Networks of Community: The Multi-Scale Phenomenon of the Huerta and its Role in Cultural and Climatic Resilience

Región de la Araucanía, Southern Chile

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Abstract

Through the lens of the huerta, a small scale agro-ecological garden, we are able to understand the existing socio-ecological networks within the Araucania region in Chile and how this type of food production and its corresponding social fabrics might exhibit resilience to climate change and cultural hegemony in the coming decades. The Araucania region has an existing history of cultural erasure and fragmentation through both past and present colonial regimes, resource intensive and ecologically harmful conventional farms, and, presently and into the future, faces a changing climate mostly characterized by more extreme temperatures and a decrease in precipitation. Visiting three different sites in the Araucania region, we conducted a comparative case design study using ethnographic observation, semi-structured interviews and network mapping, followed by literature review and contextualization of results. We found that these huertas function as bastions of ecological and social resilience through a variety of means including, but not limited to, seed saving, soil amendment, community engagement, product sales, and pollinator gardens, expanding resilience from the site to community level through trade and education networks. These spaces must be understood as complex adaptive systems, made resilient chiefly *by* their complexity that are crucial to bio-cultural preservation in La Araucania region.

Key words: Complex Adaptive Systems; Huertas; Resilience

Introduction to the Research Problem

Our research takes place in La Araucanía region of Southern Chile. We were motivated to investigate the research question, "Through understanding the phenomenon of the garden as a complex web of multi-scale relationships, what role does the garden and gardener play in building cultural and climatic resiliency?", due to the various levels of strain induced on both the food system and cultural fabric of the people of La Araucanía. We identified the sources of these pressures as changes in climate, both current and projected, resource intensive monocultural conventional agriculture, and the history of colonization and cultural erasure in the region. Investigating the resilience of both the huertas and the stewards who tend them reveals how these ways of growing food have survived and might continue to do so as climatic pressures increase.

The first threat we identified to the food system of La Araucania region was climate change. Anthropogenic climate change, due to industrialization and methane gas emissions, is a global problem, but it is affecting different regions of the world at different paces. Present day, the identified climatic issues in Central Chile are primarily wildfires (González & Veblen, 2006), decreased precipitation, and more extreme temperatures, of both heat and cold.

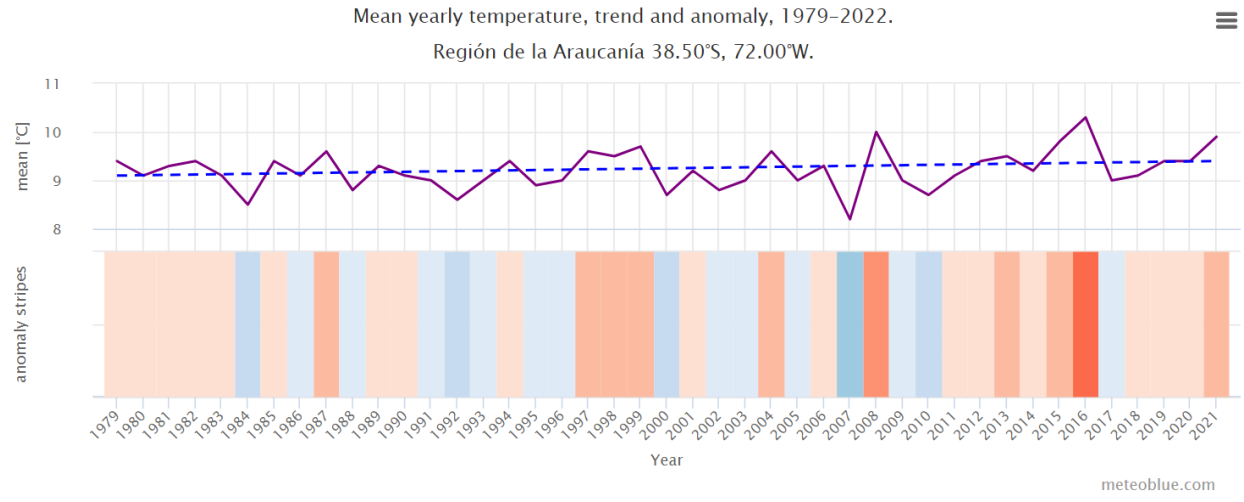

Figure 1: Climate change región de la araucanía (meteoblue.com, 2022).

If residents, specifically land stewards of La Araucania region are already feeling the effects of climate change, this indicates already present methods of adaptation or resiliency in *huertas* or the food system at large. However, our research question investigates specifically what kind of resiliency, if any, will small-scale agriculture have in the face of future climate change, which is predicted to demonstrate climatic changes and events far worse than La Araucania is experiencing present day. Projected changes appear to be much bleaker, with a minimum temperature increase of 2 degrees Celsius in the austral winter by the end of the 21st century, and a precipitation decrease of over 40% in the central-southern zone of Chile (Araya-Osses et al., 2020). Additionally, changes in temperature and precipitation can be predicted for La Araucania based on projections done for the Quino Basin and Muco Basin (Figures 2 and 3, Martínez-Retureta et al., 2021).

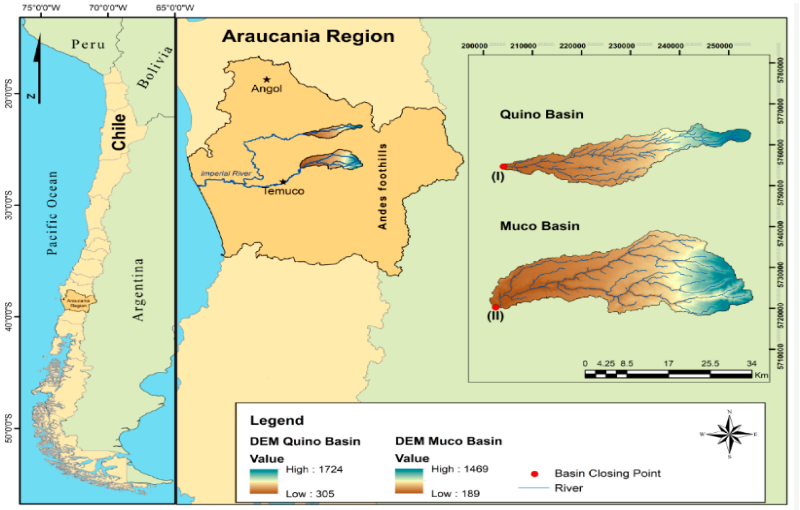

Figure 2: Geographical location map of Quino and Muco basins (Martínez-Retureta et al., 2021).

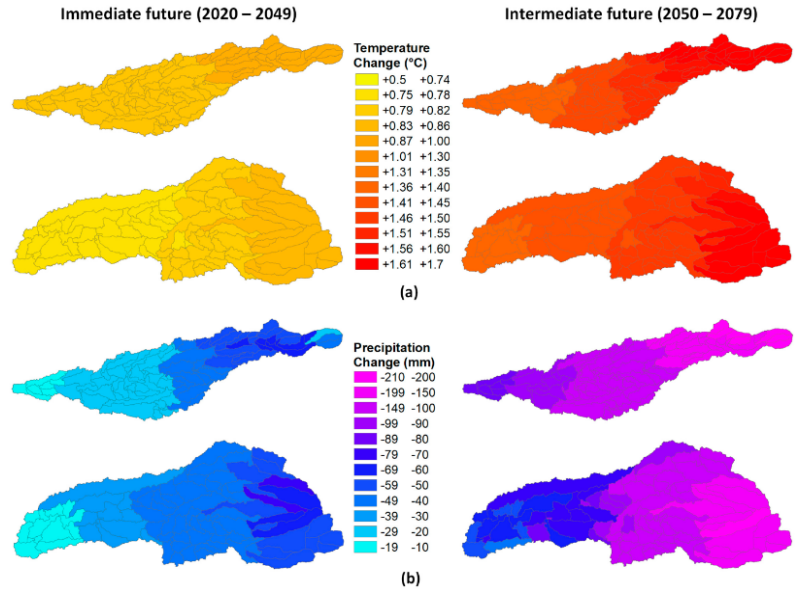

*Figure 3: Changes in the yearly average (**a**) temperature and (**b**) precipitation at the sub-basin scale, using RegCM4-MPI-ESM-MR, scenario RCP8.5. Upper basin: Quino, lower basin Muco (Martínez-Retureta et al., 2021).*

Significant change in temperature and weather patterns can affect food production in many ways: premature bolting, plant death in extreme cold or heat, changes in seed phenology, emergence of new pests, loss of pollinator biodiversity, insufficient water availability, and overall decrease in both crop and seed yields (Singh et al., 2013). It is important to determine whether small-scale food production in La Araucania, via the huerta, is adapting to these changes and risks, and by what means.

