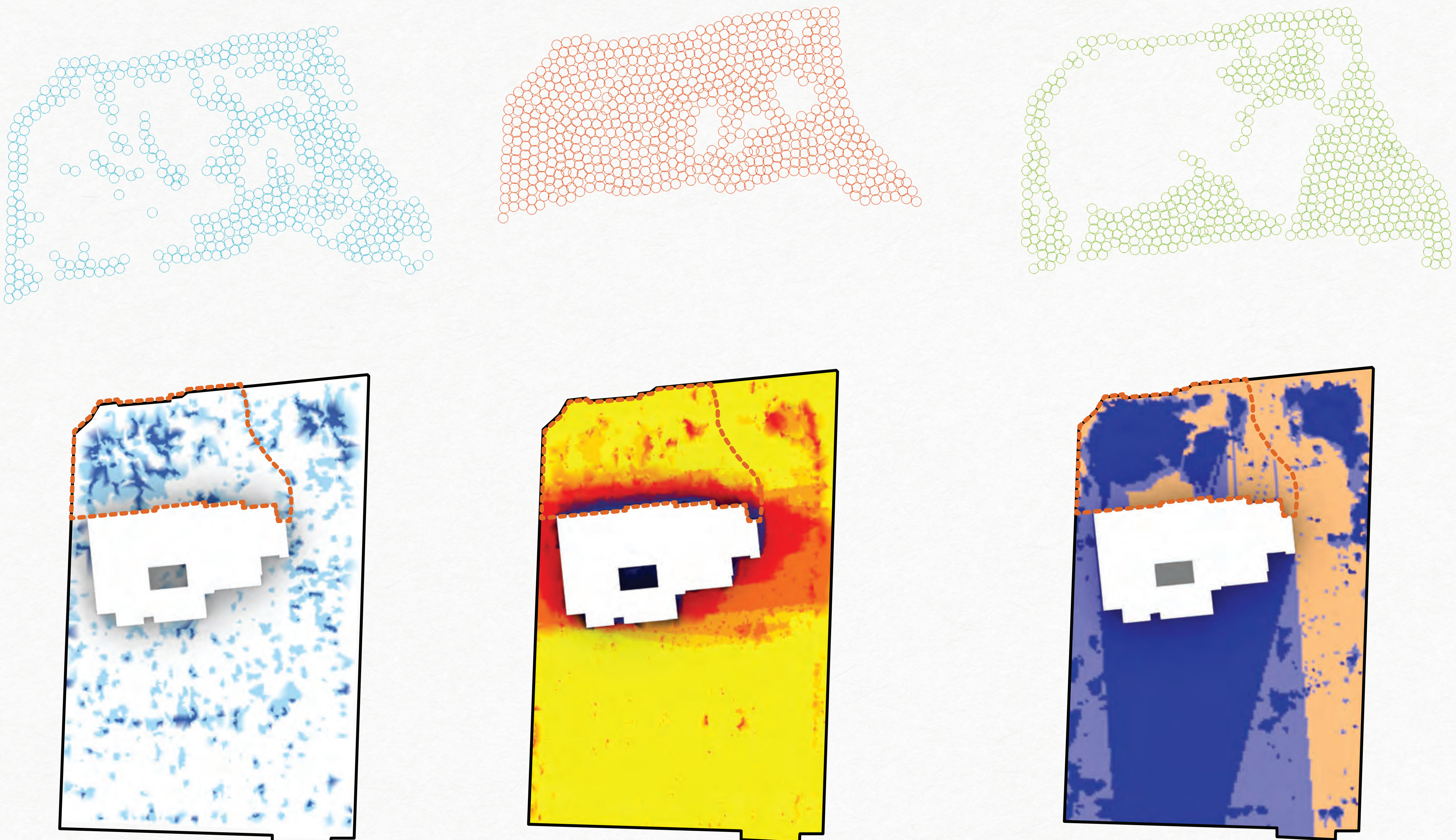
"**The ollas have helped our trees grow faster than we ever anticipated!** *There is a sweet acacia that has grown to about 20 to 25 feet tall, providing valuable shade for not only our smaller plants, but also for the birds and insects that we commonly find underneath in our sagebrushes. And every spring, birds and butterflies are common visitors. We do have an irrigation system, but we only have to turn it on during the wickedest of 118-degrees days during the summer."*

PLANNED PARENTHOOD

Eugene- Springfield Health Center

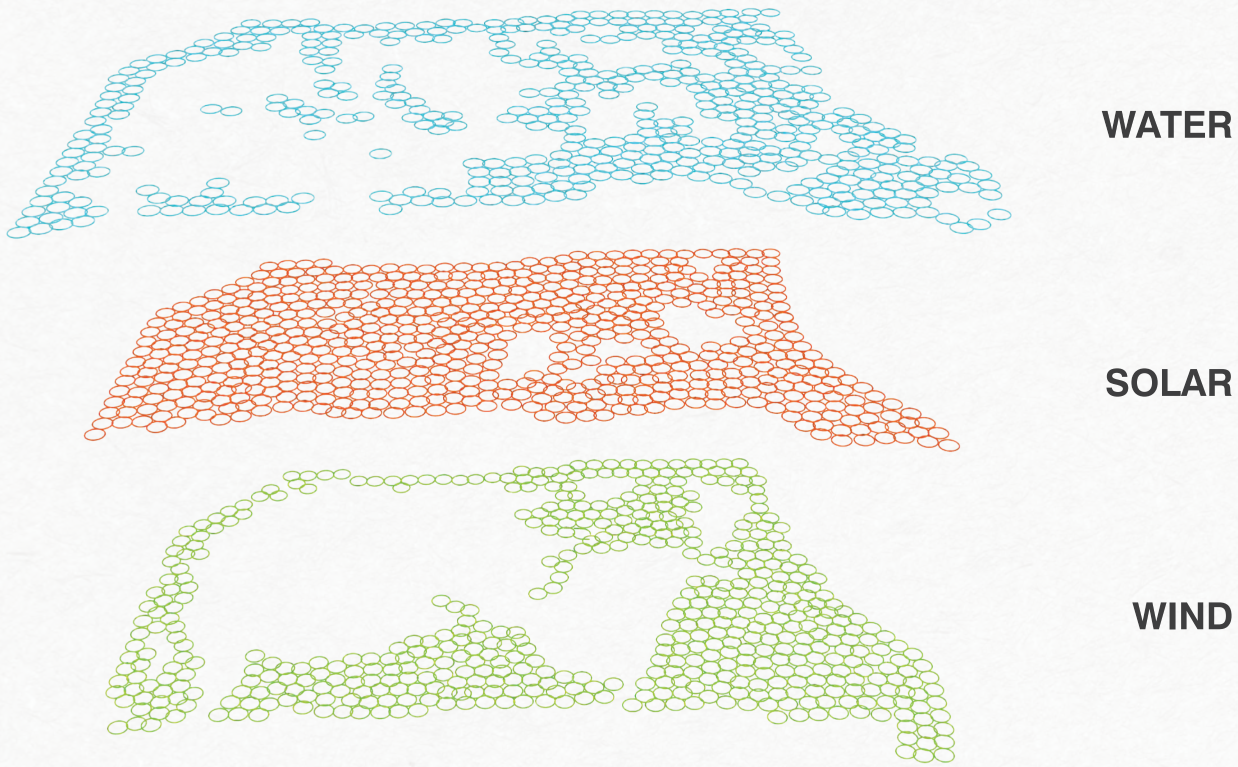
Learning from the Burges Residence case study, I wanted to see how I could apply these ideas to willamette valley. As I had briefly mentioned, my aim was to explore a hybridized irrigation method, specifically for a landscape with a highly dense planting plan. This stage is not fully developed, because believe it or not, it was incredibly hard to find a firm that will give you their irrigation and planting plan in Eugene. Thankfully Delaney hooked me up with a project from CM, she asked for permission of course, of a project they had designed in 2011 for Planned parenthood. While the overall project is extensive, I focused my attention on the entrance garden for the purpose of my study.

