Do Farmers Know Better? Exploring Innovation, Environmental Change, and Rural Livelihoods among US Hop Growers

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Abstract

This dissertation examines the paired social and environmental impacts of farmer-driven innovation through on-site interviews and participant observation with US hop growers. Together, these three research articles make an important contribution to environmental and rural sociology along with science and technology studies by showing how farmer-directed science can support more sustainable futures. While most large-scale US farmers are already technologically and economically "locked" into unsustainable practices, hop growers break this mold, using profits resulting from the craft beer boom to innovate their own implements and further develop their own on-farm breeding programs. Using qualitative methods, I examine these growers as a case study, revealing that farmer-driven innovation can result in improvements to environmental sustainability and adaptive capacity. However, I also find that without policy interventions, small farmers are excluded from profitable new technologies and laborers still face unequal exposure to environmental and financial risks. The three articles each examine different aspects of this dynamic: Chapter 2 overviews the contemporary state of Yakima Valley hop farming and describes hop growers' efforts to "decommodify" hops. Chapter 3 is a "deep dive" study into knowledge-politics involved in producing new genetics at the largest farmer directed hop breeding operation in the US (HBC). Chapter 4 examines the small farmers that operate as an alternative to the large neo-plantation farms indicative of the new US and Yakima-focused hops marketplace.

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1. Introduction

One of the first sights I recall after snaking through the Yakima valley on the way to visit the first participating farm for this study was a large mural painted on the side of a utility building fenced in barbwire. The mural is freshly painted--it tells me that I'm a half mile from Toppenish—"the city of murals"—and on it there is a depiction of a white, male farmer operating a horse-drawn plow in a hay-strewn field against a flat blue sky. The individual farmer using his implement and animal to make a change in the environment—to grow food. I pulled over to take a picture of the mural through my car window. I haven't been able to shake the impression it gave me since—that, in a way, it encapsulates the relationship between humans, technologies, and environment that *is agriculture.* It also encapsulates a specific ideology that is prevalent in the US: that strong, tough, individualist, humans (and almost always white males) are the entities which do agriculture. The three articles in this dissertation take a materialist, relational approach to better understanding farmer-driven innovation in the US hop growing industry. By examining humans and non-humans involved in this industry, these articles unpack how numerous actors are involved with innovating more, or less, sustainable futures. Lessons taken from these articles trouble notions about *who farms,* examine how farmers can be partners in innovating more sustainable solutions, and expand on previous research that critiques the ideology that individuals are wholly responsible for farming actions in the first place.

This research focuses on hop growers in the US, with an emphasis on those largest growers in the most prominent hop growing region in the US, Washington State's Yakima Valley. Because of hop farms' increasing profitability over the last thirty years, a number of hop farmers have developed breeding programs and invested in on-farm infrastructure development while smaller farmers have not. The guiding goal of this project was to understand the conditions

under which some farmers innovate their own solutions while others remain dependent on outside research and the differing kinds of innovation each regime demonstrates. Hop farming in the US offers a natural experiment to understand these diverging approaches to agricultural technologies. I compare large hop growers in Washington who have developed extensive breeding programs and pioneered mechanical innovations on farm with emerging hop growers in Idaho, Michigan, and throughout the US who tend to have smaller operations with fewer resources and are therefore less likely to invest in on-farm research and innovations. Farmer decision-making is comparatively analyzed as a way to understand how multiple forces including beer-industry economic demands, agricultural technologies, and global climate change converge in the lived experiences of hops farmers in established (Northwest) and emerging (Idaho/Midwest) growing regions. Specifically, on-site interviews and participant observation on farms and rural spaces were conducted inside and outside the Pacific Northwest hops growing regions to understand: **(1)** *How do environmental and market pressures impact decisions about technologies used on the hop farm? What kinds of innovations do hop farmers pursue and how?* **(2)** *What comparative lessons do hop producers have for environmental and technical considerations in other agri-food regimes?*

Figure 1-1: Toppenish Mural

Beer, Hops, and Global Environmental Change

At the center of global environmental change are the foods we eat, drink, grow, and transport. Over the last century, what gets grown (and how it's grown) by farmers has been predominately been determined by large agrichemical, seed, and implement companies who have dominated the research, development, and implementation of on-farm technologies since the 1980's (Kloppenburg, 1988). Many global environmental changes, losses in biodiversity, and rising costs for farmers are directly tied to the scientific, technological, and economic practices of these companies (Carolan, 2010a, 2018). Some have suggested that less economically dependent farmers will innovate and respond to agricultural pressures in more generative and

environmentally sound ways if the agricultural input industry's dominance is held in check. The three articles in this dissertation use the increasingly profitable and innovative hop farms of the US as a case study to explore whether on-farm, grower-driven research and innovations practiced by these hop farmers actually yield more promising environmental and financial futures for farmers.

Since the fifteenth century, when post-reformation European countries established hops as a core ingredient in beer making, hops have been an important agricultural commodity. Today, beer is the single most consumed alcoholic beverage in the world (World Health Organization, 2011) and the use of hops in beer is so ubiquitous that the market segment for unhopped beer is too small to be included or noted in global or national market analyses (Marketline, 2015b, 2015a). The future and effects of agricultural commodities are intimately linked to the industrial food networks in which the commodities are used. Hop farmers depend on beer producers to buy their agricultural product and beer producers of all scales depend on a relatively small group of hop farmers to supply this integral ingredient. This is particularly true as a growing number of small beer producers demand larger quantities of expensive, often proprietary 'aroma' hops grown and bred predominately in the US Northwest. These hops have been and continue to be bred by private, farmer-driven breeding programs and picked and treated often using custom equipment and infrastructure. Understanding hop farmers' unique relationship with genetic and mechanical technologies will yield insights as to the effects of encouraging innovation and experimentation on farm instead of in laboratory and university settings.