A second issue identified with the food system in La Araucania region is the methods of conventional agriculture widely used in the region. Globally, these methods are dubiously unsustainable, garnering a predicted topsoil depletion, in addition to excessive water usage and resource intensive chemical fertilizers and pesticides. On the local level, larger scale crops dominate the food system: called *fundos,* these farms contribute to the production of conventional crops. In La Araucania, land is not distributed equally. Fundos are allotted several hundreds or thousands of hectares, while rural populations own much smaller parcels of land. Most Mapuche residents own smaller huertas or farms near much larger fundos operated by non-Mapuches, which further divides the community both agro-ecologically and socially (Barreau et al., 2019). Since *fundos*, following conventional agricultural practices, are more likely to be environmentally harmful, and exhibit higher vulnerability due to monocultural practices and dependency on chemical inputs, investigating the presence of a more ecologically sound (and potentially resilient) farming system in the form of small scale-gardens reveals a critical alternative (Andres et al., 2016).

The third problem identified in La Araucania region is the history of colonization and neoliberalism, which has diminished the practice of culture and tradition, of both the Mapuche people and of the campesino lifestyle. La Arucania and the Mapuche people were very resistant

to Spanish colonization in its nascent days; however, though technically victors in the Arauco war of the 16th and 17th centuries, the Mapuche people of La Arucania endured great hardship (Robles Ortiz, 2020). La Arucania was first incorporated into Chile as part of the Occupation of Araucania, a series of military invasions by the Chilean army and settlers in 1861-1883 (DeMarrais, 2009). The economic reforms induced during Pinochet's regime "elevated" the nation into the status of a more globalized economy, becoming a prime representation of contemporary neoliberalism. However, this economic reform perpetuated social conflict in La Arucania region, especially for the Mapuche. State programs and the timber industry, under the guise of multiculturalism and development projects, sustain colonialist legacies and are not in line with Mapuche claims for cultural autonomy and representation (Richards, 2013). Through a long history of social conflict, Mapuche tradition and culture has faced division, erasure, and assimilation. For this reason, studying the cultural resiliency through the network of the huerta is of critical importance: in a region with a long history of cultural erasure, a system of both neighborly and community connections, and traditional practices of food consumption and production, could potentially serve as a vehicle for cultural resilience.

The importance of a stable, reliable, and nutritious food system, as well as an established and well connected community, becomes even more imperative given the state of healthcare in La Araucania. In fact: "the health indices in the Araucania are the worst in the country despite the existence of the most extensive network of rural and urban primary health clinics" (María, 2004). Chile has a dual healthcare system, meaning both private and public health insurance are available. This leads to a discrepancy in care and thus makes income one of the chief determining factors in healthcare access: a significant issue in La Araucania, the poorest region in Chile. A study conducted on the reliability of healthcare in different municipalities in Chile,

based on individual capacity to respond vs institutional capacity to respond, found that Padre Las Casas fared the worst, with Temuco still ranked below .5 for both of the established metrics (figure 4, Vecchio et al, 2021).

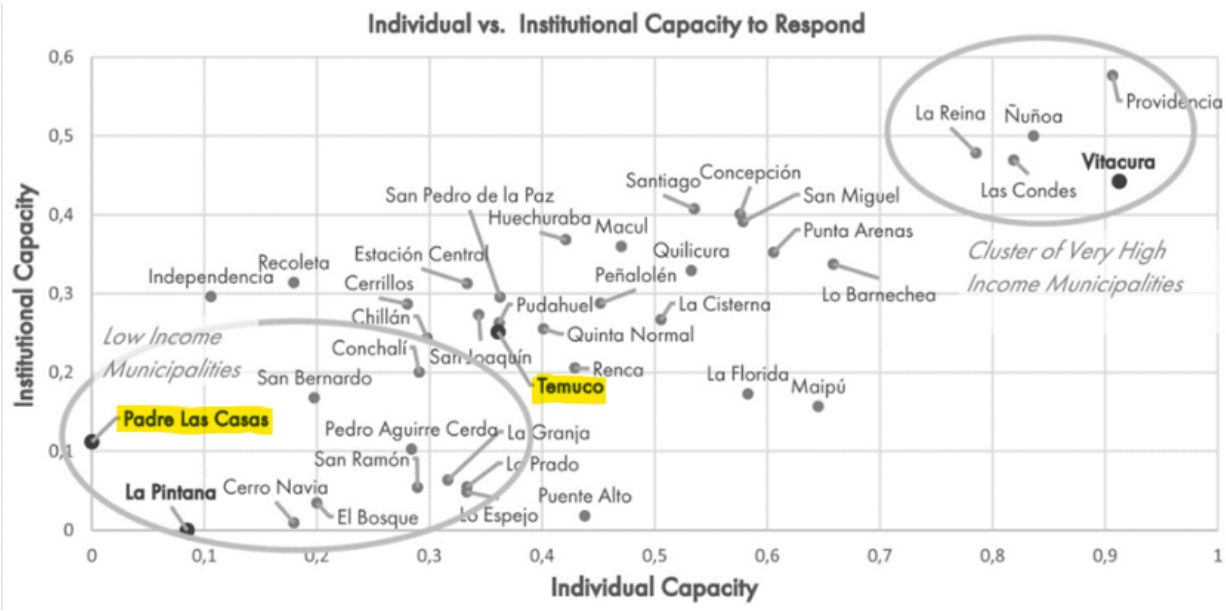

Figure 4: Institutional vs. Individual Capacity to respond to a health emergency. Temuco and Padre Las Casas have been highlighted (Veccio et al, 2021).

Additionally, investigation into the perceptions of healthcare of both mothers and healthcare providers in La Araucania region found that current healthcare is "not culturally appropriate to the mothers' ethnicity, culture, and geographic origin" (María, 2004). Most medical research in La Araucania relating to Mapuche people has been on genealogy and biological markers compared to the general Chilean population, as well as the susceptibility of this ethnic group to different diseases. nndies". There is thus a significant gap left in conventional healthcare for cultural understanding. A strong social fabric, one with significant input and output of knowledge sharing, is necessary to bridge said gap. In fact, both mothers and healthcare providers agree that the first therapeutic resource for illnesses in children is the mothers' own empirical knowledge (María, 2004). Due to the culturally uninformed, expensive,

and inaccessible healthcare in La Araucania region, investigating what kind of community networks exist here through the lens of the huerta, collective knowledge sharing, and use of medicinal plants is of pivotal importance. Ultimately, structurally-complex and communitarily-situated huertas have not only "the potential to play an important role as biodiversity reservoirs," (Ibarra et al 2021) but as reservoirs of *biocultural* resilience in an era of climatic and cultural change. We seek to understand this potential in our research questions and objectives.

Research Question and Objectives

Research Question: Through understanding the phenomenon of the huerta as a complex web of multi-scale relationships, what role does the huerta and huertera play in building cultural and climatic resiliency in this region?

Objective 1: Understand some of the relationships that create the socio-ecological phenomenon of huertas and how these relationships affect community in this region

Objective 2: Understand the history between each huertera and their land, and how this changes how they grow food.

Objective 3: Investigate what changes the huerteras have seen in their land and crops, if any, in the past decade.

Objective 4: Understand how huerteras function as community actors of climate & cultural resilience / the role of huertas in an area impacted by climate change.

Theoretical Framework: **Multi-Scale Biocultural Resilience through Redundancy, Memory, and Heterogeneity**

Our research is grounded, first and foremost, in an understanding of the world as a set of complex, adaptive, and multi-scale *biocultural systems* (Levin 1998, Meadows 2008, Ibarra 2022). A biocultural understanding of the world implies that rather than functioning as discrete and separate entities, "la diversidad biológica y cultural forman vínculos indisolubles y complejos / biodiversity and culture form indissoluble and complex bonds," (Ibarra 2022). From this paradigm, we can apply a complex adaptive system (CAS) framework: these *indissoluble and complex bonds* in turn form networks across spatial and temporal scales, from the microbiome and mycorrhizal networks of a handful of soil, to the knowledge and practices that connect people to each other and to land in a particular region or a particular garden, to global climatic and economic systems (Filotas et al. 2014). This understanding of systems as sets of relationships is further supported by the theoretical frameworks of relationality put forward by Donna Haraway and Anna Tsing, who argue that none of us exist in isolation, but that we all are products of sympoeisis– or making-together– shaped by encounters, relationships, and multi-species entanglements (Haraway 2003, Tsing 2015). A culture cannot be understood separately from its territory, nor any actor separate from its relationships.