ENVIRONMENTAL ANALYSIS



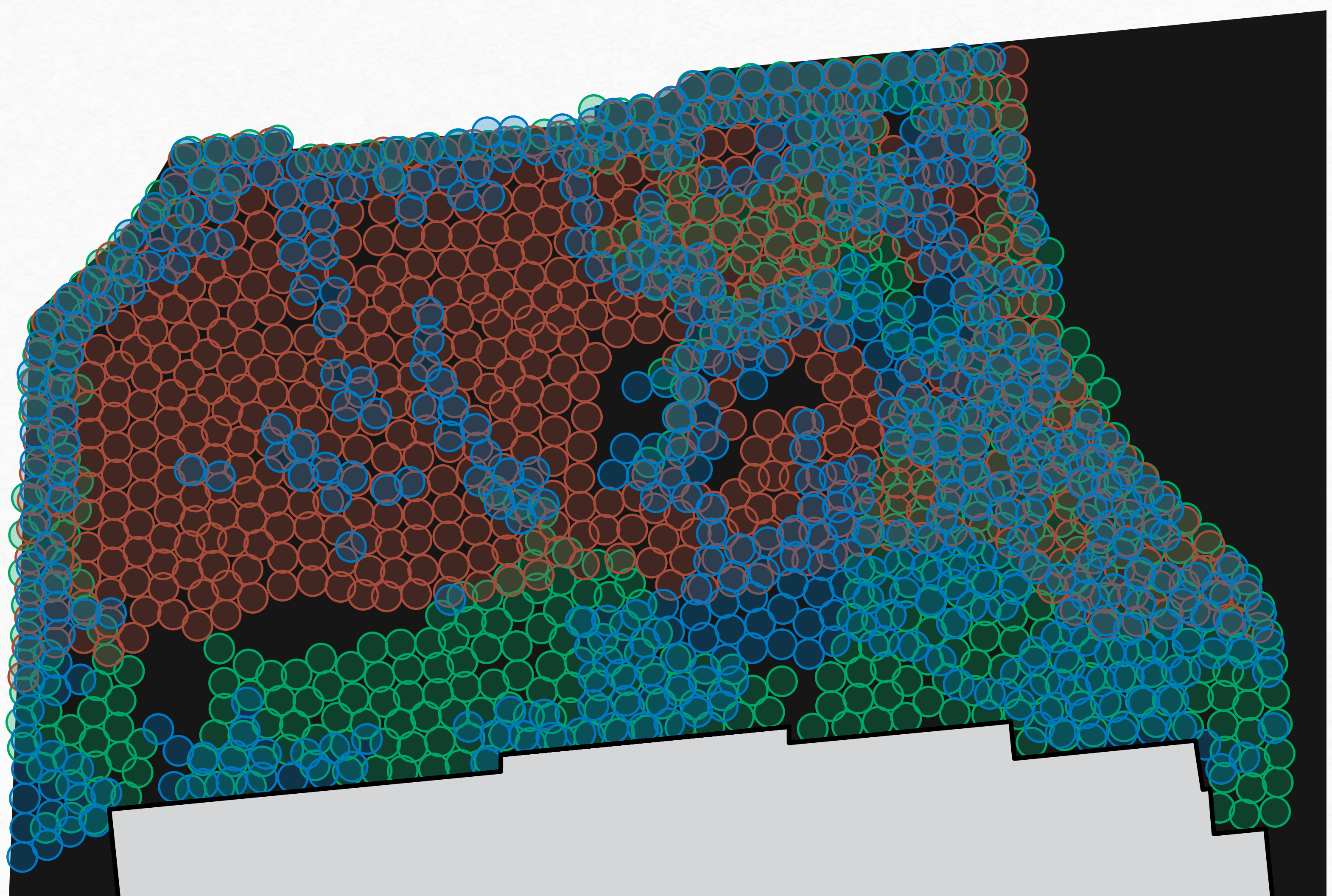
WATER SOLAR WIND

For this design, I opted to utilize a commercially available clay pot, specifically a larger version of the pot I used in the greenhouse. This larger version has a water capacity of 6.5 liters and a watering diameter of 4 feet. Considering the scale of the site, using clay pots exclusively would require approximately 800 ollas. The circular shapes depicted here represent the watering diameter of the clay pots. Given that the landscape was initially designed for spray irrigation, my objective was to identify an area where I could propose the replacement of spray irrigation with clay pots. So I conducted an environmental analysis, specifically for water flows, solar radiation, and wind movement during the summer months. For each analysis, I strategically positioned the clay pots in the most challenging environments, which is also the same areas where I predict the spray irrigation would be least effective and could be replaced with clay pots to mitigate water loss. Specifically, I placed the clay pots in the driest areas with high solar radiation and in windy spots where spray could easily be lost through evaporation. This approach allowed me to assess the potential benefits of using clay pots in the areas most prone to water loss and evaluate their effectiveness in these more difficult micro-climate conditions.



OVERLAID ENVIRONMENTAL ANALYSIS

Using the overlaid placements from the different analyses, I identified areas where there was consistent overlap in all three layouts. This analysis led to the identification of this orange area that primarily follows the perimeter of the garden.



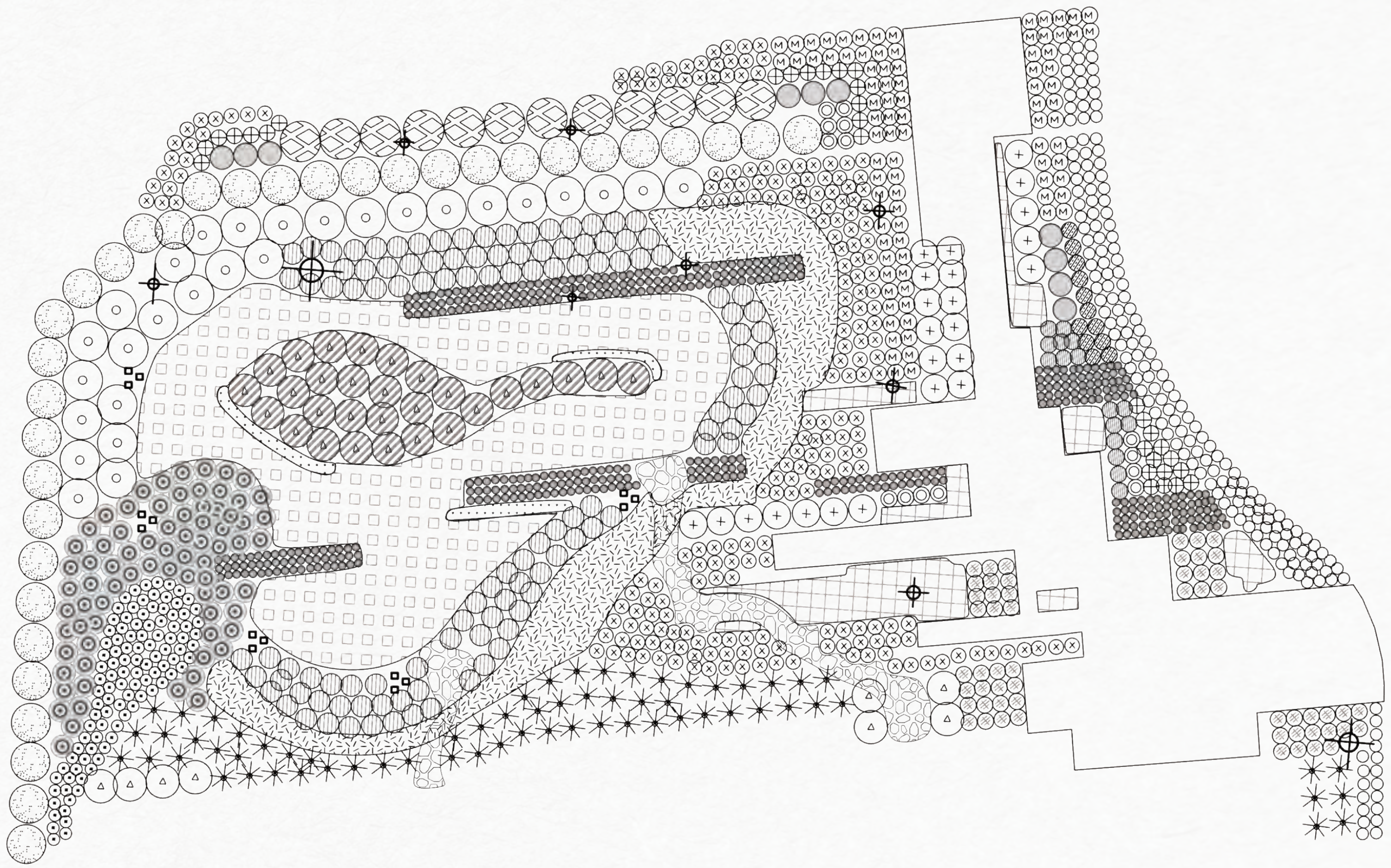
PLANTING PLAN

SHRUBS

BOTANICAL NAME	COMMON NAME
Berberis thunbergii 'Aurea'	Golden Japanese Barberry
Callicarpa dichotoma	Purple Beautyberry
Cornus sericea 'Flaviramea'	Yellowtwig Dogwood
Cornus sericea 'Isanti'	Isanti Redtwig Dogwood
Cornus sericea 'Kelseyii'	Redtwig Dogwood
Daphne odora	Winter Daphne
Enkianthus campanulatus	Enkianthus
Euonymus alata 'Compacta'	Dwarf Winged Euonymus
Forsythia viridissima 'Bronxensis'	Bronx Forsythia
Gaultheria shallon	Salal
Mahonia repens (L)	Creeping Mahonia
Mahonia repens (S)	Creeping Mahonia
Prunus laurocerasus 'Mr. Vernon'	Mt. Vernon Laurel
Prunus laurocerasus 'Otto Luyken'	Otto Luyken Laurel
Rosa gymnocarpa	Little Wood Rose
Sarcacocca ruscifolia	Sarcococca
Spiraea betufolia 'Tor'	Birchleaf Spiraea
Viburnum davidii	David Viburnum