As the global climate quickly approaches a 1.5ºC average temperature rise, the importance of understanding the differential impacts of global climate change become increasingly apparent (IPCC, 2018). Agricultural industries, and particularly input-intensive, ecologically-specific commodities like hops are uniquely positioned as both a cause and likely victim of anthropogenic climate change. Over eighty percent of the globe's hops are grown between 46-48 degrees of latitude North in sub-maritime and inland valleys with freezing but not frigid winters and warm summers (Dodds, 2017; Food and Agriculture Association of the United Nations, 2014). Well-drained soil with frequent rainfall or heavy irrigation and sufficient cover is essential. The narrow ecological niche in which contemporary industrial hop production takes place is uniquely pressured by the effects of anthropogenic climate changes in hop-growing regions. This may have significant impact on the humans who practice this high-cost and high-infrastructure form of perennial agriculture (Hop Growers of America, 2015). This effect is redoubled by the highly organized and increasingly data-driven techniques and industry standards for hop production alongside the small number of global buyers who purchase, use, and resell hops on forward contracts with farmers for predominately commercial beer making applications. Hop farmers in a small number of particular rural spaces scattered around the globe face local, material decisions about uniquely global concerns which affect, and are affected by, global environmental and economic outcomes.

Methodology

The specific details of methods applicable to each study are supplied within chapters in keeping norms for articles. To untangle and situate these chapters, I introduce the conceptual motivations for my methods broadly here followed by a detailed justification for the research design. This dissertation research uses a qualitative, multi-sited approach to examine the

agricultural and environmental phenomenon of the "distributed farmer" (Comi, 2020c) in hop-growing localities around the US. These distributed farmers are committees of people, plants, technologies, and things that together enact farming practices and environmental interventions—individual humans are rarely solely responsible for decisions on a large commercial agriculture operation. Studying these farmers requires a relational and more-than-human approach (Carolan, 2020; Darnhofer, 2020; Legun & Burch, 2021). The articles in this dissertation explore hop growing as a case study in the diverging outcomes on-farm technological innovation may bring. By mixing participant observation and interview methods in local settings, a more holistic view of the social assembly of farmer, technique, environment, culture, and place is also achieved.

This research design draws on a rich tradition of research on farmer decision making that cross validates interviews with on-site observation and participant observation (Campbell & Rosin, 2011; Dwiartama et al., 2016; Forney & Stock, 2014; Legun, 2016; P. V. Stock, 2007). This project uses two methods for qualitative data collection: on-site interviews and participant observation. Qualitative methods study the depth of a social concern more readily than the breadth, allowing for the collection, reporting, and reconciliation of incoherence in social science research (Law, 2004). These methods allow the researcher to investigate global commodity production concerns in a way which complements agronomic and agricultural-economic research (Davern, 1997; Wield et al., 2010). It also allows the researcher to study the triangulation of agriculture, environment, and economies (Lewis et al., 2016; S. A. Moore & Robbins, 2015) in particular places.

This method is designed to answer both key questions that guide the wider inquiry of each article. My approach borrows from from Legun's (2016) research model for her exploration of farmer-decision making and the changing commercial apple's flavor and color profile.

Similarly other agri-food scholars utilize similar qualitative approaches including Campbell's (2011) and Stock's (2007) research, alongside an ethnographic tradition of research in both farmer decision making and autonomy (Adams, 2003; Goldschmidt, 1978; Larmer, 2016), demonstrate the effectiveness of conducting interviews in the space of the farmer on their land to better enable research which responds to grounded aspects of decision making and farmer autonomy.. In response to limitations arising from Covid-19, I cut short my in-person interviews and farm visits. This required the inclusion of a limited number of phone interviews with a diverse group of hop growers—to incorporate this data I drew from Carolan's (2015) wide-reaching interview model which included both phone and on-site interviews studying the dispersed and interconnected effects of big data in agriculture research, particularly in as it relates to generalizing from a limited qualitative research model, informs my decision to include multiple research sites. Human Research Protection Program (HRPP) at the University of Kansas has reviewed and approved the study's research design and the researchers' data archiving plan (IRB# STUDY00143772).

Significance

These articles contribute to our disciplinary understanding of hop growers—a group that is largely unstudied by critical agri-food scholars. While a small number of historians have examined US hop growers over the last century and a half (Peter Adam Kopp, 2016; Larsen, 2016; Parsons, 1940) there remains little empirical data on the social lives and decision-making of these farmers. Qualitative social science on hop growers has been largely absent from the critical agri-food discourse with the only a few notable research outputs: a turn-of-the-century ethnography published in the early years of AJS and a few studies on decision making with UK

hop growers conducted in the 1980's (Ilbery, 1983; MacLean, 1909). To my knowledge, the only other group of critical social scientists currently conducting active research with hop growers are working with growers in European and Austral-Asian contexts. While data from their research is not included in the following articles—the author has collaborated with this group on work that is global and comparative between our two data sets. By illuminating the unique experiences of US hop growers, the articles reveal a range of insights that have value for a number of inter- and trans- disciplinary discourses on (1) the relationship between agriculture and climate change, (2) technological innovation in agriculture, (3) farmer decision-making, and (4) cultural aspects of agri-environmental regimes.

Agriculture and Climate Change

Global climate change differentially impacts people, places, and industries across the globe (Anderson & Bows, 2012; Antonio & Clark, 2015; Nagel, 2016). Agricultural systems in the twenty-first century occupy contrasting statuses simultaneously: agriculture is a primary causal factor of anthropogenic climate change as well as a practice particularly vulnerable to such environmental changes which is, in turn, integral to the continued survival of local and global populations (Forney et al., 2018; C. J. Rosin et al., 2012). This paradoxical characteristic has become both a key policy concern at the United Nations Food and Agriculture Organization (UNFAO) and a key research concern in the social and agronomic sciences (Beuchelt & Badstue, 2013; UNFAO, 2014; Saj et al., 2017; Scherr et al., 2012). The changing status of the post-war, globally circulated, industrial food complex centering on chemical agriculture, global trade, and data-driven techniques of scale is particularly linked to the massive petroleum cost and land-management problems which emit large amounts of CO2 and contribute significantly to a warming planet (Bronson & Knezevic, 2016; Crutzen & Stoermer, 2000; Spiekermann, 2011).

Rightfully, significant attention has been paid both to the articulation of the scale of these environmentally harmful practices (Kloppenburg, 1988; Mitchell, 2013) and to many alternative practices like agro-ecology, de-growth, and conservation agriculture (Harrison et al., 1998; Kallis & March, 2015; Nyanga et al., 2012; Saj et al., 2017; Shiva, 2016; Wolf, 1995). These are all relevant approaches to studying global agriculture in the Anthropocene (Angus, 2016; Biermann, 2014) but many of these approaches lose sight of a key goal of critical agri-food as well as science and technology studies: situated knowledges in particular fields of technique and production (Law, 2002; Lewis et al., 2016; Linke, 2016).