Further, according to both the CAS framework and the more philosophical analysis of systems behavior outlined by author Adrienne Maree Brown, each scale of a system is inherently linked, shaping and shaped by each other (Filotas et al. 2014, brown 2017). The patterns and relationships we practice at a small scale can ripple to the largest scales, while large-scale patterns affect small-scale relationships: key to the CAS framework is the notion that "locally interacting entities produce global dynamics that cannot readily be predicted from their

individual behaviors," (Filotas et al. 2014). In a world very much shaped by climate change, colonialism, and capitalization, these frameworks re-highlight the importance of small-scale, relational, and regional systems: just as these large-scale forces are affecting local outcomes, so too can local systems create disruptions in seemingly hegemonic paradigms. Thus, huertas in the surrounds of Pucón, Región de la Araucanía, Southern Chile, become not only isolated sites of food and medicine production for a single person or family, but a rich tangle of relationships, from which might emerge practices and knowledge that carry a climatic and cultural significance greater than the sum of their parts.

The CAS framework further states that "complex systems share the properties of heterogeneity… adaptation, memory, non-linearity, uncertainty," and redundancy (Newman 2011, Filotas et al. 2014). These properties of heterogeneity, memory and redundancy are key to a system's resilience, the capacity of a system to "adaptively persist following… disturbances while retaining [its] essential structures and functions, i.e. the system's identity," as well as incorporate new knowledge (Levin 1998, Meadows 2008, Messier et al 2013, Ibarra et al. 2020). Redundancy is the degree to which several components or relationships are performing the same function within a system: if one fails for some reason, there are several backups (Ibarra et al. 2020). In an agro-food system, a clear example is growing a polyculture instead of a monoculture: if one crop has a bad season, you won't go hungry because you're growing several others. Systems with high redundancy are thus more resilient, able to persist through periods of disturbance, or in fact make room for reorganization, novelty, and renewal (Nykvist et al. 2014).

Memory is inherently linked to biocultural resiliency as well: "social-ecological memory (SEM), defined as the accumulated experiences and history of ecosystem management collectively held by a community in an [socio-ecological system] (Barthel et al. 2010), is

described as one such source of resilience to nurture and draw from in adaptive governance of [socio-ecological systems]," (Folke et al. 2005, Nykvist et al. 2014). Particularly, huertas are sites of this biocultural memory, where relationships, practice, and knowledge are passed down intergenerationally and horizontally, as well as being ingrained in the soil and the physicality of the land (Barthel et al 2010, Marchant et al 2020). This biocultural memory can be a powerful well of ecological caretaking, serving as a "repository of alternative choices that keep cultural and biological diversity flourishing," (Nazarea, V.D. 2006). Additionally, the transmission of biocultural knowledge can counteract processes of forgetting (Barthel et al 2010) initiated by colonialism, land dispossession, and urbanization, where cultural and ecological practices of stewardship and connection are undermined. Thus, we are investigating huertas as potential sites of biocultural memory and redundancy across several scales, fostering cultural and climatic resiliency.

Finally, heterogeneity among differing socio-ecological memories and their associated practices, relationships, and knowledge plays a key role in building resilience on a larger scale. Heterogeneity is "expressed by the uneven nature of interacting entities and their behaviors, spatial location, structural organization, and history," (Ibarra, et al. 2020). This analysis is based on the framework of specific and general resilience as described by Nykvist and von Heland, who identify a difference between specific socio-ecological memory (SEM) (i.e. based on a particular set of practices and cultural definition) and general SEM, as the diversity or *heterogeneity* among specific SEMs contained within one biocultural system. They argue that general SEM is essential for system-wide resilience, as it "provides experiences of many and different pathways that can be experimented with and drawn upon in the face of change and uncertainty, spurring renewal, novelty, and innovation," (Nykvist et al 2014). Further, they

highlight that “a diversity of SEM in an SES does not necessarily lead to general resilience because communities do not necessarily use the full range of SEM existing in the SES in which they reside,” (Nykvist et al 2014). Linking different repositories of SEM in a regional biocultural system such that a broader range of knowledge and practice is available to any engaged actor can further be understood as building redundancy *and* memory at this scale: there are more components performing the same functions of ecological stewardship *and* more pathways to the transmission of biocultural knowledge within the larger system. Key to this linking is that the integrity of each specific SEM is maintained; the diversity of multiple SEMs is not competitive but collaborative. It is through this mechanism that a broader biocultural resilience can be fostered within a culturally diverse region.

Thus, our model for a resilient biocultural system contains elements of redundancy, memory, and connective heterogeneity at multiple linked scales. We are seeking to understand the relationships within a huerta at an ecological scale, the relationships emerging from huerta at a social scale, and finally how these seemingly small-scale relationships relate to large-scale phenomena of culture and climate through a resilience lens. Our ultimate objective is to understand the role of huertas in an area impacted by climate change, using instances of redundancy, memory, and heterogeneity as indicators of potential resilience.

Methodological Framework

Our primary data collection was conducted over three full days, spending one full day at each site with each actor. Two sites were home huertas with stewardship practices passed down from the previous generation who had similarly stewarded that land, while the third was a market garden only recently transitioned from conventional to regenerative practices. Initial

introductions were made via a professor who came with us, followed by guided tours of the space, a shared meal, informal conversation and semi-structured interviews, and at two of the three sites we contributed our labor to gardens. The specific methods of data collection differed at sites based on social contexts, needs of the physical space, and consent.

The structure of our research is an informal comparative case-study design. We gathered data from 3 sites with differing socio-ecological contexts in order to conceptually understand each agriculture system and find patterns of similarities and dissimilarities. The initial field methods are all qualitative and consist of ethnographic observation, semi-structured interviews, and participatory network mapping. These methods were employed to generate an understanding of each individual site as a system, gathering data about the components and relationships within and extending from each huerta. The secondary post-fieldwork methods include a literature review and network mapping as identification of the components of resilience within our sites.

Field Methods:

At each site visit, continuous ethnographic observation was conducted as we were given guided tours of the location. This took the form of note-taking, consensual photos, and informal conversations. Following this observational data collection and introductions to the huerteras, we conducted guided semi-structured interviews. A key aspect of interviews is trust building. Due to the nature and time constraint of our research we couldn't build personal relationships with the huerteras, but instead relied on the existing relationships built by the professors to transfer some level of trust onto us. Each interview had the same set of predetermined open-ended questions (listed below), but the interviewee led the conversation. By asking the same questions to each actor (a method known as triangulation) we are able to conduct comparisons between case studies in order to understand a concept from multiple perspectives. Further, we used free listing

to understand what exists in the space according to their importance. At Site 2, we also attempted participatory network mapping, by creating visual representations of relationships within the garden on the site in collaboration with the interviewee (she chose to provide feedback for ours rather than create her own). During interviews we took minimal notes but did not transcribe or record interviews to avoid being invasive or uncomfortable for the interviewee. Immediately post-site visits we compiled and organized group field notes under our interview questions.

Semi-structured interview questions:

1. Who are you? How long have you been stewarding this land, and why?
2. What do you grow, and why?
3. Do you feel like the land or climate is changing here?
    a. What about the region?
    b. How are you responding to this change, if at all?
4. What practices do you use to steward this space, and why? eg, composting, seed saving, cover cropping, etc
5. Where did these practices come from? How did you learn?
6. Are other people connected to or involved in this garden, in any way? Are there cultural or community practices relevant to this garden?
7. Do you eat what you grow? Do you have recipes using food from your garden?
8. What feelings do you associate with the garden? What does it mean to you?

Secondary methods:

Firstly, we ground our project in its geographic/climatic/theoretical setting through a literature review on frameworks of complex adaptive systems and resilience, as well as climatic projections for the region to understand the regional stressors and threats to biocultural

well-being. We then analyze our field data by applying this framework of resilience to identify significant components and relationships to illuminate the role of huertas in building cultural and climatic resilience. A key analysis method is the creation of site-specific and a synthesized regional network map. These maps seek to illustrate the significant horizontal and vertical relationships between components of each huerta across several scales, linking the situated socio-ecologies of each site to communities, landscapes, and climate. Post fieldwork, our notes were analyzed via coding methods to identify patterns between sites. We identified significant relationships through both free-listing and storytelling by the actor at each site. By asking an actor to free-list what was growing in her garden, we assume that plants with more significance (whether it be personal, familiar, medicinal, that grows particularly well, or a favorite) would be listed first, and asked *why* they were growing these particular plants to understand the story and relationship behind them. We repeated this process to identify significant practices, people, and micro/macro external networks and factors. We represented these relationships within network maps, illustrating the key components of each site and the significant relationships between them across ecological, social, and cultural scales (Figures 6, 7, 8). For Site 3, we created relational network maps in real time with the huertera, who explained directly the key components of her huerta and the key relationships emerging from it, which we then synthesized with a geographical map of the land. Figure 5 shows these primary source materials.