GROUNDCOVERS & ORNAMENTAL GRASS

BOTANICAL NAME	COMMON NAME
Allium 'Globemaster'	Flowering Onion
Archtostaphylos uva-ursi Big Bear	Big Bear Kinnickinnick
Blechnum spicant	Deer Fern
Carex oshimensis 'Evergold'	Variegated Japanese Sedge
Carex testacea	Orange Sedge
Echinacea purpurea	Purple Coneflower
Hemerocallis sp	Orange Daylily
Iris tenax	Tough-leaf Iris
Juncus patens	Spreading Rush
Liriope muscari 'Big Blue'	Lilyturf
Panicum virgatum 'Hanse Herms'	Red Switch Grass
Pennisetum alopecuroides 'Hameln'	Dwarf fountain grass
Polystichum munitum	Western Sword Fern
Rudbeckia fulgida 'Goldsturm'	Black-eyed Susan



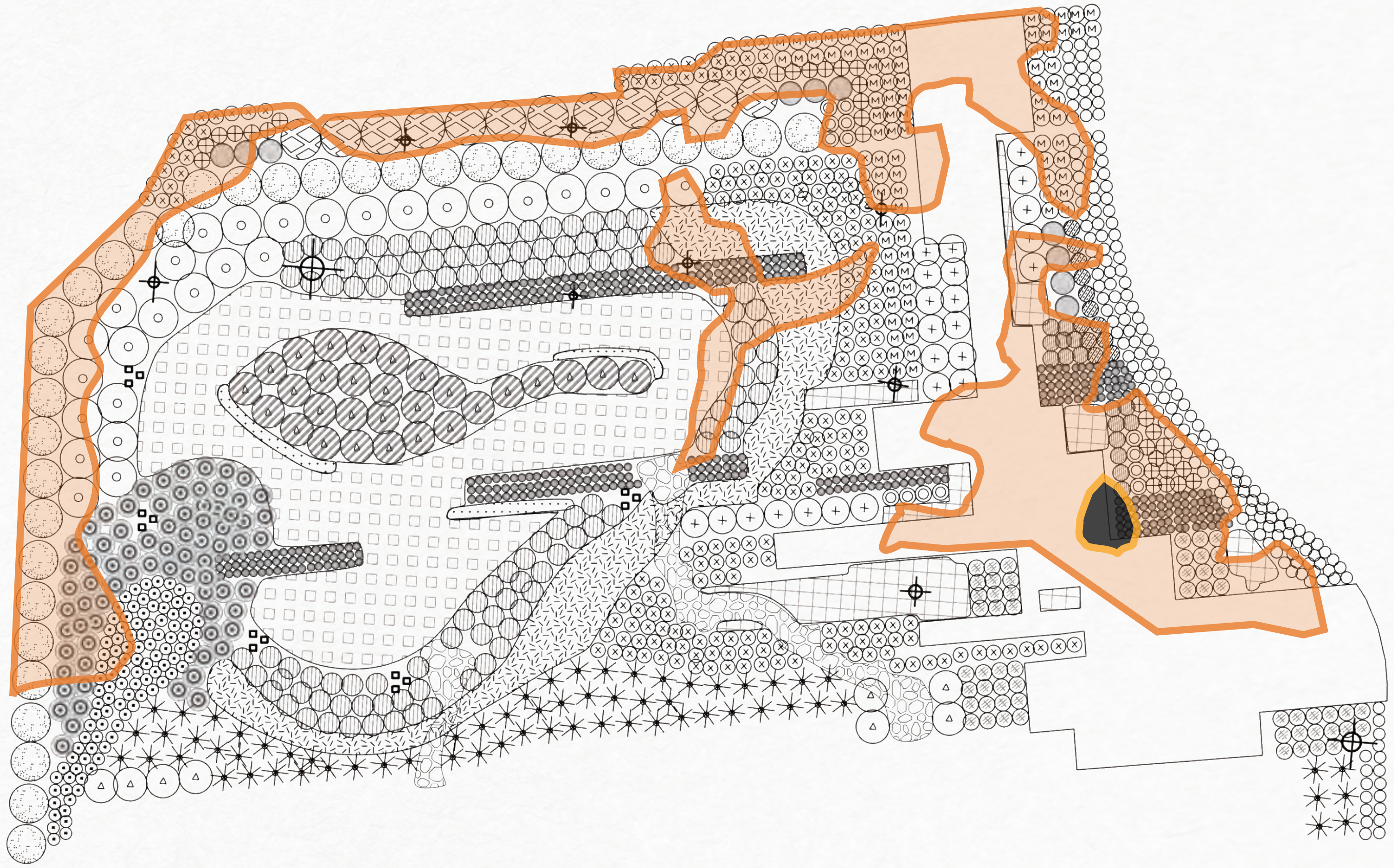