Important research has studied the significant impact global climate change has had on local populations and agricultural practices in particular regions (Amara-Alvarez, 2005; Beilin, 2018; Burgess et al., 2000; Harcourt, 2017) and by extension the globe (J. W. Moore, 2017). By connectively studying the linked localities growing hops in the US, this research project fills a gap in understanding the contours of this industrial food system as it may face pressures from changing regional and global climates.

Technological Innovation among Hop Growers

Science and technology studies (STS) scholars have historically been concerned with the social, cultural, and aesthetic means by which scientific knowledge is produced and maintained alongside the societal turns by which this knowledge is revised (Callon & Law, 1982; Kuhn & Hacking, 1962; Latour & Woolgar, 1986; Law, 2002; Mol, 2002). Their research has often been confined to the technological apparatuses, physical laboratories, and research centers where knowledge is produced and/or stabilized. As interactions with previously expert technologies become commonplace, STS scholarship has continued to reimagine mediating roles of

technological actors in social settings. Following the problematically rigid but influential work of Actor Network Theorists (ANT) in the 1980s and 1990s, a number of scholars turned to assemblage or other materialist approaches to better understand the complexities of technology, science, and knowledge (Bennett, 2010; Müller, 2015; Pellizzoni, 2015). These theoretical approaches have informed exciting work in agri-food studies at all levels (Dwiartama & Rosin, 2014; Goodman, 2001; Heley & Jones, 2012). However, such research has largely been confined to the agricultural technologies of commodity crops where research, innovation, and knowledge production is conducted in the occluded labs of agrichemical, seed, and implement companies (Carolan, 2010a; Comi, 2019). Studying hops producers allows a case study in how agricultural technological research may occur differently when that research is conducted for farms of scale (as commodity crops) if conducted for and by those same farmers. Much research assumes that the power of large agrichemical companies produces a distinct agri-technological future, but is the character of that innovation different when large farmers have money, agency, and willingness to carry out their own breeding programs and infrastructure designs?

Hops production, particularly in the US, has undergone an unprecedented shift in scale and profitability. In the Yakima valley, this has resulted in fewer than fifty farms cultivating more acreage than what was previously farmed by over a thousand farmers. The increasing profitability of particular hop genetics (e.g. Citra™, Simcoe™, Amarillo™) enable farmers to consider technological innovations on the farm through breeding programs, tissue-testing, implement design, infrastructure design, and so forth. Some hop farms even employed full-time, on-farm engineers to design, modify or rebuild hop picking and kilning apparatuses.

Commodity crop growers face a deep disconnect between the innovation of genetics and implements and their own on farm decisions. This locks farmers into specific practices and

techniques that are designed by and for private chemical companies and Land Grand Unviersities(Carolan, 2010a; Comi, 2019). Unlike corn and soy commodity crop farmers, who do not often deeply participate in breeding programs, genetic research, or infrastructure design and engineering, hop farmers engage in these technological considerations regularly. This research contributes to a body of STS literature which confronts disciplinary presumptions about where and how expert knowledge is produced and reinforced. Secondly, this work considers technology and agriculture within distinctly rural spaces. The dispersed rural places have fluid, changing landscapes co-informed by global market pressures, agricultural technique, and local cultural values (Adams, 2003; Blanco et al., 2015; Bronson et al., 2019; Carolan, 2017b). Social and policy concerns about agriculture and environmental governance necessarily bring together local rural stakeholders with global earth-systems (Carolan, 2018; Heley & Jones, 2012; Steffen, 2004). As data-driven techniques for agricultures of scale become increasingly commonplace, so do techniques and technology become increasingly politicized sites of social meaning-making and contestation (Bronson & Knezevic, 2016; Fraser, 2018; Griffin et al., 2017; Kshetri, 2014; Robinson et al., 2014). Understanding these farmers' unique agricultural and technological considerations includes understanding the places and cultures in which they participate.

Farmer Decision Making

Industrial-scale farmers represent a small population of the total US and global workforce yet they occupy the paradoxical position of tending to a large percentage of the global land cover while earning relatively modest incomes. Their decisions affect their lived experiences and local and global environmental outcomes along with the related social effects on local and global social organizations. Rural sociologists and agronomic researchers have long considered how

farmers make decisions and the effects these decisions have on surrounding communities (Adams, 2003; Goldschmidt, 1978; Griffin et al., 2017). While farmer decisions, especially on industrial farms, have long been considered primarily rational-economic, over the last twenty years, farmer decision making has been reconsidered as a process informed by a diverse range of social factors. Farming decisions in small-scale, organic, and industrial iterations have been found to be broadly informed by aesthetic sensibilities (Bell, 2004). The identity of being a *good farmer* is stabilized in many farmers' interior world by the way they see their material farm expressing good farming (Bell, 2004; R. Burton et al., 2021; P. V. Stock & Forney, 2014). In these studies, farming is seen as a distinctly cultural as well as environmental and economic practice (R. J. F. Burton, 2012). While these studies explore the farmer identity, this research project draws on decision-making scholarship which aims to widen the scope of actors and agencies involved in on-farm actions (Comi, 2019; Dwiartama et al., 2016; O'Connel & Osmand, 2018). In these studies, farmers and farming decisions are studied as triangulations between other farmers and a diverse array of cultural, political, and economic pressures converging in particular rural places. However, unlike much agronomic scholarship which attempts to triangulate market forces, this project recalls that while a triangulation of participants is a key part, human intentionality persists (Dwiartama & Rosin, 2014). This research contributes to this area of scholarship by further parsing the scope of decision making available to hop farmers and interrogating spaces of control and limited autonomy in global commodity production, particularly in commodities with concentrated value-added product end markets. To put it another way, when faced with global pressures of environmental change, global marketplaces, and large-scale buying entities, how do farmers persist (or not) in genuine decision making about the future iterations of their farms?

Hops and (Agri)Culture

While hop production constitutes a much smaller fraction of total global production when compared to rice and other grains, the industry's particular constraints make it a critical case study for understanding the human-technology frontier in agriculture. Additionally, while their practices are far from identical to commodity farmers, their unique relationship to technology yields insights to an ongoing discussion on the cultural considerations "data-driven" and "big data" agricultural techniques in commodities and crops grown at scale (Bronson & Knezevic, 2016; Carolan, 2015, 2018). Agri-food social science research in response to cultural concerns has engaged in mapping a diversity of food ways around the world (Dwiartama et al., 2016; Jones et al., 2018; Legun, 2015). This research responds to both these considerations by contributing novel insights about an under considered good which also has a contested relationship as a commodity of scale and a craft good.