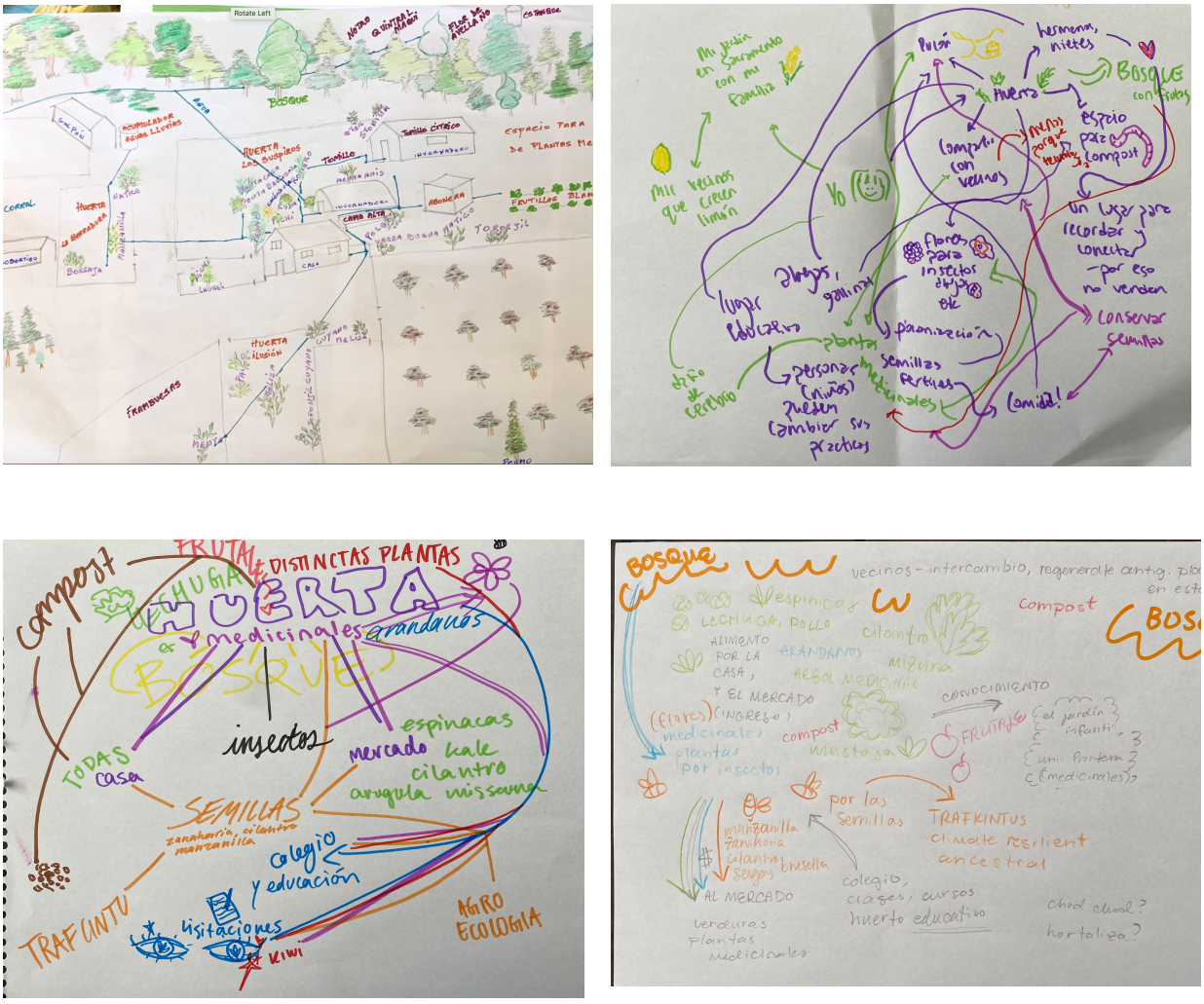

Figure 5: Top-left: geographic map of Site 3 made by actor; clockwise: 3 on-site participatory network maps made by researchers and guided by actor's interview, conversations, and real-time feedback

By identifying key components and relationships that build redundancy, memory, and heterogeneity within and between each site, we are able to analyze the situated resilience and vulnerabilities of each site. However, to expand our understanding from the site specific level to a regional level, we synthesize each site map and the larger-scale forces of change identified in our Research Problem to create a multi-scale systems map of the regional phenomenon of the huerta (Figure 11). This map includes significant elements of each site, both shared and individual, their relations to each other and to community networks as identified in each

site-map, as well as to regional dynamics and global dynamics identified in our Research Problem and by each huertera in our interviews. This mapping practice allows us to visually identify the repositories of resilience, connectivity, and competition within the larger regional biocultural system across multiple linked scales.

Findings

Objective 1: **Understand the socio-ecological phenomenon of gardens and how these multi-scale relationships affect community in this region**

Using data compiled from our site visits, including semi-structured interviews, field observation and participation, informal conversations, and participatory network mapping, we have created relational network maps for each of the sites. These maps illustrate the significant horizontal and vertical relationships between components of each huerta across several scales, linking the situated socio-ecologies of each site to communities, landscapes, and climate. For example, at Site 1, soil amendments to bolster the microbial soil ecologies were made up of fallen leaves, sheep poop, food scraps: components of the multispecies landscape affect the garden at a micro-scale. These strengthened micro-relationships in the soil in turn make the garden more productive and healthy, resulting in food/medicine production and the growth of plants used for dying wool, enabling the gardener/weaver to continue both feeding herself off of her land (interspecies relations), trading foods and medicines with her neighbors (interspecies relations, community network), and weaving the patterns that have been passed down in her family for generations, preserving and sharing a cultural art/knowledge (community network, bio-cultural scales).

These relationships are illustrated in the below network maps for all three sites (Fig 6, 7, 8). Ecological/interspecies connections are shown in orange; interpersonal / social connections are shown in green; practices specifically relevant to cultural knowledge are shown in blue. These maps are not intended to be comprehensive but rather to identify the overall structures at play, as well as the most significant relations at each site across 3 scales.