PREDOMINANT PLANTS IN AREA

Mt. Vernon Laurel

Dwarf Fountain Grass

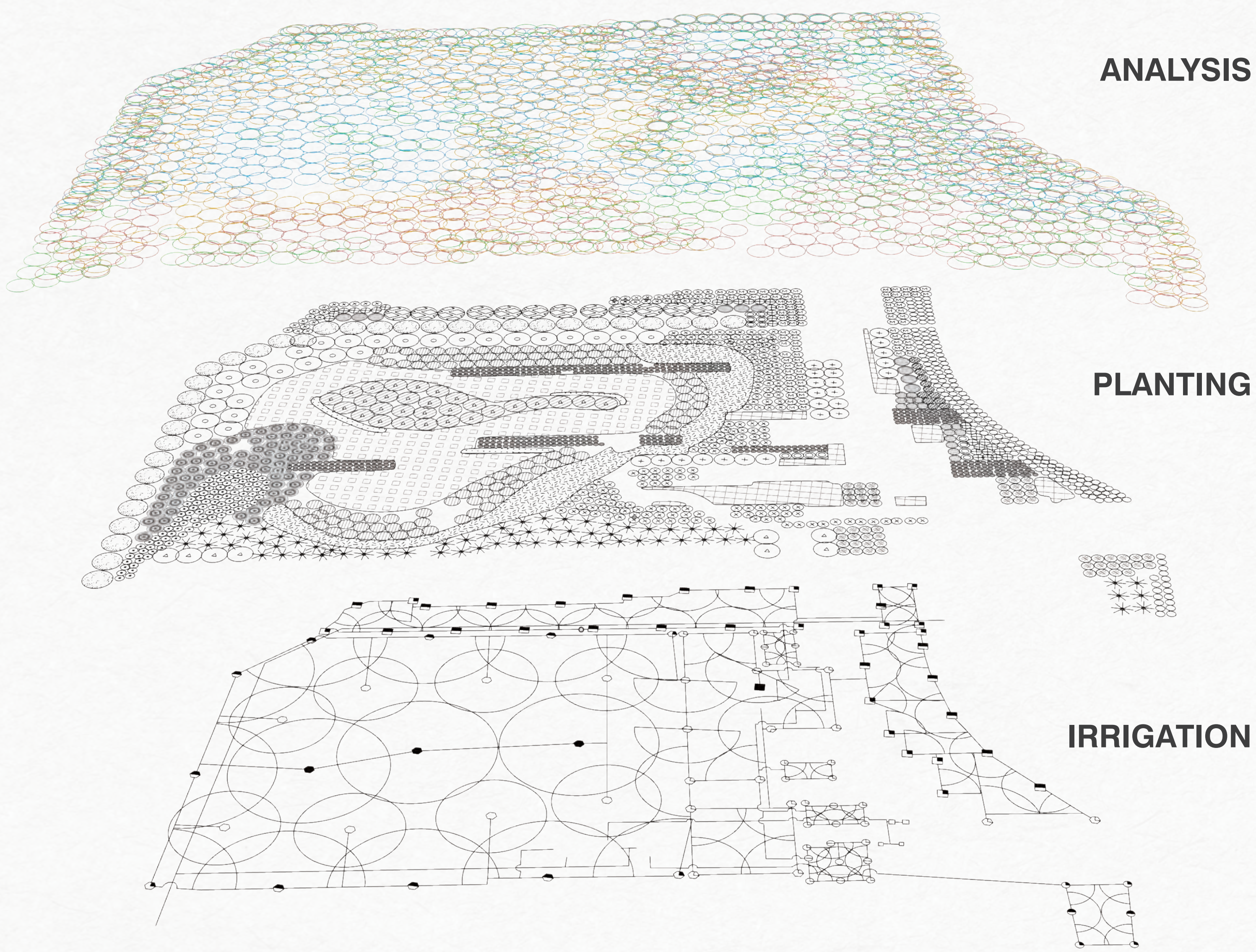
Red Switch Grass

Dwarf Winged Euonymus

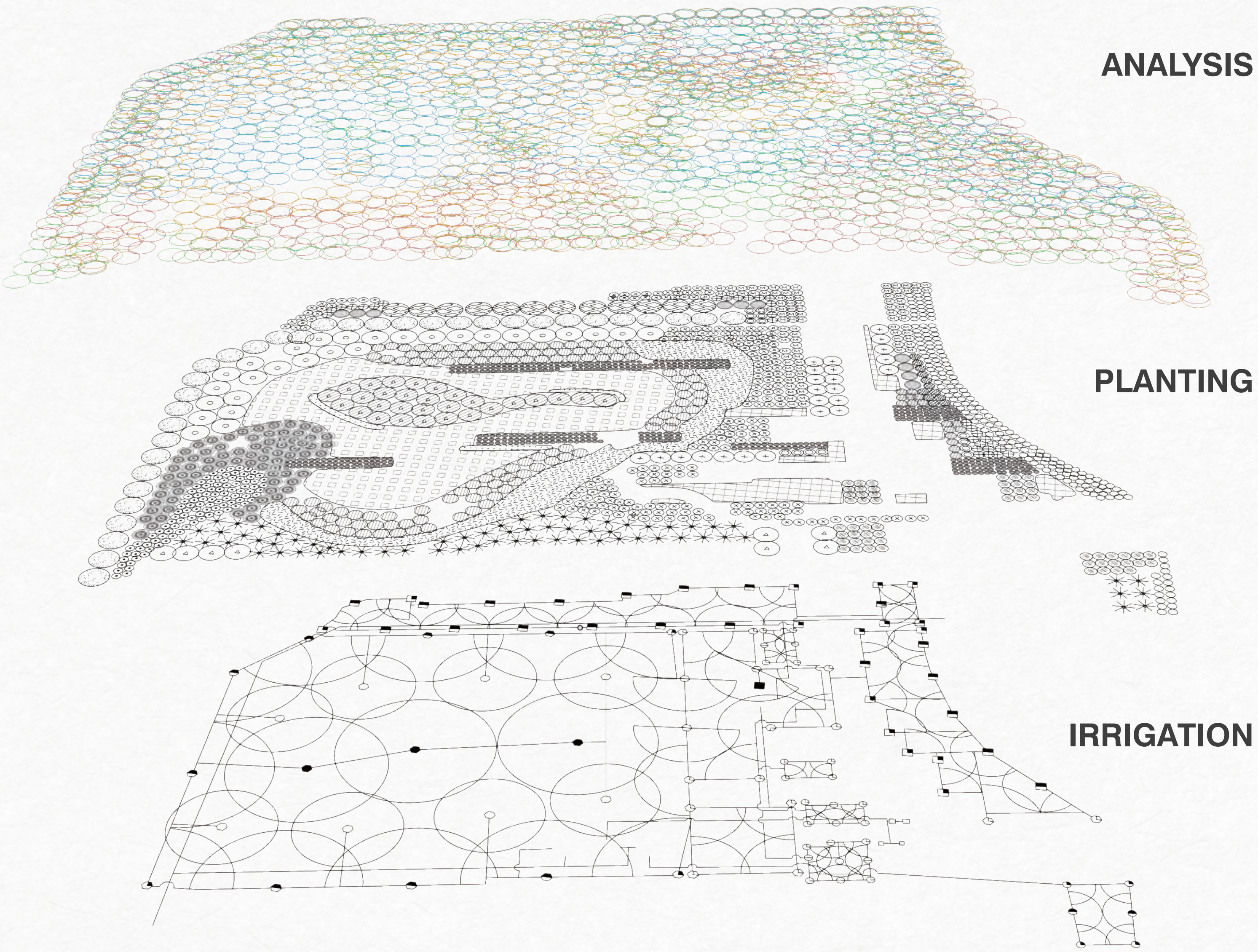


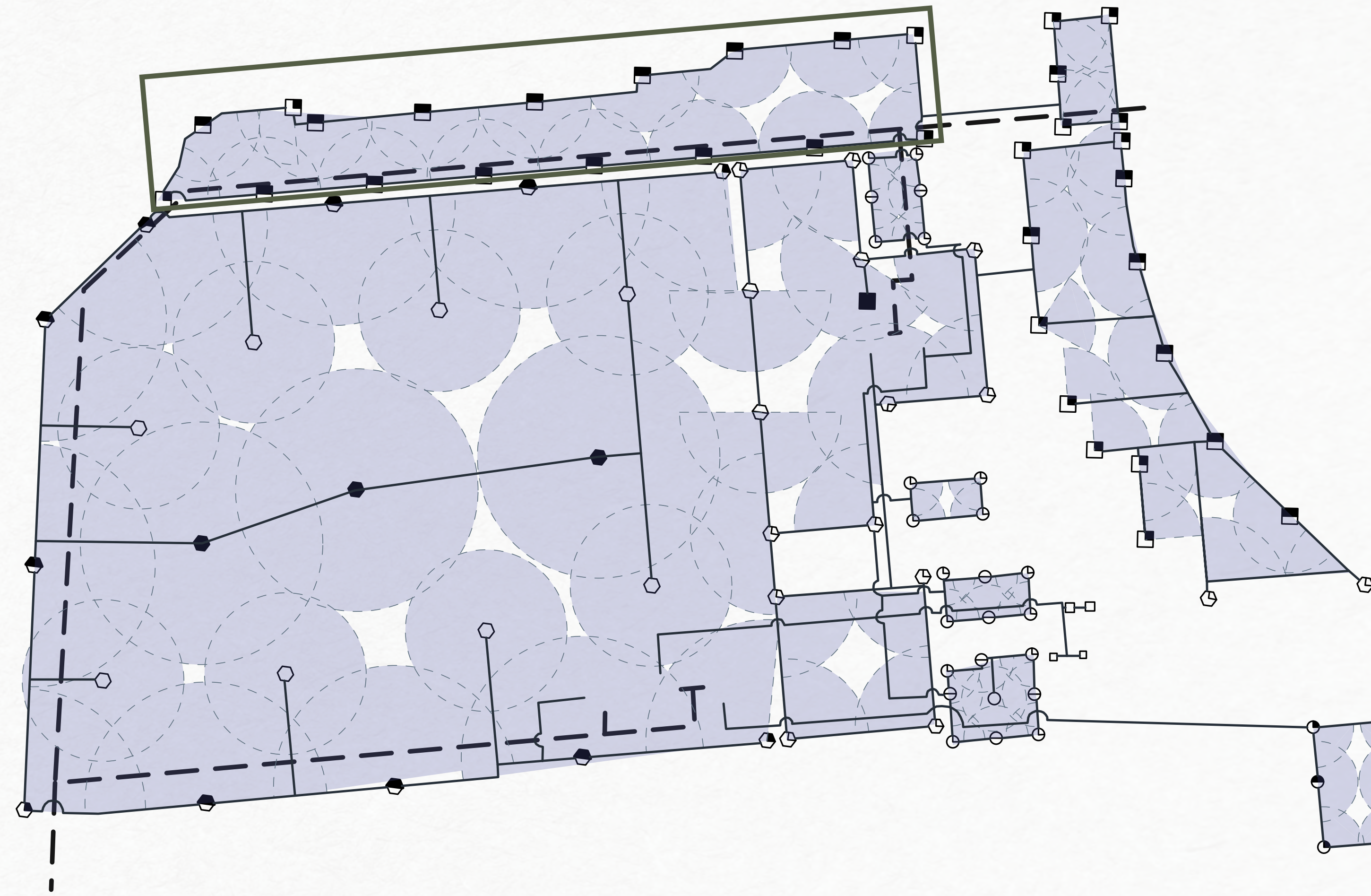
Within the designated area of the overlaid environmental analysis, the predominant plant species include the Mt. Vernon Laurel, Dwarf Fountain Grass, Red Switch Grass, and Dwarf Winged Euonymus. These plants have low maintenance requirements and are able to thrive in drought-prone conditions once established. Additionally, most of these plant species possess fibrous root systems that are well-suited for integration with clay pots.

