Seeds of Change: Greenhouse Infrastructure for Icelandic Afforestation

Carey Clouse[1]
[1]*University of Massachusetts Amherst*

Abstract

Iceland's afforestation program is a well-coordinated national effort, buoyed and amplified by greenhouse structures. These low-carbon footprint structures are key producers of millions of saplings used in forestry programs across the country. This paper analyzes the greenhouse from a design perspective, looking at this vernacular form, material makeup, technology and application for broader lessons under climate change challenges. Several key takeaways emerge, including the benefits of multifunctional greenhouse spaces, their broad coordination with natural resources, and the value of incorporating new technologies and research in these structures. These advantages establish the Icelandic greenhouse as a model for other regions, while at the same time, demonstrate that the role of design has been largely untapped in Icelandic silviculture.

Introduction

Iceland's greenhouses produce more than flowers and food products; they also provide critical enclosure for the country's bourgeoning tree sapling industry. In this small subarctic island nation, extreme weather conditions make it difficult to both create and sustain open air forestry efforts. As a result, this industry has relied on advances in greenhouse technology and their widespread use for the production of saplings. The greenhouse enclosure protects young trees from wind and snow, retains geothermal heat throughout the colder months, and projects artificial light for up to seventeen hours per day (Garðarsdóttir, Pétursdóttir, and Nickayin 2021). This sphere of protection greatly increases early sapling growth, giving these plants a vital head-start before they permanently move out into the elements.

This paper explores the greenhouse as a climate adaptative design response, for its significant role underpinning the Forest Service's afforestation efforts. In addition to promoting rapid sapling growth and improving survival rates, the greenhouse structure creates additional co-benefits, such as pest protection, physical security, and better working conditions for growers. This model has implications for the design and planning of agrarian and silviculture landscapes, as spatial design, systems design and productive infrastructure design will need to transform to "provide a framework for developing the potential for cultivating new urban ecologies, economies, and cultures" (Nasr and Potteiger 2023, p. 20) under climate change projections.

The Icelandic sapling greenhouse bridges multiple divides: the utilitarian practice of tree planting and more technologically-advanced horticultural methods; the need for rapid production of millions of seedlings and the slow, precision work of developing genetically-selected species; and the often distanced disciplines of architecture and landscape architecture. The greenhouse is a design response born out of necessity in the challenging environmental conditions of Iceland, and as such it may demonstrate best practices for other resource-constrained environments under climate change. In so doing, this forestry practice may offer a new standard for other places and conditions, particularly where more traditional methods for afforestation have failed. (Figure 1)

Figure 1. Tree sapling Nursery in Reykholt, Iceland Image: Author

Background

Icelandic afforestation programs were created as a direct response to human-induced deforestation across the island; environmental degradation that began in the Settlement Era. By the start of the 20th century, nearly all of Iceland's trees were cut down for fuel, building material and the creation of pasture, leaving the country with just one percent of its land forested (Fountain 2017). Once these trees disappeared, their role in retaining soil, creating animal habitat and serving as natural windbreaks became excruciatingly clear (Aradóttir and Arnalds 2001). Today the country has doubled the number of hectares of forested land on the island, by applying a variety of techniques for afforestation efficiency, including the greenhouse model described in this paper.

The challenge of rebuilding forests after extreme decimation is difficult in Iceland, because the country has a short summer growing season, poor soils, and extreme natural forces such as wind and volcanic activity (Askarsson, Sigurgeirsson, and Raulund-Rasmussen 2006; Blöndal 1987). However, the small size of the country and the government's investment in forestry ensure that afforestation projects are well coordinated and designed to function efficiently even in this context (Eysteinsson 2017). Greenhouses are widespread in Iceland, occasionally folding co-benefits related to human experience, tourism, research and engagement into otherwise staid agricultural spaces (Garðarsdóttir, Pétursdóttir, and Nickayin 2021; Pavlakovič and Turnšek 2019).

The physical structure of the greenhouse could be considered a pan-disciplinary space, where interactions between architecture, landscape architecture, engineering, horticulture, and silviculture align. The greenhouse is well represented in scientific and scholarly literature, where

it appears in cultural landscape histories, in technical journals relating to geothermal heat production, and in horticultural, gardening, and farming sources (Achour, Ouammi, and Zejli 2021; Badji et al. 2022; Jordan 2010). It is rare, however, to find coverage of the greenhouse in design scholarship in the disciplines of architectural or landscape architecture. The reason for this omission may have something to do with the greenhouse's utilitarian form and structure, which may be seen as a working factory rather than a designed space. Paradoxically, the architecture of containment too often recedes in the collective memory because it is overshadowed by interior landscapes; this architecture merits deeper design investigation.