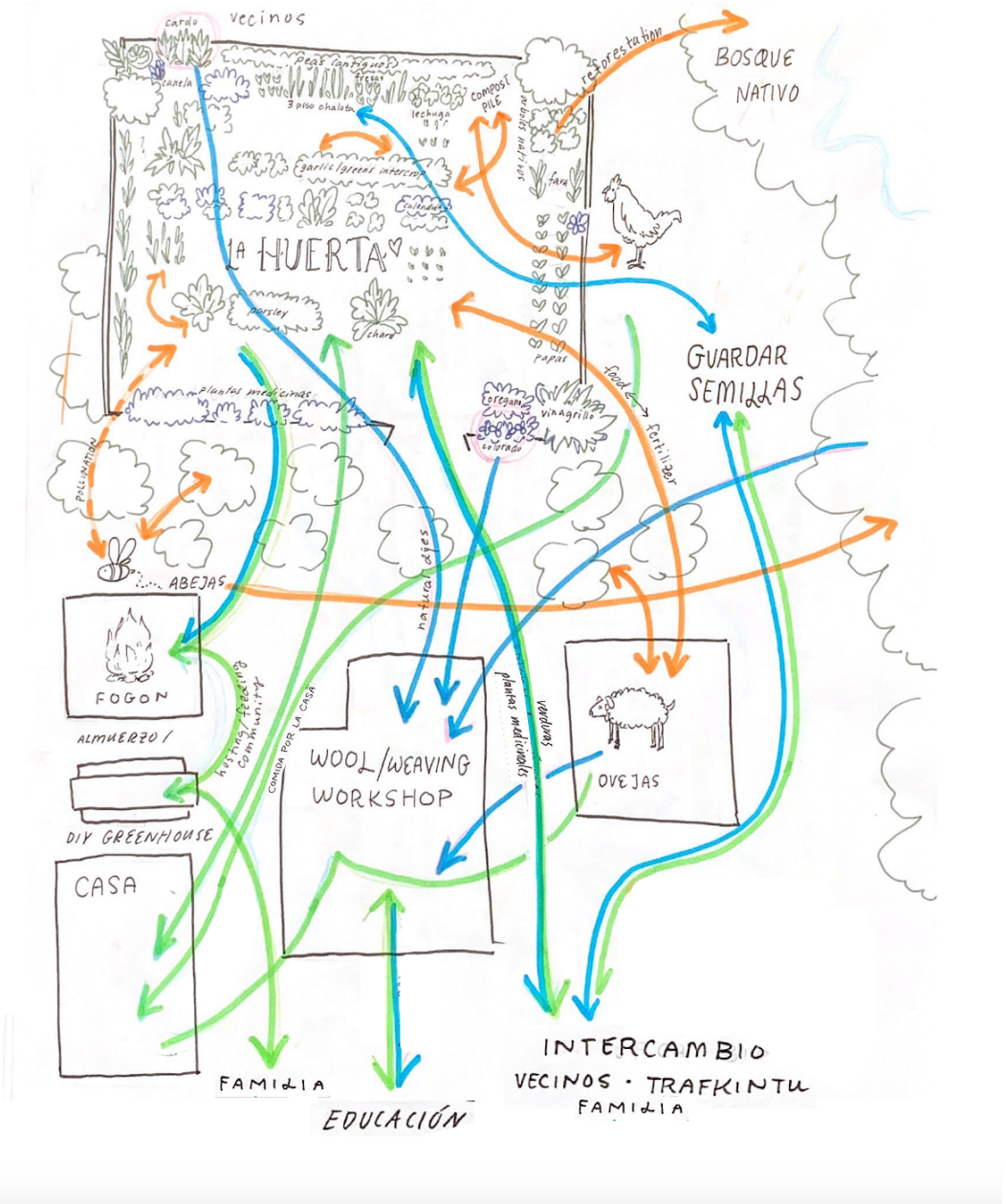

Figure 6: Site 1 Network Map

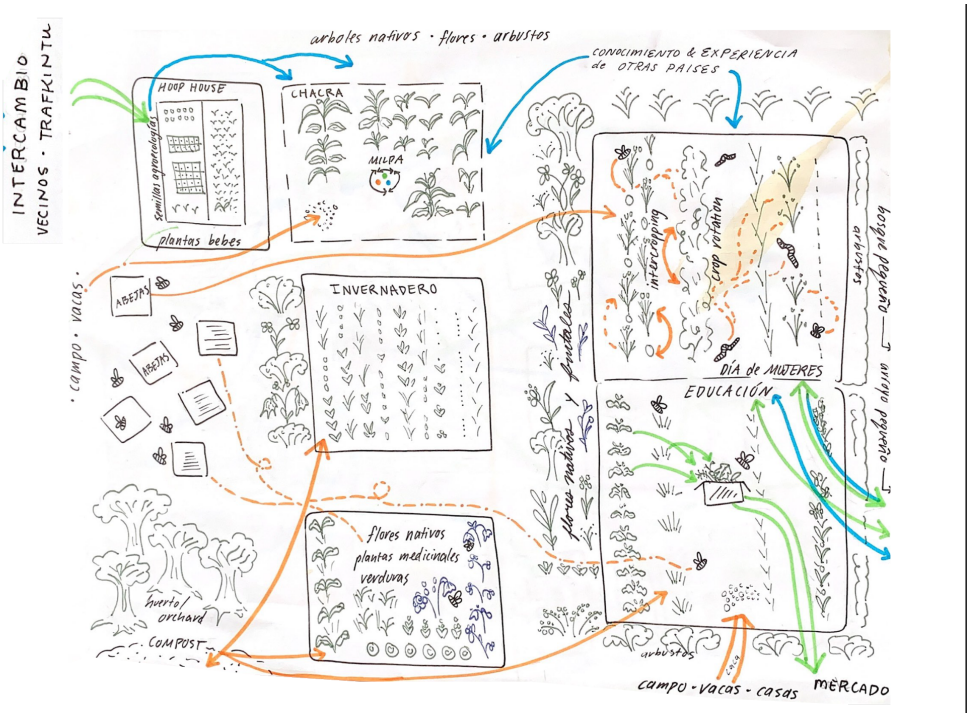

Figure 7: Site 2 Network Map

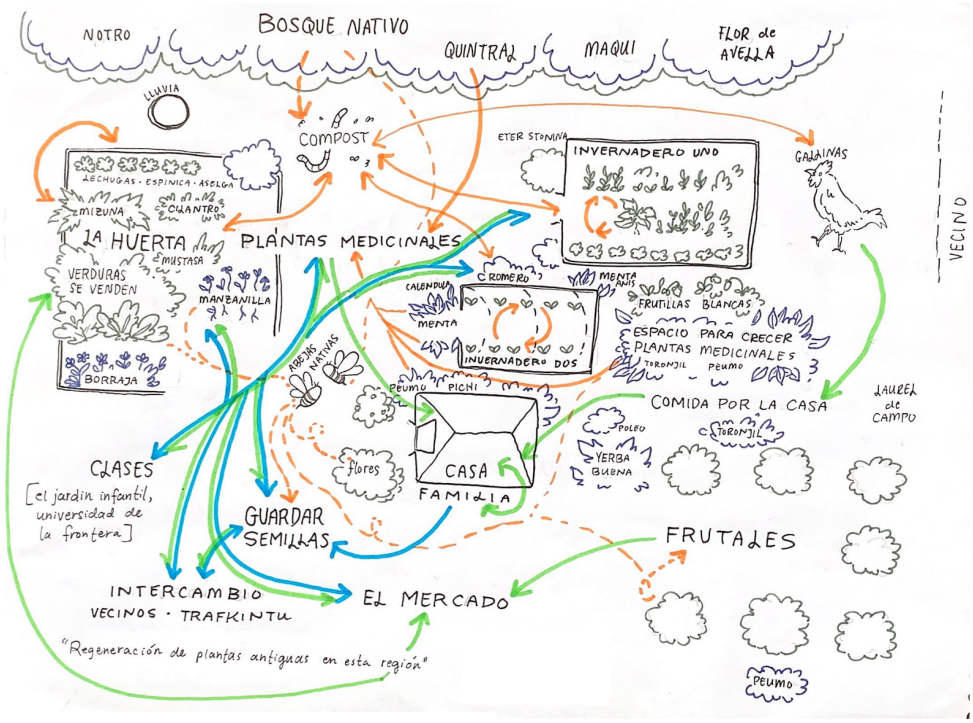

Figure 8: Site 3 Network Map

Objective 2: **Understand the history between each farmer and their land, and how this changes how they grow food.**

Through informal and semi-structured interviews as well as informal and comparative case studies, we gathered information about three local huerteras' relationships to the land they cultivate. We found that the history between each actor and their land varied from site to site, and shifted their growing practices in some ways. The first actor we visited grew up across the stream from where she currently lives. She moved to her current home two years ago when her father, the lonko, passed away. She transplanted many long-standing plants from her previous huerta to her new smaller one, but not all of them survived due to the poor soil health of her new huerta that she had to heal and resuscitate. She grows plants for subsistence, medicine, and her weaving practice. Her growing practices are inherited and site-specific, built, learned, and maintained through community and familial ties to the region.

Our second site visit was to a 7,000-hectare fundo owned by a wealthy family, which they deforested for livestock grazing 40-50 years ago. Although the huerta was always there, using more conventional practices, its function and purpose shifted once the patriarch passed away and his son inherited the land. The son, interested in using regenerative practices, shifted the focus of the huerta to being a bio-intensive agroecological system. The actor we spoke to does not live on the property, and works the large market huerta almost daily for 8-14 hours a day. She is an employee with a deep passion and joy for what she does, applying practices she learned through traveling and farming on several continents. Although she has only stewarded this land for one season, she is highly committed to cultivating a space for education, inspiration, growth, nourishment, and community.

Our third and final site visit was to the home and huerta of a Campesina who grew up at the site since she was 4 years old. She inherited the 6.5-hectare plot from her father when he passed, simultaneously inheriting multiple fruit trees, “plantas antiguas”, and the intention to conserve and care for the land through plants. She grows for subsistence, medicine, and sale, vending produce, seeds, and preserved products in the nearby town. She is involved in education and taught a Jardin Infantil garden class pre-pandemic, occasionally hosts classes at her huerta, and developed a class on medicinal herbs for la Universidad de la Frontera.