OVERLAID IRRIGATION PLAN



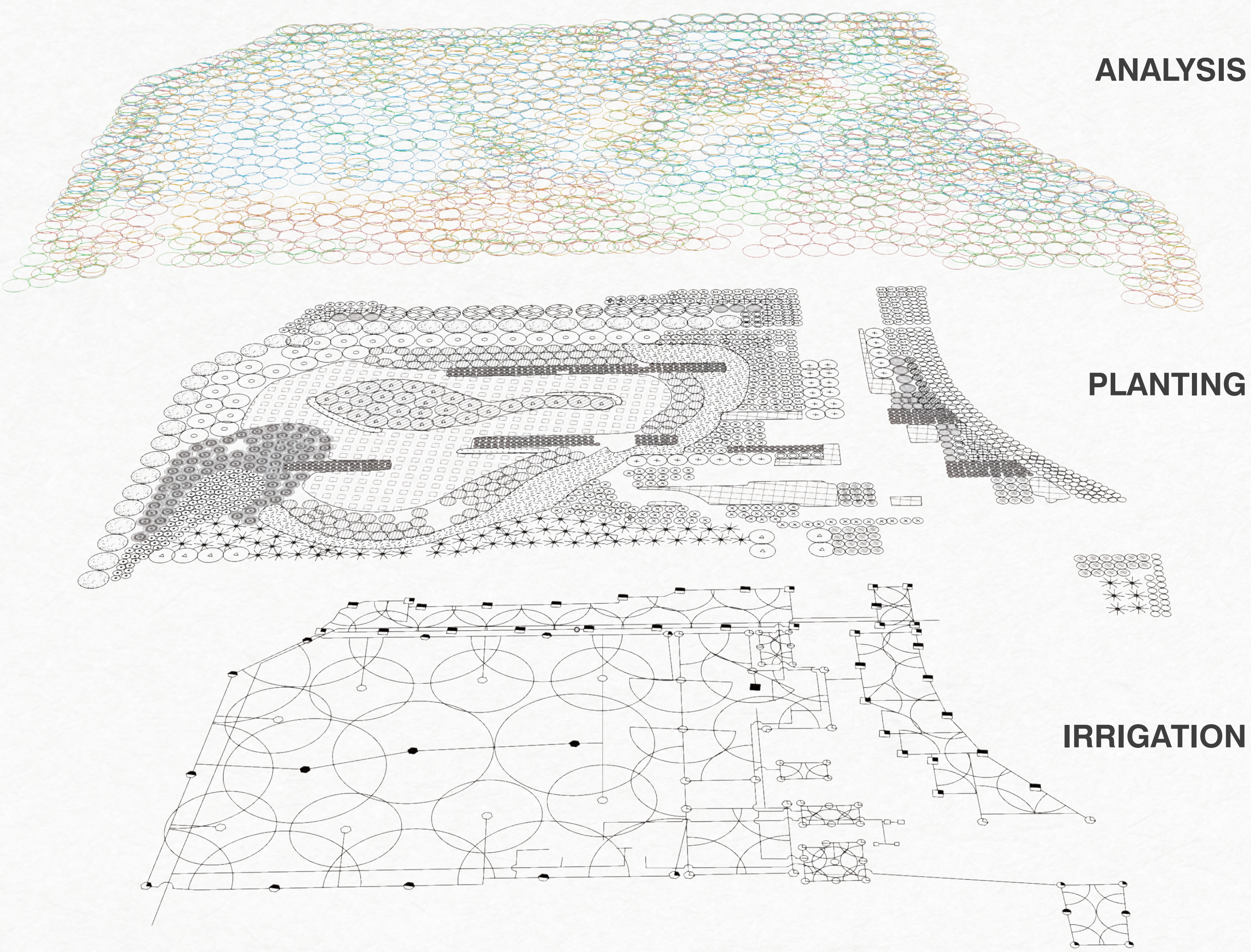
OVERLAID IRRIGATION PLAN





If I had been involved in the design and construction process of the CM project in 2011, I would have suggested replacing the spray irrigation system in the designated area with clay pots. Although this area is relatively smaller, it would still require approximately 30-50 clay pots, depending on any potential rearrangement or updates to the plant selection in the planting plan. Additionally, considering the proximity of this area to the mainline, it could be feasible to connect the clay pots to a water source using a hose system.

FINAL SELECTION AREA



Integrating ollas with other drip and spray irrigation methods in a residential landscape design can offer a more comprehensive watering solution that combines the benefits of each system. While ollas provide precise and localized watering directly to the root zone of plants, drip and spray systems can cover larger areas, providing a broader distribution of water.

CONCLUSION

06

FUTURE WORK

While I enjoyed using digital technologies throughout the many stages of this project, I would like to recognize that many of the steps may not be necessary. 3D printing offered opportunities to customize and analyze the shape of the clay pot, but perhaps the time honored design is simply the best. It is conceivable that the design itself may not be as crucial as the use of a porous clay container buried in the ground to supply water to plants.

In my opinion, further development of the environmental analysis could greatly benefit landscape architects in considering a hybridized irrigation approach. By combining traditional methods with modern techniques, we can create more efficient watering systems for landscapes. Lastly, I would be interested in exploring the possibility of increasing the size of the clay pots and utilizing clay sourced from the design site itself.

REFERENCES

06

SCRIPT:

0. BEGINNING SLIDES

SLIDE 2: However before I begin, I would like to express my heartfelt gratitude to the remarkable individuals who have contributed to this long project. Their support, invaluable expertise, and endless patience have been instrumental to my journey. While I may not be able to mention everyone who has contributed, please know that your contribution has been deeply appreciated and has left an indelible impact on this project.

- First and foremost, I would like to extend my deepest appreciation to my advisor, Ignacio, for his exceptional guidance, patience, and weekly crisis support. Ignacio's commitment to teaching and his willingness to answer my questions at almost any time of the day has been truly gracious.
- Brian Gillis for your insight and guidance during a critical time in my project. The fabrication of the clay pots would not have been possible if wasn't for your class.
- Mary Polites for sharing your enthusiasm and expertise on digital fabrication and root systems.
- Kory Russel and Robert Ribes for their advice and instruction over the last 5 months.
- Mike Bartell for graciously giving me access to the Polymer Lab and assisting me with all of my 3D prints.
- Damon Harris for firing the clay pots and providing advice in times of fabrication uncertainty.
- I would like to extend a special appreciation to Delaney and Celia for their unwavering friendship and motivation throughout this exhausting process. Your presence has been a source of strength and inspiration, and I am grateful for the countless hours we have shared in studio.
- I would also like to send my love to Maggie and Seren for their constant support and encouragement throughout my graduate school journey. Your unwavering belief in me, willingness to listen, and ability to lift my spirits have been invaluable. Thank you for being there for me through the ups and downs of the past three years.

SLIDE 3: I have organized my presentation into six chapters to provide a comprehensive overview of this project. First, we will explore the intricate mechanics of clay pot irrigation, nah I kid, we will be understanding how this system is the simplest yet most efficient way to irrigate. Next, I will introduce the underlying structure of my project. We will then dive into the design and testing process of clay pots, followed by their practical application in a landscape setting. Lastly, I will touch upon future prospects and discuss the additional work I would have loved to undertake if only we could add another year to this three-year program. Let's get started!

1. HOW CLAY POT IRRIGATION SYSTEMS WORK

SLIDE 4: Clay pot irrigation, in its simplest form, utilizes unglazed baked porous clay pots buried in the ground near the root system of a plant and is filled with water. As the water slowly seeps out through the clay wall, it provides controlled irrigation for plants. These self-regulating systems are highly efficient due to the water flow rate varing with the plants' water demand.To prevent evaporation and keep out soil and insects, the pot is typically covered with a lid or cap. Known by various names such as the pitcher method or ollas, this technique has proven to be well-suited for small-scale farmers worldwide. In fact, it demonstrates exceptional efficiency, surpassing even drip irrigation and offering up to ten times greater effectiveness compared to conventional surface irrigation methods. AND those names that I previously mentioned, olla and pitcher irrigation, will be used interchangeably with clay pot irrigation.