Hops represent not only an agricultural technique but also particular cultures for the practice of agriculture. The growing popularity of hop-focused "craft" beers has created a particular cultural niche for the hop farmer and their techniques (Frake, 2016; Kopp, 2012, 2016) and has popularized the precision involved in the production, treatment, and measurement of hops and hop-content in the application of beer production (Darwin, 2018; Peter Adam Kopp, 2016). This uniquely situates hops as an industry linked to data-driven techniques and 'big data' applications not only by economies of scale but also by cultural values of the precise, unique, measured hop production (Bronson & Knezevic, 2016; Burch et al., 2018). Big Beer's preference for a globally homogenous, bland lager is well understood (Dighe, 2016). However, craft beer's own interest in cultures of metrology (Henry, 2017; C. Rosin et al., 2017) also contributes to a

particular, politicized, data-driven form of agriculture. The cultural value of precision in hop production is reflective of a trend towards (big) data-driven techniques in other areas of food-production (EPRS, 2016; Griffin et al., 2017). While this is often glossed as scientific, the datafication of agricultural production and food ways often masks particular politicized goals of the agencies and actors involved in establishing and reifying those metric which are measured and how those metrics are reported (Bronson & Knezevic, 2016; Henry, 2017). How do these goals vary, though, when looking at goods like hops, fruits, or vegetables instead of commodity grains and legumes like the corn and soy industry which has been extensively targeted for big-data applications?

Chapter Outline

The following chapters are organized as three substantive articles, followed by a conclusion and directions for further research. Chapter 2 "Other agricultures of scale" comparatively surveys the broad contours of hops growing in Washington State with an emphasis on larger growers in the Yakima Valley. Findings reported in this chapter reveal how 'distributed farmers' on large farms are able to mobilize committees of people and materials toward more equitable and sustainable outcomes—though not without some social, environmental, and economic costs. Chapter 3 "Do farmers know better?" takes a deep dive into the workings of farmer-directed hop breeding programs—specifically a large operation responsible for some of the most profitable new varieties of hop material including Citra™ brand hops. These findings reveal how farmers uniquely navigate the material, political, cultural, and ontological worlds of plant breeding and have broad implications for environmental sociology and STS scholarship. Finally, Chapter 4 "Farmers who tinker" focuses on the experiences of small to medium farmers who improvise,

reuse, and "tinker" with farm inputs to make a living in an expensive, high-infrastructure agriculture. Findings from this research yields novel insights into the on-farm experiences of small growers and suggest that "tinkering" solutions demonstrated by small growers can be scaled up to larger operations and that "tinkering" may be a useful ontological alternative to "incrementalism" in environmental and agricultural practice and policymaking.

Overall, this dissertation provides novel insights into pathways for sustainable innovation that are made possible by farmer-driven innovation. Part of these findings also demonstrate that new, and real, obstacles also develop when farmers are left to innovate their own solutions and these can lead to anti-competitive practices, particularly in farmers' proactive use of IP law to protect their own innovations and limit information sharing that could advantage small farming operations. What is left is a complex picture where farmer innovation produces both exciting, diverse, and usable technologies that improve environmental adaptive capacity while limiting the proliferation and success of small operations. In the broadest strokes, my research suggests that farmer driven innovation provides an important, grounded pathway forward for a more sustainable future if farmers have autonomy and motivation to innovate ecologically specific practices. However, it also suggests that a robust policy framework for governing this innovation could improve farmer-driven research while promoting a more equitable commons for the agricultural science innovations these farmers research and discover.

2. Other Agricultures of Scale: Social and environmental insights from Yakima Valley hop growers

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Introduction:

Hops are a bine-habit herb in the *Cannabaceae* family that are cultivated for their small strobili (referred to as cones in the hop growing industry) which are known for their complex and aromatic resin and oil content. These compounds are essential ingredients in the production of all kinds of beer and are used in multiplicatively greater quantities in the growing marketplace for "craft" beer. Understanding how these hops are being developed, grown, and processed along with the farmers who grow them provides an opportunity to observe a specific agriculture of scale and to study its implications for other agricultures on a warming planet. Drawing from interviews and ethnographic data with Washington state hop growers (n=15), I explore the social and environmental worlds of these farmers and their unique relationship with on-farm innovations. I examine a range of practices and agricultural contexts making up the diverse Yakima hop growing bioeconomy, including novel farmer-owned breeding programs that have been successful in increasing the value of hops and marginally improving environmental adaptive capacity in the region. Insights from the hop-growing agricultural arrangement have implications for other, more ubiquitous, agricultures and the possible ways forward if farmers and agricultural researchers are to innovate more sustainable futures.

Most significant changes in plant-genetics and agro-chemical research with direct applications in agricultural praxis in the US over the last half-century have been carried out

either by land-grant universities (LGUs) or, increasingly, by research funded by private agrochemical and pharmaceutical companies (Bronson, 2015; Carolan, 2010b; Deibel, 2013; Kloppenburg, 1988; Olmstead & Rhode, 2008). While LGUs' public-facing agenda necessitates greater inclusion of local farmers in their plant-research practices, in both the LGU labs and the research departments of private companies farmer inclusion is limited to roles as *participants* or *recipients* whereby a farmer might host a test plot or provide feedback but where plant-breeding, or other technological innovation occurs elsewhere in *expert* contexts (Comi, 2019; Eastwood et al., 2017; Latour & Woolgar, 1986; Wynne, 1996). The unique history of hops production confronts this model and calls into question where applied plant research may take place and therefore reshapes the bioeconomic arrangements of both plant science and agricultures of scale.