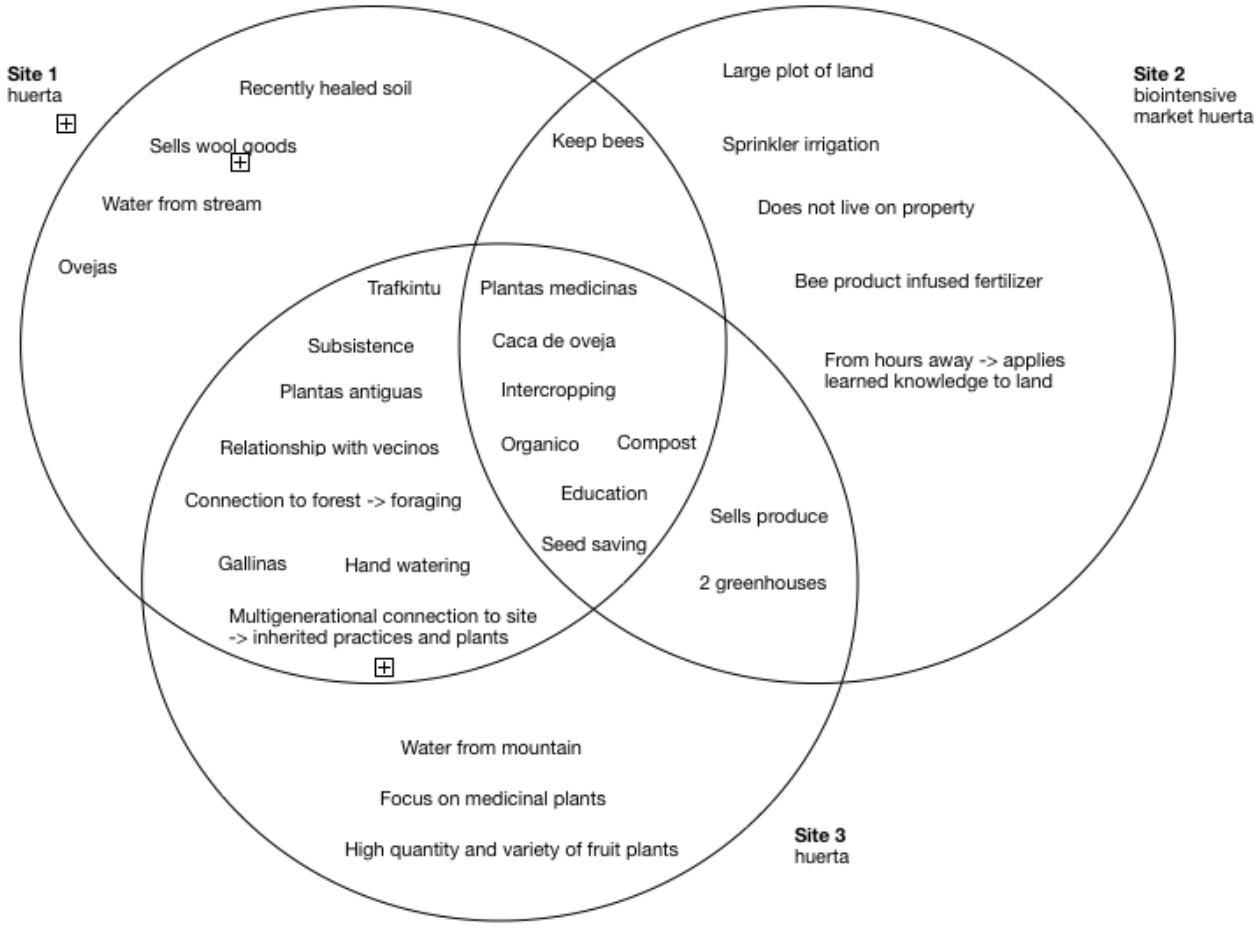

Figure 9: Venn Diagram of Practices and Connections

In deciphering what we gathered about each actor’s unique personal history, we found that huerteras with multi-generational connections to the land have inherited growing practices

from their families and lifetimes spent engaged with one specific site or region, whereas the farmer new to the land is applying practices gathered from a wide range of geographic and climatic experiences, simultaneously adapting her learned knowledge to the changing land. Having a generational connection to one physical site over time creates an ingrained understanding of the land and its microclimate to inform planting decisions. Both huerteras with generational connections also spoke of growing plants and seeds inherited from family members as well as specific foods or medicines based on family knowledge. Our actor with a recently built relationship with the land, however, is expected to grow for production and sale on a large plot and uses trial and error to gauge what grows successfully. One of our generationally connected huerteras grows produce to sell in an agroecological market, influencing the quantity of specific crops grown, whereas the other generationally connected actor grows solely for subsistence, medicine, and yarn dyes.

Huerteras 1 and 3, with campesina or Mapuche identities, have long standing multigenerational memory pathways that have been site-specifically developed over time and create and reinforce knowledge about the land they are in close relationship with. Our actor who is new to the region carries memory pathways that are learned from various regions where those biocultural memories have developed site-specifically. Our actor synthesizes this knowledge and applies them to the land she is building a relationship with. All actors share deep relationships with the land they cultivate that are informed by care and unique pathways of information and knowing.

Objective 3: **Investigate what changes the farmers have seen in their land and crops, if any, in the past decade**.

We obtained data relating to our third objective through semi-structured interview settings to investigate the felt effects of the cultural and climatic changes identified in our Research Problem. From these interviews, all three land stewards revealed that they have experienced drier summers (drought), more extreme cold events in the winter, and inconsistent mid-seasons with sporadic heat and sporadic rain. For example, Actors 1 and 2 both explained that when there is a heat wave and then cold rain in spring, many baby plants go to flower too soon, or die in sudden cold spells. Further, Actor 1 noted that not all of her generationally-grown Semillas antiguas sprout anymore in hotter and drier springs, as they were adapted to the region's traditionally snowy and rainy winters. Actors 2 and 3, both with greenhouses, noted that now it is both possible to direct-sow certain plants that historically could only be started in a greenhouse due to rising temperatures and *impossible* to grow certain plants *without* a greenhouse to stabilize the temperatures in sporadic springtimes.

In addition to the changing climate, huerteras also discussed a change in access that affected their land stewarding and gardening practices. Mapuche land is being increasingly parceled and residents are losing access to agricultural land and forest spaces. When Actor 1's father died, his land was parceled among his children: Actor 1 moved from her larger family home to her current plot of land, which is substantially smaller than the original. As each child receives a smaller sub-section of the previously held family land, while still subject to land laws that prevent Mapuche land from being held in *common*, they are forced to live off of smaller and smaller gardens, with less room to grow traditional crops. They are forced to buy or trade more and more food from other sources. For Actor 1, this manifested as being unable to grow a "chacra" on her current plot of land, a space where traditionally wheat, corn, beans, and potatoes – row crops needing substantially more area– are grown: she simply doesn't have the space.

Further, native forest land exists behind more and more fences and property boundaries, limiting access to traditional knowledge and practices that are linked to the landscape. Thus, subsistence farming and the ability to live off of a huerta is becoming increasingly challenging for the Mapuche people. Simultaneously in the same region, Actor 2 is paid to steward more land than she can handle, employing agroecological practices for the first time since the land was deforested for cattle grazing in the dictatorship era. While the specific history of this land is unknown to us, it certainly was Mapuche land within the last 150 years, if not far more recently. Thus, the same forces of colonial land allocation and redistribution are affecting Site 1 and Site 2 with drastically different outcomes.

Objective 4: Understand how huerteras function as community actors of climate & cultural resilience / the role of huertas in an area impacted by climate change

Finally, we apply the earlier-outlined frameworks of resilience to the systems illustrated in our network maps and the cultural and climatic contexts determined in Objectives 2 and 3 to understand if and how these three sites produce climatic and cultural resilience in this region. Once again, resilience is the capacity of a system to not only adaptively persist following disturbance but actively incorporate new knowledge while maintaining its identity. Key properties of resilience within a complex adaptive system are heterogeneity, memory, and redundancy. We have found that these properties exist both at the garden scale and at the regional scale. However, there are necessary connections to be made in order for regional heterogeneity to be a positive tool for community-wide climate and cultural resilience rather than a source of competition.

Across all three sites, we identified four common practices that, intentionally or otherwise, function as *redundancy* and/or *memory* within the CAS of the site and its extensions,

in some cases similar site to site and in some cases representations of *heterogeneity* between the sites and their associated socio-ecological memory. The key components for building redundancy and memory within sites are medicinal plant use, regenerative land stewardship practices, seed saving, and community engagement. The ways in which these practices build redundancy, memory, and inter-site heterogeneity are outlined below (Fig 10).