SLIDE 5: Clay pot irrigation is an ancient technique that traces its roots back thousands of years and has been practiced by various civilizations across the globe. Although the precise origins of olla irrigation are not extensively documented, it is believed to have emerged in regions characterized by arid and semi-arid climates, such as India, Iran, Africa, certain South American countries, and parts of Central America. This technique likely evolved as a means to conserve water and irrigate crops in areas with limited rainfall. It is intriguing to observe that various cultures across different continents have independently arrived at the same conclusion: the use of clay pots for irrigation. One of the earliest accounts of this irrigation practice was documented over 2000 years ago in China by agronomist Fan Shengzhi.

SLIDE 6: Pitcher irrigation offers numerous benefits, including the promotion of accelerated plant establishment and enhanced growth rates. However, it's important to note that plants must be located within a specific radius of the pot, which varies depending on its size or volume. Additionally, the complexity of the root system should be taken into account. Buried clay pots provide a versatile solution for various plant types, including vegetables, trees, bushes, and berries. This method is particularly effective for plants with well-developed horizontal root systems, ensuring their optimal irrigation and growth.

SLIDE 7: Olla irrigation, a time-honored technique, continues to be practiced in numerous regions worldwide, especially in regions where water is scarce or expensive. In recent years, there has been renewed interest in olla irrigation for its sustainable and environmentally-friendly nature. The applications of clay pot irrigation are diverse, effectively serving in farms, gardens, restoration sites, and propagation. Additionally, clay pots are practical in most soil mediums, even in sandy or gravelly soils that drain very quickly, making them suitable for a wide range of settings.

SLIDE 8: The concept of clay pot irrigation remains consistent regardless of whether the plant is indoors or outdoors. In this method, a clay pot serves as a porous barrier between the plant's root system and water. The water gradually seeps through the pores in the clay, ensuring a steady supply of moisture for the plant's roots. Using a clay pot for houseplants offers the advantage of maintaining a consistent level of soil moisture, which can be challenging with traditional watering techniques. If you're interested, there are various house plant watering systems available on platforms like Etsy.

SLIDE 9: Today, there are many different designs for both indoor and outdoor clay pot irrigation systems. Whether it’s extending the neck length, glazing specific areas, or attaching the clay pot to a hose, there are many ways to explore the efficiency of this irrigation system.

SLIDE 10: While the shape of clay pots has received more extensive research regarding plant growth, it is important to also explore the role of surface area and texture in maximizing root interactions with clay pots. Increasing the surface area can be achieved through various methods, such as incorporating ridges, grooves, or perforations on the pot's walls. This enables the root system to establish a more extensive contact with the porous clay surface. Additionally, incorporating textures that promote root adhesion, such as slightly rough or uneven surfaces, can further enhance the root-pot interaction. These strategies not only encourage better water uptake but could also stimulate root branching and overall plant growth.

2. INTRODUCTION TO PROJECT

SLIDE 11: Having discussed clay pots and identified design opportunities, I am now excited to now explore the multifaceted aspects of this project.

SLIDE 12: Throughout time, clay pots can be crafted in various ways depending on the available tools and skillsets. Drawing from my rudimentary historical knowledge of their evolution alongside the tools utilized, it is likely that the earliest pots were constructed through hand-building using simple coiling or pinching methods. Subsequently, between 6,000 and 4,000 BC, the potter's wheel was invented, revolutionizing pottery production. Wheel throwing enabled faster and more efficient pot-making, allowing potters to create symmetrical vessels with consistent thickness and shape. As time progressed, around the 1st millennium BC, slip casting emerged as a technique. Slip casting facilitated the production of vessels with intricate shapes and fine details that were challenging to achieve solely through wheel throwing. With the advent of 3D printing, there is now the potential for further innovations in clay pot manufacturing, particularly when coupled with slip casting techniques.

SLIDE 13: My project focuses on utilizing digital technologies to evolve the design and application of a vervalcular irrigation system, the clay pot. Through research and experimentation, the aim was to gain a deeper understanding of how these digital tools can be utilized to enhance irrigation performance, reduce water consumption, increase root interactions and improve land management. Over the last year, there have been many veins to this project that have started at different times. Root and irrigation research, digital fabrication, and 3D modeling were the beginning vessels propelling this project forward, and with this accumulated knowledge base, other areas were later explored such as landscape design and micro-climate analysis.

In order to assess the success of this project, which I will elaborate on later, I conducted ,what I might call, preliminary research on the clay pots that I designed. In this experiment, I used the pots for irrigating Roemers Fescue, a native grass species characterized by its fibrous root system. The clay pot design yielding the highest biomass of the grass will serve as a gauge for the success of this project. While the experiment itself is not complete enough to run a statistical analysis, the information collected will be used to understand how new tools could be applied to an ancient technology. Other sub-research inquiries that I also probed were:

- How will root architecture influence the design of the clay pots?
- How does the analysis of micro-climates and different plant needs inform the spatial arrangement of the clay pot irrigation systems?
- Will increasing the surface area of different clay pot designs increase the growth of Roemers Fescue?
- Can an evolutionary solver help to inform the design of the clay pots to meet specified objectives?

SLIDE 14: To provide a contextual understanding of the research implications, let's briefly compare conventional irrigation systems with clay pot irrigation. The primary purpose of landscape irrigation systems is to supplement the water requirements of plants. In the United States, residential landscape irrigation alone accounts for over 9 billion gallons of water used outdoors. Furthermore, 50 percent of the water wasted outdoors comes from inefficient irrigation methods. To better understand how water waste can be reduced, it is effective to compare the conventional irrigation systems to clay pots at a small scale. Clay pot irrigation reduces water usage by up to 90 percent compared to spray irrigation while promoting improved plant survival and growth, enabling plants to better withstand seasonal drought. One advantage of using clay pots is the ability to maintain a consistent soil moisture level, which can be challenging with traditional watering techniques. Drip irrigation is an efficient method that utilizes a network of tubes or hoses with small emitters to deliver water directly to the plant's base. This precise delivery system reduces water waste and enhances plant growth. On the other hand, spray irrigation involves the use of sprinkler systems to distribute water. Water is sprayed into the air and then falls onto the soil, providing moisture to plants. Water loss due to evaporation and wind can occur, and excessive water pressure can potentially damage plant leaves.

SLIDE 15: On a larger scale, clay pot irrigation is a low-tech, cost-effective method that can be easily replicated and maintained. It is well-suited for small-scale projects. However, its limited water capacity may pose challenges when using it for larger land use. In contrast, drip irrigation is widely used in large-scale farming and gardening. It can be automated using timers and sensors to optimize water usage. Nevertheless, there are considerations to keep in mind. Small emitters in drip irrigation systems can become clogged due to sediment or debris, affecting water flow and plant health. Additionally, the installation and maintenance costs of drip irrigation systems can be relatively high, requiring regular upkeep to prevent leaks and ensure proper functioning. While spray irrigation is commonly employed in large-scale farming and gardening, it is less efficient compared to other methods. Furthermore, the installation and maintenance expenses associated with spray irrigation systems can be significant.

SLIDE 16: In general, residential gardens in the Willamette Valley benefit from consistent rainfall, providing sufficient water for most of the year. However, the occurrence of summer droughts and extended dry spells necessitates additional watering, making clay pot irrigation highly advantageous. This emphasis on irrigation efficiency becomes even more crucial in light of future climate conditions. By 2080, the climate in Eugene is projected to resemble the current climate in Granite Bay, California. In Granite Bay, summers are typically 13.8°F hotter and 86.2% drier than in Eugene. This anticipated shift in summer drought and heat will have significant implications for growing conditions and will require ongoing adaptation of irrigation practices. The profession of landscape architecture is uniquely poised to have a special role in climate change mitigation and adaptation efforts. Landscape architects, with training in systems thinking and ecological planning, must urgently respond to landscapes facing water scarcity. To address the predicted seasonal droughts, efficient irrigation systems such as buried clay pots can be used and specifically could provide utility to many types of landscapes.