Methods

Research was conducted in the southern part of Iceland in 2024 and 2025, through greenhouse visits and open-ended interviews with growers. Interviews with stakeholders, including members of the Icelandic Forestry Association, the Icelandic Forest Service, and individual growers were aggregated for research themes. Greenhouse structures were photographed and surveyed for physical, technological, and crop components. A literature review produced information about Icelandic greenhouses, as well as afforestation trends, and forestry planning within the design disciplines. Farm visits were selected based on their role as sapling producers in Iceland, including greenhouses at various scales and ages. Additionally, visits to two retired greenhouse farms, now reconfigured for other uses, provided a counter example to the other successful greenhouse business models.

Results

By finding the types of species that work well in Iceland's climate, and then growing the birch, Sitka spruce, lodgepole pine, Russian larch, black cottonwood and other varieties of saplings from seed in greenhouses, the forest service is able to control the quality of trees planted through their afforestation program. (Figure 2) This is an important advantage in Iceland, where climate change has already impacted the species that thrive here, and high initial investments are required to enable growth. The greenhouse structure enables genetic cross-breeding research in a well-contained, highly controlled environment, and then these same armatures protect saplings as they grow from seed. Mature saplings produced in Icelandic greenhouses have a high rate of survival; this is the central reason for their indoor production model (Askarsson, Sigurgeirsson, and Raulund-Rasmussen 2006).

Figure 2. A Forest Service greenhouse test site in Mógilsá, Iceland Image: Author

Forest service representatives and stakeholder interviews revealed a wide variety of competing afforestation interests and agendas. For instance, interviewees cited a need for tree planting in order to create long-term carbon sequestration (M. Hunziker, O. Arnalds, and N. J. Kuhn 2019), wildlife habitat, wood products (including Christmas trees, fence posts and wood chips), for shelterbelts from wind and views, and notably, to reduce soil erosion. At times these varying products, outcomes or interests can be at odds, and in this case the Forest Service manages maps and other decision-making guidelines for forest use. The cost of operating a greenhouse nursery is significant, because although water and energy–particularly the heat that comes directly from underground geothermal reserves–is cheap or free, human labor, greenhouse technologies and infrastructure, and electricity can be costly (Butrico and Kaplan 2018). However, the greenhouses enable a greater quantity of successful trees to be planted, enabling a wide variety of uses for these forests.

Greenhouses were seen to provide co-benefits, enabling the use of geothermal heating to stimulate plant growth and new technologies for year-round research and production. However, several stakeholders noted that many of these structures have emerged from patchwork or ad-hoc processes, rather than any intentional design or planning efforts. Collaboration with designers could encourage Icelandic growers to adopt new, more successful prototypes (Proksch and Ianchenko 2022).

Discussion and Conclusion

The production of saplings in Icelandic greenhouses makes sense financially and physically, given the afforestation goals of the country and the island's climate and context. However, limitations exist within this system, not the least of which is the high cost of labor, operations, and initial technological or infrastructural investment. (Figure 3) Greenhouses remain expensive in Iceland, and efforts to drive down these costs could come from better design, in terms of material, organizational and production efficiencies. A second limitation for this silviculture model comes from considering the carbon footprint of the whole process, from energy use in greenhouses to the transfer of saplings from greenhouse to a more permanent site. Finally, greenhouses offer a physical barrier to environmental threats, but also create a separation from outdoor space that is often privatized, even while producing trees for public use. Future design interventions could provide a greater level of design thinking and dialogue between various uses, and in so doing, could provide a multifaceted programming approach for these spaces.

Figure 3. A state of the art sapling production system at the greenhouses at Sólskógar. Image: Author

Building up sapling production capacity, through the Icelandic greenhouse model, could increase the types of species planted, improve their survival rate, and capitalize on new advances in energy and technology. Under climate change, many places around the world may need to adopt interior environments, as open air landscapes continue to be impacted by changing temperatures and

climate regimes. Food production, in particular, may necessarily move into greenhouses. Plants may need greater protection from heavy hail, wind, sandstorms or flooding. At the same time, design scholarship predicts new futures for functional agricultural and horticultural landscapes (Lickwar and Thoren 2021; Lickwar, Thoren, and McKee 2020; Waldheim 2010). The design disciplines may be useful in reimagining contemporary planting processes, to consider concerns such as water, material and energy scarcity, local production, and possibly even security threats (Lipschitz 2022).

Greenhouses are just one piece of the broader success of silviculture in Iceland, but as an interior environment, they appear to be suited to more formal engagement with the design disciplines. Spatial, experiential, and physical problem-solving will be needed in these structures; these are skills that can be provided by designers. Finally, the multifunctionality of the Icelandic greenhouse model may be limited, but it has shown promise in aggregating and layering programming interests within an interior landscape. This plurality of approaches enables greater greenhouse co-benefits across stakeholder groups, and could be more deeply explored in future design collaborations. By building on the progressive legacy of greenhouses in Icelandic silviculture, and capitalizing on the many benefits that this interior environment offers, both the project of forestry and the people building those forests may flourish.