Following the end of US prohibition, the Northwest hop growing regions continued to face difficult circumstances as the beer industry concentrated into fewer global buyers and these "big-beer" companies demanded lower prices for higher concentrations of the bittering chemical compounds in hops, known in the industry as "alpha acids" (Dighe, 2016; Peter Adam Kopp, 2016; Larsen, 2016; Reid et al., 2014). By 1980, relatively few hop farmers remained in the Northwest, and these had slim profit margins. Public research engagements for the small sector of hop growers by LGUs in Oregon, Washington, and Idaho remained limited because of their small funding for this niche agricultural sector. While public breeding by LGUs, particularly in Oregon has begun to resurge, in the early 1980's a constellation of hop growers who were unsatisfied with genetics produced by LGUs began their own private breeding operations in the absence of active public breeding, producing the now well-known, patented genetic lineages that supply the craft beer market and had rebounding effects on hop-growing practices at all levels: Citra™, Simcoe™, Mosaic™, and others (see figure 1). Now these farmers' and their children

have continued to grow these large, often family-owned, operations. They have continued employing on-farm innovation, particularly through plant-breeding, as a method for increasing profitability in the hop-growing bioeconomy. While Yakima hop-growers' ability to reshape their engagement with the global hops market, and their growing innovations are both contextually situated and therefore not directly imitable; querying how they conduct their on-farm research and implementation of that research calls into question *where* expert knowledge happens in agricultural innovation and what may be possible if other agricultural sectors mimic this practice.

Figure 2-1 Hop breeding yard during May, (Fred in Background), most varietals in background are unique, foreground varietals are mid stage multi-hill, clonal propagations to begin testing for consistency.

In my results I highlight three contexts that show how Yakima's unique dominant bioeconomy has produced an alternative agriculture of scale. In the first case I show that these

Washington state hop farmers have operated and owned their own breeding programs and have used this capacity for innovation to create more profitable material arrangements, a process they call "decommodifying" hops. Employed here in the emic sense, these farmers used "decommodification" as a broad term to describe how their on-farm innovations have returned pricing power and influence to this group of large hop growers. While this practice concentrates wealth among only a small population of large farm owners, it has also produced improvements in the Yakima-area industry's environmental resilience and slow, though also positive, reduction in chemical loads on contemporary hop yards. In the second and third cases, I describe two hop farming models which diverge from the first case: those mega-farms which rely on innovative farm's models while including hop growing as only part of a large portfolio of production and those smaller farmers which do not have access to the benefits derived from the unique genetic marketplace of expensive proprietary varietals and must find other avenues to produce value.

In the discussion, I suggest that farmers' efforts to "decommodify" hops represents a novel self-aware disruption of a commodity bioeconomy which has lessons for how human intentionality and material agency converge in the production and maintenance of agricultural practices. In the conclusion I further suggest that the practice of Yakima's farmer driven innovations demonstrates how commodity farmers operating as research *participants* instead of *recipients* yields incremental benefits to financial and environmental sustainability. Such arrangements could also establish frameworks that have the potential to facilitate quicker uptake of technological changes should more immediate, radical, or meaningful policies for adapting to and mitigating climate change be adopted. This incremental improvement is well summed up by this farmer's reported attitude about adaptations being selected in the breeding program for which he is a part owner:

> I do know that we have increased [weather] variability. So, I would say the increased variability has had an effect on the farming. Not so much…to a big negative. But it has...we've had to adjust and in some cases it has had an effect on a variety but not to the industry as a whole because there's new genetics coming out and maybe those genetics were selected based on climate conditions we're used to and maybe older ones have been affected more because they were never selected for maybe a harvesting cycle with early morning dew at the tail end. [Bruce]

This attitude shows how even laissez-faire attitudes about climate change can result in meaningful environmental adaptations in the Yakima growing context where local breeding is part of a robust and profitable bioeconomy. This paper argues that insights drawn from Yakima hop grower's particular experiences have insights for other agricultures of scale which will require large scale adaptive behaviors as global temperatures continue to increase over the coming decades.

Historical Context: Changes in hop growing and beer production

Like many specialty agricultural goods, hops function economically as a commodity. As with apples, much of the minimum pricing depends upon global pressures (land, water, chemical, and petroleum costs), while its desirability and therefore maximum pricing is governed by socio-material constraints of taste and desirability (Legun, 2015, 2016). For decades following American prohibition, hops were an especially low-value agricultural product inextricably linked to the global economies of big beer companies, and the cultural constraint of taste was determined by the chemical compounds "alpha-acids" which are used to estimate total bittering capacity of the hop. The price-point of these, so-called "alpha hops" were set by the global

demand for cheap beer and the petroleum and water dollars that impacted the production, circulation, and distribution of this beer (Cabras & Higgins, 2016; Dighe, 2016; Frake, 2016). However, over the last 40 years, and especially in the last two decades, a large shift in US hop production has occurred, while "alpha hops" are required ingredients in almost every beer, the presence of unique, flavorful "aroma hops" have grown in popularity with the craft beer movement and especially in the now ubiquitous popularity of the India Pale Ale (IPA) style beer. These beers utilize aroma hops in multiplicatively higher volumes per barrel of beer. The hop growing industry has both responded to this beer market demand by proliferating new aroma hop varietals for use in IPAs and increasing volume of production for these hops, but they have also intentionally marketed these varietals, encouraging brewers of all scales to adopt these "aroma hops" in higher quantities in their beer making practices.

Hop yards before the 1980's and 90's were small, family affairs and often barely generated an income at all, let alone a robust livelihood for the hop yard owners and many of the hop growers in this dataset have family connections to these historic growers. As hop growing faced a pricing crisis during the dominance of big-beer in the 1980's the number of hop farms alongside the acres harvested decreased dramatically as the long-stalled price of alpha hops rendered many smaller Yakima hop farms financially untenable (see figure 2). In this era, hop farms followed the trend of a typical agriculture of scale where operations consolidated and grew to try to increase profits by decreasing input costs across a greater number of acres. However, at the turn of the millennium the popularity of "hoppy" beer styles reshaped the flagging economy surrounding this agricultural practice. The small number of remaining hop producers operating in the Yakima valley both encouraged, and responded to, this new demand for "aroma" or "dual-purpose" hops to be used in craft beer and leveraged that market demand into a new kind of hop

production. Figure 2 and 3 show the effect of this change: the rising average selling price of hops from 2004 onward is an artifact of the local industry's emphasis on producing so called "aroma" varieties popular in these hoppy beers.