SLIDE 17: While clay pots are readily available for purchase at garden stores, the utilization of 3D printers presents a range of advantages when it comes to exploring clay pot design and efficiency. 3D printers provide enhanced customization and precision, allowing for greater design flexibility and intricate details. Additionally, they offer accessibility and efficiency in the manufacturing process, enabling individuals without specialized wheel-throwing skills to engage in clay pot production. The integration of digital design with 3D printing has revolutionized product development, offering designers unprecedented freedom to create complex and customized objects. With 3D printing, digital designs can be translated into physical objects by adding material layer by layer, opening up new possibilities that were previously challenging or impossible with traditional methods. This innovation enables iterative prototyping, allowing designers to modify digital models and print new iterations quickly and cost-effectively. Forexample, in fields like healthcare, the combination of digital design and 3D printing allows for extensive customization, addressing individual needs. Design optimization algorithms further enhance the process, fostering lightweight and efficient designs that minimize waste and enhance product functionality. Additionally, digital technologies and computational modeling can help assess micro-climate variations on-site, guiding the layout of clay pot irrigation systems by analyzing factors such as water flow patterns, sunlight exposure, shading influences, and wind direction.

3. HOW TO DESIGN CLAY POTS

SLIDE 18: Exploring different clay pot shapes and surface areas is crucial because the form directly impacts water distribution, evaporation rate, root growth patterns, aesthetic appeal, and space optimization. When considering the use of algorithmic solvers to aid in design solutions, it was important to deconstruct and analyze the pot geometries in order to create a definition in Grasshopper. While this approach illustrated on the slide may seem basic, it provided a solid foundation for analyzing with Wallacei.

SLIDE 19: Wallacei is a powerful evolutionary solver integrated with Grasshopper 3D, enabling users to conduct evolutionary simulations. The main difference between evolutionary solvers and regular solvers lies in their problem-solving approach. Regular solvers focus on solving specific problems based on known mathematical models and problem structures, while evolutionary solvers are more flexible and suitable for complex and poorly-defined problems where explicit models may not be available. Wallacei combines advanced analytics, comprehensive selection methods, and detailed tools to help users' understanding of their evolutionary runs. Through the iterative process of generating and evaluating design alternatives, I used these tools to explore a wide range of possibilities, taking into account factors such as water distribution, volume, surface area and structural integrity.

SLIDE 20: The specific objectives I prioritized in my analysis were maximizing volume, to expand the water storage for plants. Maximizing surface area, to increase the root-pot interactions and increase the slope between 10-70 to also support increasing those connectivity points. Finally by decreasing the cantilever, the structural durability was maintained. By structuring my definition accordingly, Wallacei successfully identified the top four pots that best met each objective and subsequently, the average of those fitness ranks.

SLIDE 21: While using Wallacei informed my decision-making process and facilitated the finalization of two clay pot shapes, I took over the final creative choices and added textures, inverted shapes to change the water distribution, speculated on the neck length, and adjusted the bottom of the pots to have a rounded structure.

SLIDE 22: Once the two clay pot designs have been selected, additional factors were considered during the fabrication process. One crucial consideration is the type of clay employed, as it significantly impacts the pot's porosity. Porosity refers to the quantity and size of pores within the clay material. The porosity of clay can also vary depending on its composition and firing technique. Furthermore, the type of clay chosen also affects the appropriate fabrication method, such as slip casting or wheel throwing. In this particular project, ball clay was utilized due to its availability as a slip in the ceramics studio. However, it is important to note that ball clay is less porous compared to terracotta clay.

SLIDE 23: After successfully 3D printing a mold, I moved on to the ceramic phase of my project. I must mention that, until four months ago, I had no prior experience with slip casting. Despite my initial unfamiliarity, I assure you that learning slip casting was a relatively straightforward endeavor. Slip casting is a technique employed in industrial ceramics for crafting intricate shapes and thin-walled structures. It entails pouring a liquid mixture, known as slip, consisting of clay and water into a porous plaster mold. The plaster absorbs the water from the slip, leaving behind a solid clay layer that takes on the mold's shape. The slip casting process involves several key steps. Firstly, the mold must be prepared by cleaning and thoroughly drying it to ensure proper adherence of the slip. Next, the slip is then poured into the mold, which is held right-side up to prevent leakage, and to coat the entire mold surface. The length of time the slip is left in the mold determines the thickness of the resulting clay layer. Once the desired thickness is achieved, excess slip is drained by placing the mold upside down on a flat surface. After the clay layer has sufficiently hardened, the mold is opened, and the cast is removed. Additional drying may be required before the cast is ready for finishing.

SLIDE 24: In the following slides, I will present the slip casting technique in-action, as well as the two additional steps of 3D printing and mold making as shown here.

SLIDE 25: It took a few attempts to familiarize myself with the mold and drying times, but I was eventually able to document some helpful casting notes.

SLIDE 26: During the initial stages of the slipcasting process, I had to make a decision regarding the type of mold to use: either a one-part or a two-part master mold. Although a one-part mold offers simplicity and efficiency in production, I ultimately opted for a two-part mold due to its suitability for creating complex shapes with intricate geometries.

SLIDE 27: At the conclusion of the slip casting process, I successfully fired a total of 26 clay pots: 11 of design 1, 12 of design 2, and 3 "control" pots that replicated the traditional shape and texture of tradition clay pots. With the firing complete, the clay pots were now ready for greenhouse testing.

SLIDE 28: Before diving into the details of the greenhouse experiment, I would like to emphasize some important design aspects of each pot. In all the designs, I purposely retained the mold raft to extend the length of the pot's neck. Additionally, I maintained a narrow neck width to minimize evaporation. Furthermore, the disk-like shapes were intentionally incorporated to enhance the surface area of the pots. These design choices were made to optimize the performance of the clay pots in terms of water retention and efficient irrigation.

SLIDE 29: This design shares similar characteristics with the previous pot, but there are differences in texture and water storage placement. In this design, the texture varies, providing a unique visual and tactile experience. Moreover, the majority of the water is stored closer to the soil surface, potentially allowing for easier access and absorption by the plant's roots. This variation in water distribution could have implications for plant growth and overall water efficiency in the irrigation system.

SLIDE 30: Finally, this clay pot exhibits a traditional shape with a smooth surface. While it maintains a classic aesthetic, there is a notable feature worth highlighting: the tapered body shape and rounded bottom. These design elements are intentionally incorporated to facilitate easier burial of the pot in the soil.

4. TESTING & ANALYZING DESIGN

SLIDE 31: Now we have arrived at the analysis of the clay pot designs.

SLIDE 32: The initial round of greenhouse testing played a crucial role in preparing for the actual experiment. It provided valuable insights and information that helped in several aspects to this study. Firstly, it helped determine an ideal soil composition required for accurate measurement of plant biomass. Understanding the right soil composition was essential, as it revealed that incorporating sand into the mix facilitated easier removal of roots. Secondly, this greenhouse testing allowed for the arrangement and positioning of the pots within the container to be carefully planned. This arrangement is important for ensuring consistent environmental conditions and minimizing any potential confounding factors that could affect the results. Finally, this initial setup helped me to gain a better understanding of the space limitations within the greenhouse and the extent to which I could conduct testing. This realization allowed me to plan and adjust my experimental approach accordingly.

SLIDE 33: The setup consisted of container plants such as lavender and rosemary, and commercially purchased clay pots. The testing was initiated at the beginning of February, and it is evident from the images that the container plants were root bound.

SLIDE 34: After inconsistently watering this container for a couple of months, I made the decision to stop watering it and allowed the pot to dry out completely for a period of 2.5 weeks..Upon removal of the clay pots, it was observed that the hole showed enhanced root growth patterns in the soil at the base of the pot where there was a more consistent water supply.

SLIDE 35: Additionally, the lavender plant, which still had remnants of root bound areas, displayed increased root growth on the side that had more contact with the clay pot.

SLIDE 36: For the final stage of testing, using the digitally fabricated clay pot designs, the greenhouse experiment utilized four containers filled with sand and seeded with roemer’s fescue grass to evaluate the different pot designs. Two pots from each design were allocated to three containers, while the fourth container served as a control without a clay pot. The containers were uniformly watered twice a week by pouring water into the pots or by spraying the same amount of water into the control container. The watering procedure and grass documentation was carried out for 8 weeks.

SLIDE 37: These images showcase the process of burying the clay pots and setting up the experiment. The photographs capture the stages of preparing the sand, placing the clay pots in the designated areas, and arranging the containers.

SLIDE 38: This diagram illustrates the changes in plant growth observed in each container over an 8-week period along with the shading provided from the container walls. Although the plant placement in the diagram is approximate, it aims to demonstrate the watering radius of the clay pots and estimated grass growth.