Practice	Details of Practice	Redundancy	Memory	Heterogeneity
Medicinal Plants	Growth and *sharing/trading/vending* of medicinal plants with neighbors, friends/family, community members	Community-based *free* alternatives to conventional health-care system; many types; grown at multiple sites; freely available through trade networks	Embodiment of traditional/generational practices; vertical and horizontal knowledge-sharing	Specific plants grown site to site differs; use of plants (sale, personal use, trade) differs
Land Stewardship Practices	Soil Amendments, Crop Rotations, Fallowing, Mulching, Cover-cropping used to build rich soil networks without chemical inputs	Wide range of in-system organic practices (redundancy across practices) versus reliance on one soil-depleting chemical	Rich soil networks carry memory of past crops, nutrients, seeds, etc, as expressed by volunteer crops	Specific practices differ based on different knowledge sources and needs (ex: use of sheep poop as fertilizer; planting under waning moon)
Seed Saving	Saving seeds from successful or significant crops to trade/gift or to grow again the next season	Trafkintus or trade networks between huertas build wide library of hearty, adapted seeds; Resource-sharing	Intergenerational cultural and climatic memory is embodied in saved seeds; shared across trade networks	Different seed collections and sources at each site
Community Engagement	Teaching classes (topic varies site to site) or holding educational huerta-work days for community "Neighbor" connections	Knowledge-sharing, increases number of people with access to these practices; building community-wide redundancy	Horizontal memory sharing: passing knowledge peer to peer rather than generationally	Different networks: Site 1: Weaving workshops Site 2: "young couples new to the region" Site 3: Jardin Infantil, U. de la Frontera

Figure 10: Key properties & relation to redundancy, memory, and heterogeneity

Thus, intentionally or otherwise, each huertera functions as a community actor of both climatic and cultural resilience through her role in seed stewarding, facilitating trade or educational networks with larger communities, stewarding land regeneratively, and growing medicinal plants. Huertas can thus be understood as sites of complex systems, from which properties of resilience emerge. We apply and investigate this framework through synthesis network mapping in our discussion.

Discussion

In an era of cultural and climatic change experienced viscerally in the region, we have found that huertas certainly function as local sites of resilience, through shared and distinct practices that build socio-ecological memory, intra and inter-site redundancy, and indeed heterogeneity. While two of our study sites are characterized by the presence of long-standing generational relationships and practice developed over a lifetime in this region, the third is stewarded by an actor new to the region. Her knowledge was not gained generationally but horizontally through volunteer experiences in Nepal, India, France, Spain, Canada, New Zealand– a global sampling of different local biocultural systems and memory pathways, now being applied to land stewardship in the Pucón area. Thus, while many of these practices are common site to site, they are not necessarily borne of the same specific biocultural memory pathways, nor of homogeneity between sites, as each site has a different goal and relationship to the larger region.

The rapidly developing heterogeneity of this region cannot then be overlooked, as migrations, land uses, and cultures are rapidly changing, and new biocultural practices and knowledge pathways are being introduced as shown both in our Research Problem section and in

the personal accounts of the huerteras. While in many ways, these changes are disruptions to the socio-ecological system of the region, in this diversification of biocultural knowledge there also lies the potential for building further climatic resilience. By fostering a diversity of biocultural practices and memories, there is in fact increased redundancy and increased resilience (Nykvist et al. 2014): there is increased resource sharing and a greater well of practices and knowledge to draw upon in times of disturbance; there is space for new knowledge creation in response to changing conditions. New knowledge pathways introduced to the region have great potential for aiding in climate adaptation, as they can apply practices learned in other climates and geographies to this one as it changes. However, in order to additionally foster not only climate adaptation but *biocultural resilience* locally, these new practices and knowledge pathways cannot come at the expense of existing local knowledge and cultural practice, not replacing but incorporating into existing biocultural memory and practice. Heterogeneity must come with connectivity.

By synthesizing our three site network maps and incorporating regional effects of climate and land use change identified by our huerteras and the relation to global dynamics as outlined in our Research Problem section, we can analyze our three sites as exemplary components in a single multi-scale complex adaptive system (Fig 11). This allows us to identify existing elements of redundancy, memory, and heterogeneity across *multiple scales* of this regional system, and the potential for situated relationships *within networks of community* to build resilience to larger scale forces of change (Fig 12).

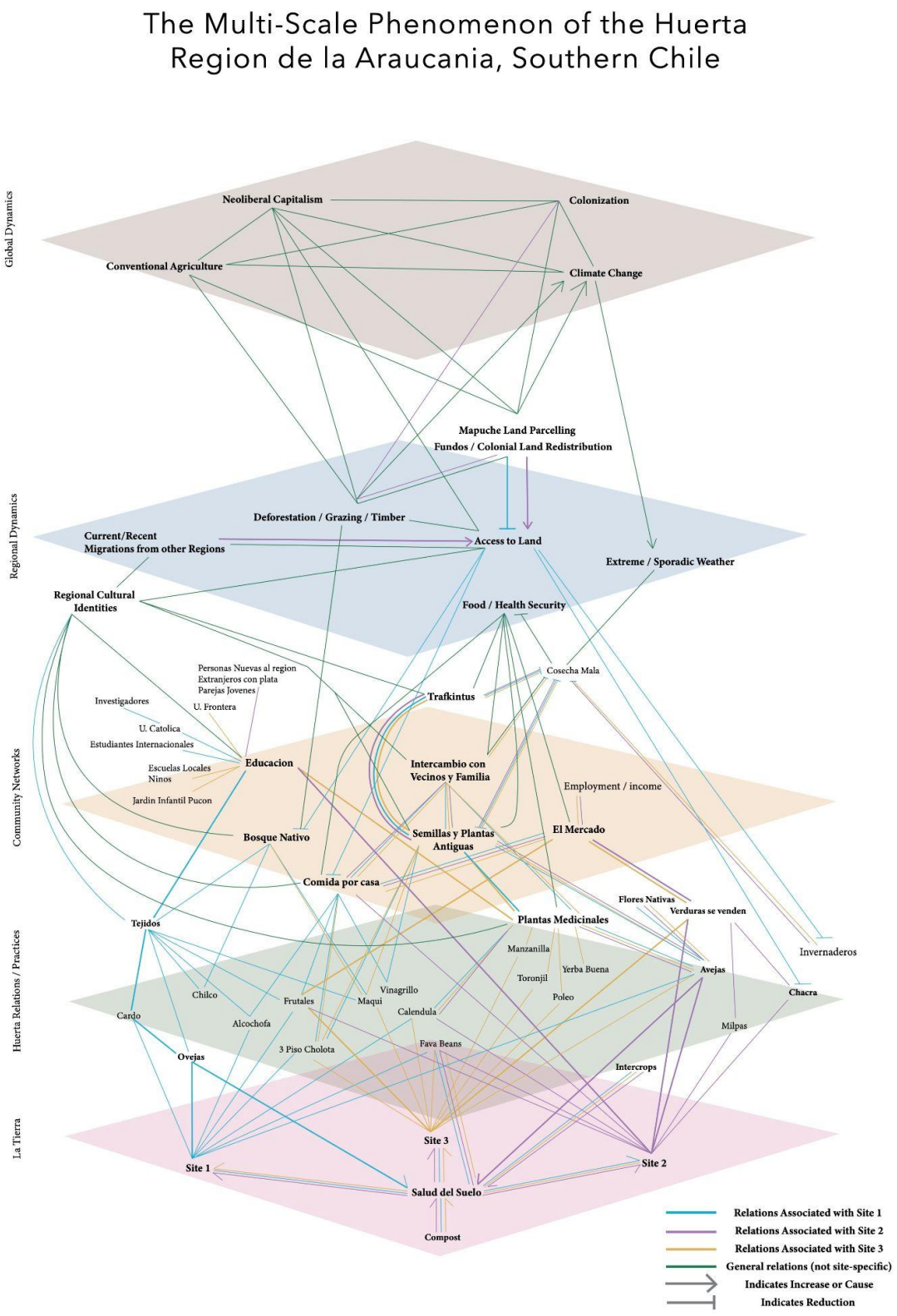

Figure 11: Multi-Scale Synthesis Map; Phenomenon of la huerta en Región de la Araucanía