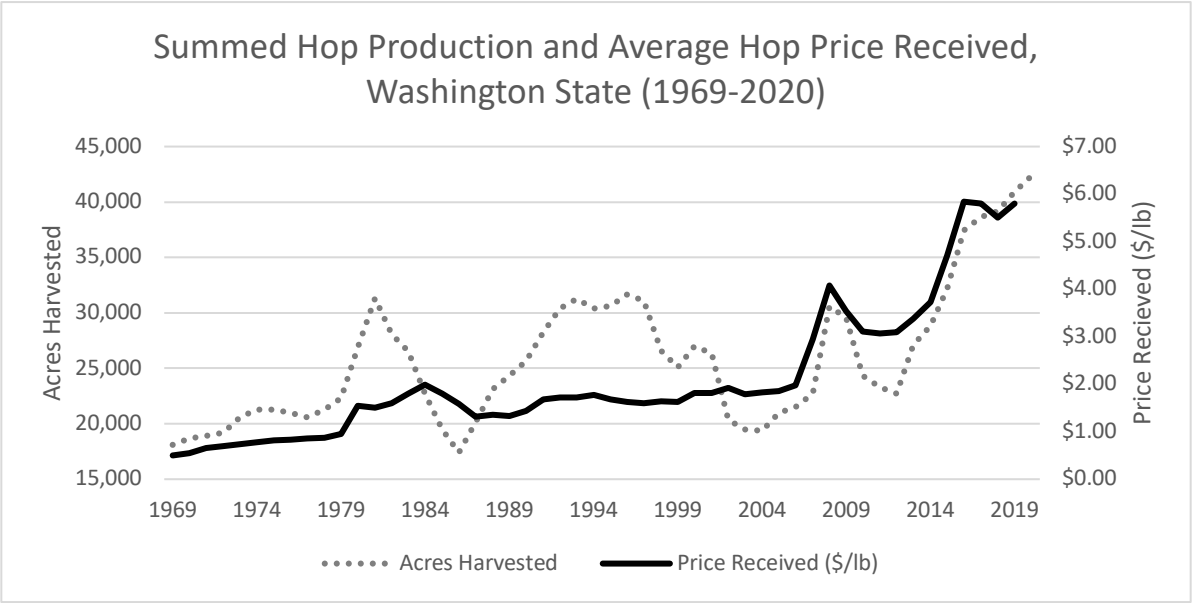

Figure 2-2: Summed hop production against average hop price received.

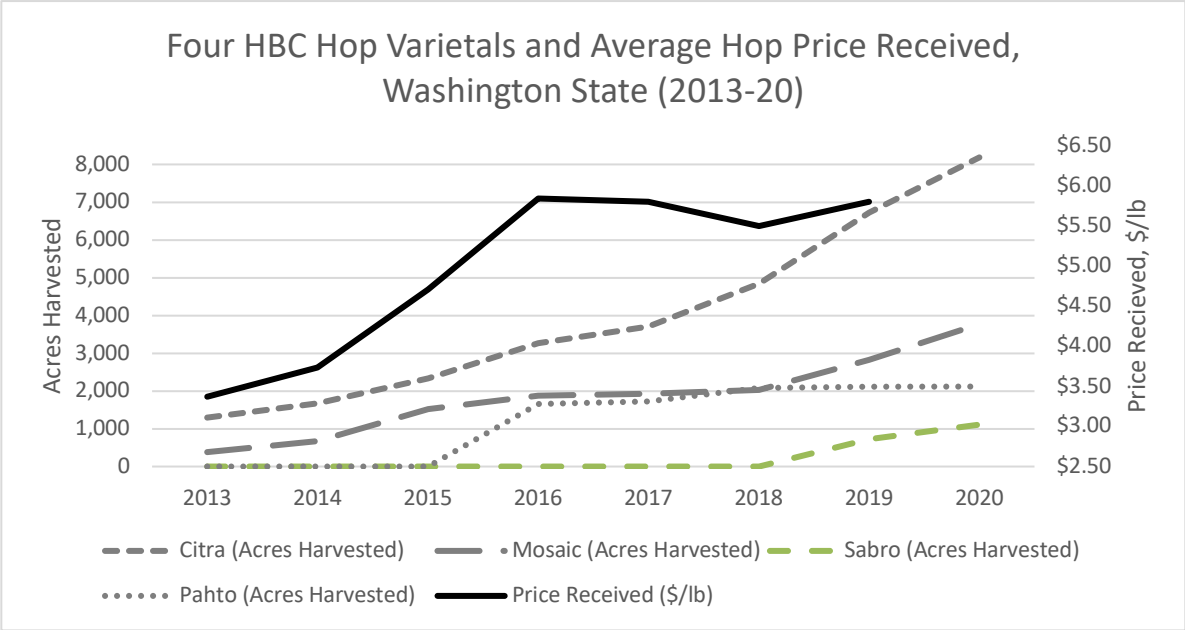

Figure 2-3: Acres Harvested for four HBC hop varietals charted against average price received.

Yakima hop yards have continued to scale up both their production of a variety of "aroma" hop varietals and their total volume to nearly match the acreage of Iowa cornfields but the method, technologies, and relationships with input producers and buyers in this new large-scale agriculture vary significantly from conventional row-crop agricultures of scale. These dual developments produced fewer farms that are larger, more profitable, and more genetically diverse (see figure 3). These farms grow in an increasingly wide variety of specialty aroma hops intended for the craft beer market and have continued to slowly divest for "alpha" hops targeting 'big beer' applications. Some of these same farms are involved in breeding and developing the same profitable varietals. In figure 3, the hop varietals listed are new or established aroma hop varietals bred by Hop Breeding Company, a joint/farmer owned private breeding company established in 2003, that is essentially the extension of two older breeding operations Yakima Chief Ranches (YCR) (joint owned by three farming families) and John I Haas Inc. who co-own HBC. Figure 3 demonstrates HBC's success over its short tenure. When considering YCR and Haas's past programs, along with HBC's current program, this small group of owners, many of whom are farmers, have bred a dominant share of the Yakima Valley's most profitable and popular aroma and dual-purpose hop varietals.

Over the last two decades, hop farmers in Yakima have functionally reversed course in their planting plans. This hop region that was once over 70% alpha hops plantings is now over 70% profitable aroma and dual-purpose varietals, many of which are these new proprietary varietals. This shift has not resulted in genetic homogeneity, but rather a proliferation of new hop varietals desired and bred primarily for their perceived taste and novelty. Within this landscape of hop production, the continued success of many aroma and dual-purpose hops bred by HBC

and its owners' earlier breeding operations has created a unique share of the hop bioeconomy which lends a large amount of power to those hop growers involved in this company's ownership structure.

The story of Yakima's hop farms, from a historical perspective is one where the unique demands of agricultures of scale have been repurposed by reinvesting in innovations that increase per-acre profitability instead of by merely expanding to mitigate declining per-acre profitability. Environmental social relationships in agriculture are necessarily linked to farming techniques and therefore farming technologies. Understanding the socio-technical arrangements for agricultures of scale impacts social science research on environmental considerations. Hop farms provide a case example of an alternative form of large-scale agriculture where becoming an agriculture of scale coexists with rising per-acre pricing, a contrasting reality from the typical agriculture of scale model. This study examines this 'other' agriculture of scale and considers its lessons for wider agricultural practices on a warming planet.