SLIDE 39: Notably, in the container without a clay pot, the plant growth appears more uniform, which can be attributed to the use of a spray bottle for watering. During week 3, I started to notice gaps in the grass growth on areas receiving more solar exposure. Finally during week 8, there was established clusters of growth around the pots, especially in the more shaded regions of the container. It is important to mention that the grass in the container without a pot suffered significantly, as no watering was provided during the final week, resulting in the death of many grasses.

SLIDE 40: After harvesting the plant biomass from each container, removing the sand, and drying the biomass to eliminate moisture weight, it became evident that the control pot exhibited the highest biomass at 3.2g. One possible explanation for the higher biomass in the control pot is the variation in water volume. It is important to note that the control pot, which was made by a beginner with limited experience, may have unintentionally contained a larger volume of water compared to the other pots. This difference in water content could have contributed to the observed difference in biomass between the control pot and the other experimental pots. In addition, it is important to recognize the presence of other limitations in this experiment, with one significant constraint being the influence of solar radiation and shading on grass growth within the containers. Over the course of a few weeks, it became apparent that the taller walls of the containers provided more shade to the right side of the container, resulting in increased grass growth in that area. To optimize growing conditions and facilitate a more comprehensive analysis, future studies should aim for consistent solar exposure and conduct additional sampling.

SLIDE 41: While the focus of this experiment was primarily on biomass, there were several additional experimental observations made on the day of data collection. Firstly, it was observed that there was a greater density of grass within a 10-inch radius of the clay pots, indicating a potentially lower porosity than anticipated. This observation can most likely be attributed to the use of ball clay material, which is less porous compared to terracotta or the use of sand in the container. Another observation was the color retention of the pots throughout the two-month experiment, with minimal green coloration visible where the surface soil layer came into contact with the neck of the clay pots.

SLIDE 42: Among all the clay pots, Design 1 had the smallest volume and relatively lower water storage near the soil surface, which could have influenced the early root establishment of the grass. However, the most concentrated root structures were observed at the base of the pot, where the highest water retention occurred. The most intriguing finding was the root architecture, characterized by elongated, fibrous roots tightly wrapping around the circular indents on the pot's surface, as depicted in the largest image. This root structure was the most well-established among all the tubs.

SLIDE 43: Despite having the majority of water stored towards the top surface of the soil, this design yielded the lowest biomass during data collection. Surprisingly, even after a week without watering, all the clay pots still retained at least 200 ml of water. And another observations that I would like to note is: upon removing the pot, the sand in the top image still contained noticeable moisture.

SLIDE 44: The control shape, based on traditional olla designs, has demonstrated consistency and durability over thousands of years, and reaffirmed its effectiveness even in the context of digital fabrication. This enduring shape has withstood the test of time, raising questions about the necessity of 3D printing and digital design in this particular process.

5. APPLICATION TO DESIGN

SLIDE 45: Drawing upon the research findings and the results of my experiment, I sought to apply clay pot irrigation to an existing design.

SLIDE 46: As mentioned earlier, buried clay pots have proven to be highly effective in a wide range of landscape applications. They offer exceptional benefits for various purposes such as residential gardens, orchard and forest establishment, environmental restoration, farming, and propagation. How they are arranged and applied in each landscape will differ, and I wanted to begin to understand how they could be coupled with conventional irrigation to provide water to an established design.

SLIDE 47: With my growing research and admiration for clay pots, I began wondering why landscape architects werent using these simple yet effective methods more frequently in design. Eventually I came across the case study: called the Burges Residence, designed by EcoSence, a landscape architecture firm based in Tuscon, Arizona. For this project Landscape designers and eco-hydrology specialists at EcoSense, utilized a passive rainwater harvesting design and underground clay vessels to allow water to percolate slowly.

In Tucson, like many other desert cities, the region faces severe drought conditions, resulting in stringent restrictions on lawn irrigation and the promotion of rainwater harvesting and gray-water systems through rebates. However, despite the arid climate, the area still experiences occasional monsoon rains amidst long periods of dry heat. Thus, creating systems that can capitalize on these sudden, intense storms becomes crucial.

Additionally, the owner of the Burges Residence desired a low-maintenance yet aesthetically pleasing garden. The images from this case study showcase how the strategically placed clay pots seamlessly blend into the landscape, aiding in the establishment of sweet acacia plants upon planting.

SLIDE 48: This integration of clay pots not only addresses the water scarcity issue but also contributes to the overall attractiveness and functionality of the garden design. It serves as a testament to the versatility and effectiveness of clay pots in creating sustainable and appealing landscapes. I would like to share a quote from the owner: “The ollas have helped our trees grow faster than we ever anticipated! There is a sweet acacia that has grown to about 20 to 25 feet tall, providing valuable shade for not only our smaller plants, but also for the birds and insects that we commonly find underneath in our sagebrushes. And every spring, birds and butterflies are common visitors. We do have an irrigation system, but we only have to turn it on during the wickedest of 118-degrees days during the summer.”

SLIDE 49: Learning from the Burges Residence case study, I wanted to see how I could apply these ideas to willamette valley. As I had briefly mentioned, my aim was to explore a hybridized irrigation method, specifically for a landscape with a highly dense planting plan. This stage is not fully developed, because believe it or not, it was incredibly hard to find a firm that will give you their irrigation and planting plan in Eugene. Thankfully Delaney hooked me up with a project from CM, she asked for permission of course, of a project they had designed in 2011 for Planned parenthood. While the overall project is extensive, I focused my attention on the entrance garden for the purpose of my study.

SLIDE 50: For this design, I opted to utilize a commercially available clay pot, specifically a larger version of the pot I used in the greenhouse. This larger version has a water capacity of 6.5 liters and a watering diameter of 4 feet. Considering the scale of the site, using clay pots exclusively would require approximately 800 ollas. The circular shapes depicted here represent the watering diameter of the clay pots. Given that the landscape was initially designed for spray irrigation, my objective was to identify an area where I could propose the replacement of spray irrigation with clay pots. So I conducted an environmental analysis, specifically for water flows, solar radiation, and wind movement during the summer months. For each analysis, I strategically positioned the clay pots in the most challenging environments, which is also the same areas where I predict the spray irrigation would be least effective and could be replaced with clay pots to mitigate water loss. Specifically, I placed the clay pots in the driest areas with high solar radiation and in windy spots where spray could easily be lost through evaporation. This approach allowed me to assess the potential benefits of using clay pots in the areas most prone to water loss and evaluate their effectiveness in these more difficult micro-climate conditions.

SLIDE 51: Using the overlaid placements from the different analyses, I identified areas where there was consistent overlap in all three layouts. This analysis led to the identification of this orange area that primarily follows the perimeter of the garden.

SLIDE 52: Next I looked at the planting plan to see how this identified area overlapped with the plants.

SLIDE 53: Within the designated area of the overlaid environmental analysis, the predominant plant species include the Mt. Vernon Laurel, Dwarf Fountain Grass, Red Switch Grass, and Dwarf Winged Euonymus. These plants have low maintenance requirements and are able to thrive in drought-prone conditions once established. Additionally, most of these plant species possess fibrous root systems that are well-suited for integration with clay pots.

SLIDE 54: Finally, I overlaid the irrigation plan provided by CM with the planting plan and the environmental analysis.

SLIDE 55: If I had been involved in the design and construction process of the CM project in 2011, I would have suggested replacing the spray irrigation system in the designated area with clay pots. Although this area is relatively smaller, it would still require approximately 30-50 clay pots, depending on any potential rearrangement or updates to the plant selection in the planting plan. Additionally, considering the proximity of this area to the mainline, it could be feasible to connect the clay pots to a water source using a hose system.

SLIDE 56: Integrating ollas with other drip and spray irrigation methods in a residential landscape design can offer a more comprehensive watering solution that combines the benefits of each system. While ollas provide precise and localized watering directly to the root zone of plants, drip and spray systems can cover larger areas, providing a broader distribution of water.

6. FUTURE WORK

SLIDE 61: While I enjoyed using digital technologies throughout the many stages of this project, I would like to recognize that many of the steps may not be necessary. 3D printing offered opportunities to customize and analyze the shape of the clay pot, but perhaps the time honored design is simply the best. It is conceivable that the design itself may not be as crucial as the use of a porous clay container buried in the ground to supply water to plants.
In my opinion, further development of the environmental analysis could greatly benefit landscape architects in considering a hybridized irrigation approach. By combining traditional methods with modern techniques, we can create more efficient watering systems for landscapes.Lastly, I would be interested in exploring the possibility of increasing the size of the clay pots and utilizing clay sourced from the design site itself.

CITATION OF IMAGES:

Images from pages 14-15:

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