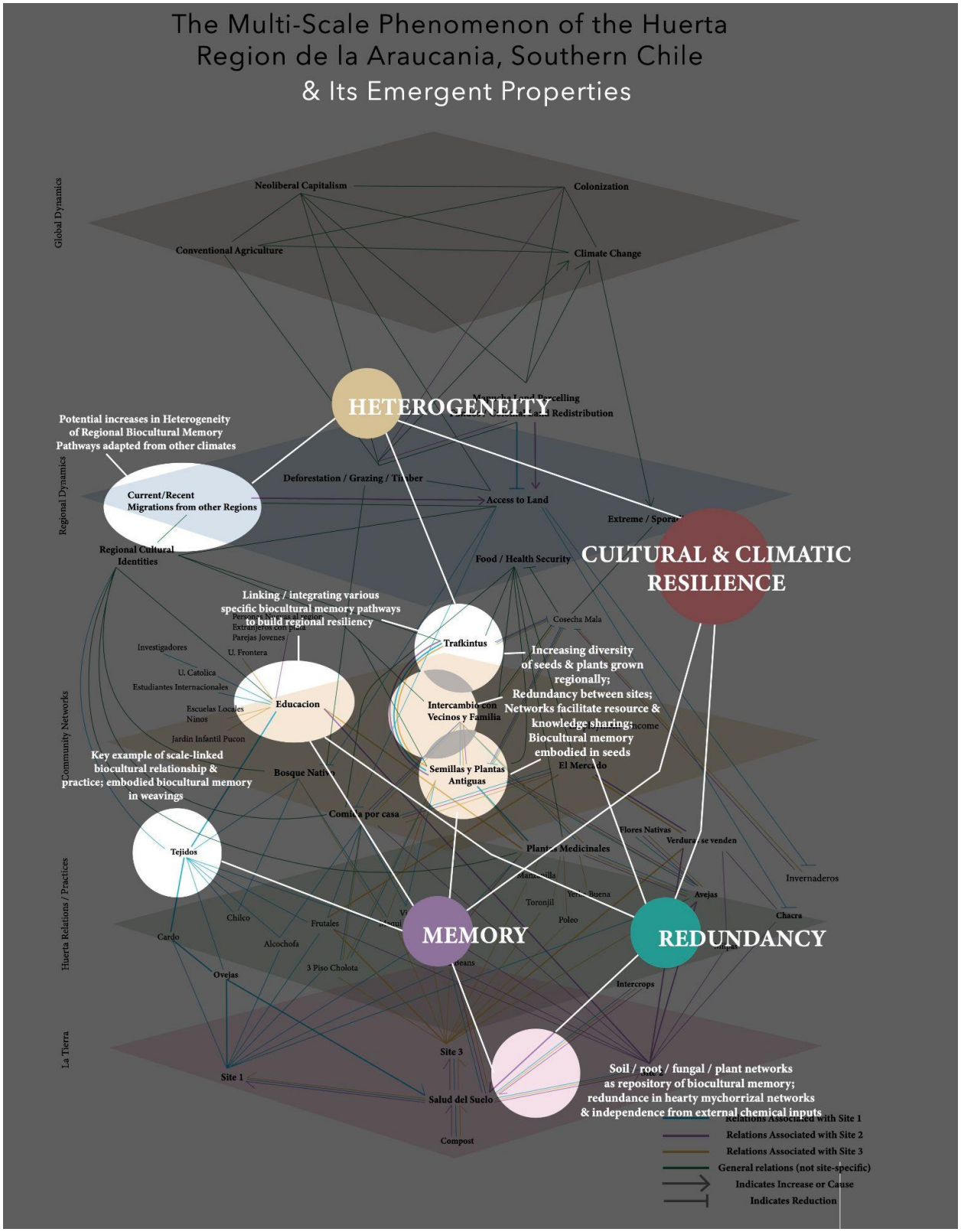

Figure 12: Emergence of Scale-Linked Heterogeneity, Memory, Redundancy; Cultural & Climatic Resilience

We identify inter-neighbor or familiar exchange, trafkintus, and education (vertical/horizontal practices of (knowledge sharing) as essential networks *linking* the site-specific scales of interspecies and interpersonal relationships with the larger phenomena of culture and climate change in this region. Each functions to link the redundancy, memory, and resources of different sites and actors with each other and with external community members of various backgrounds. As vulnerabilities are felt on individual levels, such as a particular species of semillas antiguas not sprouting in a sporadically tempered spring, practices of sharing ensure that that species is grown in another part of the region as well, and seeds saved from that harvest might be shared again: there is redundancy of resources between actors, and memory pathways are held communally, not dying with a single actor. These networks also produce regional food security: if a community member has a bad lettuce crop, healthy lettuces from another garden will be shared (Interview with Actor 1). These existing community and regional networks are *vital* for maintaining biocultural resilience and incorporating new biocultural knowledge pathways and resources. Site 2 (shown in purple, Fig 11) notably reaches people new to the region through open work days on the huerta, potentially functioning to *integrate* specific memory pathways into the larger regionally-held biocultural memory. Key to this integration is the participation of la huerta in existing local networks such as trafkintus, where seeds and plants are swapped and connections are made. Thus, her own knowledge and practices, developed in other regions of the world, are not isolated but can be accessed horizontally by both existing community members and new ones.

However, there still exist gaps, challenges, and potential sources of increased connectivity. The same system of colonial land redistribution affects access to land for all three sites, but as it has allowed land acquisition for Site 2 in the last decades, Actor 1 has experienced

an ongoing and systematic reduction of land. Meanwhile, people new to the region are able to access locally grown produce and alternative food systems through engaging with Site 2, while Actor 2 depends increasingly on markets and trades for what she does not have the space to grow on her own land. This threatens not only her own food security but the biocultural memory she stewards in her land, seeds, and weaving practices. As migrations to the region increase and land uses change, increasing pressure is put on accessibility of land. Losing access to land is a fundamental disruption of biocultural memory, embodied in multiple scales of relationships each tied to specific geographies, land-based practices, and soil networks. It also increases dependence on conventional agriculture, which lacks the same structures of redundancy, heterogeneity, and memory that build resilience, a system more vulnerable to climate change and in fact reinforcing patterns of deforestation and biocultural homogenization as discussed in our Research Problem. Additionally, climate change does threaten the longevity of certain semillas and plantas antiguas regionally. As regional climatic patterns continue to change, there will likely be a shift in what thrives and the practices necessary to cultivate crops. The two sites with greenhouses identify them as useful components in managing the felt effects of sporadic weather patterns. However, without access to enough land for a greenhouse, these protective measures are much more challenging.

Land access, as determined by colonial legacies and current tourism and migration patterns, is thus a central site of regional conflict and competition within this system. This invites the framing of potential resource sharing across sites with varying land access as a *mitigation strategy:* local trade networks and communally-held knowledge and resources continue to buffer the vulnerability of individuals. However, without active practices of decolonization in the policy that structures regional land distributions, parceling, and individual ownership, Mapuche

communities will continue to lose access to land generationally. As we have shown, these land-based relations are central to the maintenance of cultural and climatic resilience regionally; land-loss for Mapuche communities equates to loss of heterogeneity, redundancy, and memory not only for individuals but for the greater biocultural system. The ongoing homogenizing properties of colonization are thus key threats to the cultural and climatic resiliency of the entire complex adaptive system that relates huertas, community, and land in la Región de la Araucanía, Southern Chile. Existing cultural and climatic resilience that emerges from huertas regionally can only be sustained through the fostering of community networks and active practices of decolonization.

Conclusions

Climate change, processes of colonization, and the replacement of regenerative community-based food systems with conventional or industrial agriculture are each global systems which have highly localized impacts. Resilience must then also exist on a local scale, both climatically and culturally, to meet the varying needs of multi-species communities and landscapes. The impacts of these large-scale phenomena on the area surrounding Pucón, Región de la Araucanía, Southern Chile are multiple, as changing land access, food systems, and local climate patterns threaten food security, Mapuche and campesino cultures, and the well-being of regionally adapted ecosystems.

Within the literature on Complex Adaptive Systems, we found that the primary application was on forest ecosystems. While this framework has been applied to huertas on occasion, relating differences in management practices to culture (Ibarra 2021), we seek to expand on these findings, linking the complexity found in huertas to the larger regional

biocultural landscape. By treating not only huertas but their linked communities and landscapes as part of a CAS, we are able to analyze the emergent properties on a larger scale, identifying both regional resilience and competition / vulnerability. We identify several components within our three case-study sites that build cultural and climatic resilience through heterogeneity, redundancy, and memory. Further, trade and education networks provide the connectivity that is vital to reap the benefits of regional heterogeneity and bolster regional properties of redundancy and memory.

However, a significant regional vulnerability is the competition over land use regionally. Despite the short term perceived benefits of this structural imbalance in land access for those relatively new to the region (for whom land acquisition has been enabled through government support of fundos and the legislated generational parceling of Mapuche lands), the disruption of existing biocultural memory pathways and complex situated community networks threatens cultural and climatic resiliency for all in the region. Thus, while huertas and associated community networks are repositories of resilience, the legacies of colonialism continue to degrade and undermine the memory, redundancy, and heterogeneity of local biocultural food systems, making the entire region more vulnerable to the effects of climate change.

Fundamental to the long-term vitality of the biocultural systems that each of us exist within (sometimes understood as sustainability) is first, the recognition of existing relationships between people, food, and land, and the continued fostering of connected multi-scale complexity. Second, we must reckon with extant colonialism and the homogeneity in culture and the agro-landscapes it produces, fundamentally at odds with the integrated biocultural complexities necessary for “sustainability.” We would like to conclude by asking: how can decolonialism be embodied across small and large scales? What seeds, root networks, and trellises already exist

for this systems-change? What can we do to tend the vines, share the fruits, save the seeds to plant again in the spring?

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