Assembling the hop-growing bioeconomy

Washington hop growing, in this study, will be treated as a case example which speaks to the wider discourse on agri-environmental outcomes and practices related to agricultures of scale and rural livelihoods for those involved in food production. Drawing from a vibrant discourse that considers networks of rural inhabitants and food producers to be key units for study (Bentia & Forney, 2018; Dwiartama, 2016; Heley & Jones, 2012), this research looks at Washington growers as themselves a network that forms a small node of wider industrial-food-regime of global hops production. This node has lessons which impact the social and material organization of other agri-food and agri-environmental systems. Here growers are seen as members of an assemblage of actors including many materials which only together engage in farming practices.

This study approaches the hop-growing bioeconomy as a distinct and complex assemblage of diverse farms connected to the hop-growing and selling network. Assemblages are material arrangements of human and nonhuman actors that (re)produce social worlds: they are processual, (re)emergent, and can be studied by the relational flows between materials that make up the assemblage (Müller, 2015; Müller & Schurr, 2016) Assemblage approaches to social problems allow researchers to consider a wide array of materials as agentic actors involved in social practices (such as farming) besides just humans and usefully synthesizes with bioeconomic approaches (Bennett, 2010; Heley & Jones, 2012). Assemblages are not unlike ecosystems, which are a flexible sum of the many beings, actions, and substrates that reproduce the system. However, assemblages highlight the distinct link between material and social worlds/outcomes. In the case of precision agriculture, for example, social ontologies concerning the meanings of data and the ideals of agriculture impact material worlds of the farms which in turn impact these social ideologies in the reproduction of precision agriculture farming techniques (Carolan, 2015). These assemblages are vital units for environmental social science study, and in the case of agriculture, they have revealed that many contemporary farming arrangements produce a so-called "distributed farmer" who makes farming decisions by a whole committee of people, materials, and organisms as opposed to individuals (Comi, 2020b).

Assemblage thinking approaches, drawing from the methods of science and technology studies (STS), attempt to *gather* as many of these participants and voices as possible instead of immediately sorting these voices by identifying particular domains of power and delimiting the study to one particular domain (e.g. economic, cultural, political, or environmental) (Çalışkan & Callon, 2009; Callon, 2015; Callon & Law, 1982; Law, 2004). These many materials are then assembled by tracing relationships between members of the assemblage. In this approach power

hierarchies and domains/structures of social control are eschewed in favor of flat, networks of power. These networks, following the work of Bennett (2010), are an enlivened collage of things that co-produce social and material worlds on the farm and elsewhere in the world.

Assemblage approaches are especially helpful for examining bioeconomic arrangements which necessarily relate humans to nonhumans in the production of value. This technique of gathering and assembling can effectively identify social relationships which are otherwise obfuscated by conventional critical approaches has been well established in the methodological, theoretical, and empirical literature which employs or analyzes these techniques. This has been usefully demonstrated by those taking assemblage approaches to better understanding agricultural industries. Jones et al. (2018) use an assemblage approach to identify and explore the global wool production assemblage. They find that by gathering the many materials, humans, and nonhumans involved in Welsh wool production they are better able to assemble the complex relational network of rural localities that participate in the wool production network. Put differently, the vast apparatus of things involved in wool production relate to both the local and global social construction of the industry. Similarly, hops production is a social world consisting of a vast array of materials and these can be studied by considering the relational flows between these many materials and people. As with previous research with agricultures of scale (Bell, 2004; Campbell & Rosin, 2011; Konefal et al., 2019), the approach used in this research reveals that such practices, despite monocultural tendencies, still resist monolithic social interpretation and instead present a varied and diverse social and material landscape whereby productive, sustainable interventions and alternative ways forward remain distinctly possible.

Biological economies are those economic arrangements which are reliant on the so-called "natural world" (Pawson, 2018, p. 2). Drawing from agri-food scholarship working in the area,

bioeconomies are those economies which depend primarily on live organisms which are non-human in order to produce, maintain, and circulate value (Le Heron et al., 2016). However, the term bioeconomy and bioeconomics has been in use in a variety of discourses from the 1960's onward and its uses have ranged from a general recognition that economic structures necessarily arise from biological functions and apparatuses to the specific economic apparatus that is guided by genomics and life science industries (Birner, 2018; Pavone & Goven, 2017). This study approaches the term with attention to both meanings, examining the specific arrangement of hops growing that is informed by a unique genetic marketplace while viewing the entirety of the agricultural assemblage as a distinct biological economy, whereby value and life systems coproduce socio-material outcomes (Dwiartama et al., 2016; Legun, 2016). I approach the bioeconomy of hops growing similarly to Marsden and Farioli's "eco-economy" which is a mode of economic thinking that sees bioeconomies as "more diverse and fragmented arena[s] for the development of new production and consumption chains and networks" (2015, p. 337). These diverse ecosystems for value production are studied as distinctly social in this inquiry, and because of this I instead adopt an assemblage-thinking approach to the more conventional notion of a bioeconomy.

Each practice of agriculture can be considered both as a particular assemblage but also as a distinct bioeconomy and this paired critical approach generates more holistic understandings of the many plural bioeconomies that make up world food systems (Lewis et al., 2016; Pawson, 2018). Consider the array of actors involved in hop growing require or benefit from such specific environmental and biological factors: one farmer interviewed for this research put it this way

> This is the biggest hop growing region, so it goes downhill from here…There is a band, a latitude that goes with growing hops. I mentioned that hops need daylight

> units so there's a latitude that is associated with that. 45th 46th parallel or somewhere around there. And then it's the corresponding latitude on the southern hemisphere. So, hops need lots of water and sunny warm days, that's what makes hops grow. And good soil. So, if you're on the 45th 46th parallel and you run your finger around the globe there are very, very few areas on earth that allow that. That have the right, that have the water, that have the sun, there's just very few areas…Michigan thinks that they can replicate what we can do, and they can't. They don't even come remotely close to what we can do because of what we have here in this area. [Harry]

In this context, the entire ecosystem alongside the agricultural techniques and those practitioners together make up the bioeconomic assemblage of hops agriculture. This complex, recirculating social world of materials and people relates to larger social and material contexts primarily through the economic production of value in the form of hop material. Further, hop-farmers interviewed in this study are self-aware of their attempts to reshape or, as they say, 'decommodify' the hop growing value-chain largely through modifying organisms and shifting human comprehensions with those organisms and their impacts on value-added applications for hops in beer. This arrangement uniquely exemplifies the bioeconomy as an assemblage: a unique complex social world that involves materials and people in the reproduction of meanings, materials, and value. Examining this bioeconomy further helps to illuminate the complex relationships between local environments, profitability, and agricultural decision making.