Acknowledgments

Many thanks to the employees of the Icelandic Forest Service and Sólskógar for sharing their thoughts and experiences. This research was supported through a Fulbright Iceland-National Science Foundation Arctic Research Grant.

References

Achour, Yasmine, Ahmed Ouammi, and Driss Zejli. 2021. “Technological Progresses in Modern Sustainable Greenhouses Cultivation as the Path towards Precision Agriculture.” *Renewable and Sustainable Energy Reviews* 147 (September):111251. https://doi.org/10.1016/j.rser.2021.111251.

Aradóttir, Ása, and Olafur Arnalds. 2001. “Ecosystem Degradation of Birch Woodlands in Iceland.” In *Nordic Mountain Birch Ecosystems*, edited by FE Wielgolaski, 293–306. Paris: UNESCO and Parthenon Publishing.

Askarsson, Hreinn, Adalsteinn Sigurgeirsson, and Karsten Raulund-Rasmussen. 2006. “Survival, Growth, and Nutrition of Tree Seedlings Fertilized at Planting on Andisol Soils in Iceland: Six-Year Results.” *Forest Ecology and Management* 229 (1–3): 88.

Badji, Ahmed, Abdelouahab Benseddik, Holcine Bensaha, Akila Boukhelifa, and Issam Hasrane. 2022. “Design, Technology, and Management of Greenhouse: A Review.” *Journal of Cleaner Production* 373 (November):133753. https://doi.org/10.1016/j.jclepro.2022.133753.

Blöndal, Sigurdur. 1987. “Afforestation and Reforestation in Iceland.” *Arctic and Alpine Research* 19 (4): 526–29. https://doi.org/10.2307/1551420.

Butrico, Gina, and David Kaplan. 2018. "Greenhouse Agriculture in the Icelandic Food System." *European Countryside* 10 (4): 711–24. https://doi.org/10.2478/euco-2018-0039.

Eysteinsson, Thröstur. 2017. "Forestry in a Treeless Land." 5th Edition. Egilsstaðir Iceland: Icelandic Forest Service.
https://www.skogur.is/static/files/2017/Forestry_in_treeless_land_BKL_210x260mm.pdf.

Fountain, Henry. 2017. "Vikings Razed the Forests. Can Iceland Regrow Them?" *The New York Times*, October 20, 2017, sec. Climate.
https://www.nytimes.com/interactive/2017/10/20/climate/iceland-trees-reforestation.html.

Garðarsdóttir, Steinunn, Kristín Pétursdóttir, and Samaneh Sadat Nickayin. 2021. "Gardening Practices and Food Production in Iceland: History, Botanical Species, Greenhouses and Infrastructures." Rit LbhÍ nr. 146. Landbúnaðarháskóli Íslands: Agricultural University of Iceland.

Jordan, Jennifer. 2010. "Landscapes of European Memory: Biodiversity and Collective Remembrance." *History & Memory* 22 (2): 5–33. https://doi.org/10.2979/HIS.2010.22.2.5.

Lickwar, Phoebe, and Roxi Thoren. 2021. *Farmscape: The Design of Productive Landscapes*. New York: Routledge.

Lickwar, Phoebe, Roxi Thoren, and Bradford McKee. 2020. "Grow Your Own: People Have Long Needed to Be Closer to Their Food Resources. The Pandemic Makes That Fact Only More Clear." *Landscape Architecture Magazine* 110 (6): 88–99.

Lipschitz, Forbes. 2022. "By the Numbers: Rethinking the AgriCultural Image." *Journal of Landscape Architecture* 17 (1): 48–57. https://doi.org/DOI: 10.1080/18626033.2022.2110421.

Hunziker, Mathhias, Olafur Arnalds, and Nikolaus Kuhn. 2019. "Evaluating the Carbon Sequestration Potential of Volcanic Soils in Southern Iceland after Birch Afforestation." *SOIL* 5 (August):223–38. https://doi.org/10.5194/soil-5-223-2019.

Nasr, Joe, and Matthew Potteiger. 2023. "Spaces, Systems and Infrastructures: From Founding Visions to Emerging Approaches for the Productive Urban Landscape." *Land* 12 (2): 410. https://doi.org/10.3390/land12020410.

Pavlakovič, Barbara, and Maja Turnšek. 2019. "Adding Value with Experiences: Industrial Tourism and Geothermal Food Production." *Tourism in Southern & Eastern Europe* 5 (January):507–20. https://doi.org/10.20867/tosee.05.39.

Proksch, Gundula, and Alex Ianchenko. 2022. "Commercial Rooftop Greenhouses: Technical Requirements, Operational Strategies, Economic Considerations, and Future Opportunities." In *Urban and Regional Agriculture: Building Resilient Food Systems*, edited by Peter Droege, 503–32. Amsterdam: Elsevier.

Waldheim, Charles. 2010. “Notes Toward a History of Agrarian Urbanism.” *Places Journal*, November. https://placesjournal.org/article/history-of-agrarian-urbanism/.