To extend this example, the hop varietal Citra™ which is commonly grown in Yakima, has become a desirable hop variety not only in 'local' Yakima and US contexts but in the

growing global marketplace for hop-forward India Pale Ale style beers. The genetic lineage of Citra™ is legally protected and its branding is also trademarked. It was bred by a farmer-owned breeding program in Yakima and is jointly owned by Haas Inc and YCH who contract with farmers primarily in Yakima who use merchant certified on-farm nurseries and labs to cultivate and reproduce these plants for production (see figure 4). This is an especially local enterprise, but the practices in this valley account for approximately 30 percent of the globe's hops production and Citra is both the most common variety in this region as well as one of the highest value hops in the global marketplace. The practices in Yakima are new to the hop industry and their expansion has modified aspects of the greater Yakima valley agricultural landscape. Yakima's growing dominance and profitability inspires a growing trend to vertically integrate and scale hop farms larger around the globe. This project looks at the Yakima Valley Hop farms as a specific assemblage of an agriculture of scale. I ask whether this agriculture of scale has potential to produce categorically or incrementally different environmental outcomes than other more well-known agricultures of scale and if so, what lessons this other agriculture of scale has for food production in other sectors? Further, this bioeconomic examination of these Yakima growers also helps to query the farmer's claim of regional dominance: does the genetic marketplace and ecological niche of Yakima truly produce a dominant hop bioeconomy, or do local regional growers elsewhere meaningfully contest this dominance in their own hop growing and selling techniques?

Figure 2-4: Citra™ hop pots, propagated clonally from tissue cultures (reduces disease load by comparison to rhizome cutting clonal propagation) on a nearby farm are being offloaded and prepared for planting on a new hop yard at a smaller, 600 acre farm that contracts with HAAS.

Methods:

This qualitative research draws on data collected through field work conducted during May-June 2019 with hop growers (n=15) operating in Central and Eastern Washington. Participants were initially selected from the farmer member rolls of the Washington Hops Commission and the Hop Growers Union which were obtained from these agencies through a Freedom of Information Act (FOIA) request. Because the number of Washington growers have declined as farms concentrate; every farm listed on the commission rolls (μ=51) was contacted at least once to request their participation for the purposes of this study. Subsequent requests were made by participant referral. This total sample represents 29% of hop growers operating in Washington state which is responsible for cultivating 72% of total us hop-growing acreage (USDA NASS, 2020). Participants recruited for this study were interviewed

and asked to provide a detailed tour of their farm with particular time spent showing infrastructure and implements involved in farming practices. During the interview component I used a theme-based interview protocol and audio-recorded and later transcribed interviews. In order to enable more participatory involvement, the field components of the research were not audio recorded. However, field notes and photos were taken during these times on each farm unless the participant objected to either practice. Data collected during field visits were collated with interview transcriptions and the resulting rich data set is used for this inquiry. These hybrid qualitative methods allow me to more directly study place-based considerations unique to farming practices and additionally allowed me to gain detailed insights into the practices and ontologies of hop growing in Washington.

Results:

The following section is organized into three subsections, which each address one aspect of the broad contours characterizing the contemporary arrangement for Yakima valley hop growing. The first section "'decommodifying' a cash crop" describes how hop farmers have engaged in plant breeding and other innovations to reshape the bioeconomy for hops farming. By visiting farmers that are part owners of hop breading programs, such as Bruce, Van, and Fred, I show how hop growers have chosen to reimagine how hop cones are valued as an agricultural good. This first section demonstrates the trends indicative of the Yakima valley hop growing bioeconomy while the following two sections describe qualifying considerations—large and small farms which somehow differ from this generalized model. The second section: "Diversifying the mega-farm's portfolio" returns to Bruce's farm operation, which is a large grower arrangement including a variety of fruits as well as hops. This shows a variation on the growth of hops farm—a responsive expansion to HBC's success where farmers of fruit and other

goods in Yakima recognize the increasing profitability of the innovated aroma hops model and adjust to expand. The third section "Exceptions to the large farm: making it happen on ten acres or less" describe two smaller hop growers in Washington. By visiting Sal and Lynn along with David and Linda, I show how these small farms demonstrate a meaningful but limited method for producing value: the proximity of "local hops" in the small microbrewery marketplace. Together, these results survey specific cases drawn from my collected data to demonstrate the meaningful shifts involved this other agriculture of scale along with those growers that qualify the broad contours of the unique hop growing assemblage in Yakima Valley.

Growing hops: "decommodifying" a cash crop

During interviews with hop farmers, many participants described a long-term goal of "decommodifying" hops. Those who didn't necessarily see this as their project often referred to this concept as an event, a time before craft beer when hops were a commodity, and a time after craft beer when Yakima hops became a different kind of market material with different rules. For these farmers, "decommodifying" hops is a practice (or event) which causes hop pricing to be set based upon taste, quality, or other farmer- or brewer-driven markers as opposed to external forces such as petroleum cost or merchant demands. In this sense, I use decommodification in the *emic* sense, and not in its more common social science and Marxist parlance. I do not mean that hops are no longer a commodity, but rather that some group of these farmers are attempting to reset the methods for value production in the hop growing bioeconomy. Has this self-described "decommodification" actually occurred though? Lending greater control over hop pricing to the farmer or at least some group of farmers? And if so, if this does not constitute a critical decommodification what are the new material arrangements which produce value in the absence of common value standards for other commodities in agricultures of scale?

Even during the years when hops were primarily grown for big-beer applications and were priced largely as a function of transport/petroleum costs, hop farmers were engaged in breeding practices. Perhaps this is because hops have long been a small agricultural good with limited industry and LGU support. Additionally, as perennial plants propagated clonally by root cuttings or tissue cultures, there has never been a vibrant marketplace for seeds. These hop breeding operations have varied in success over the years and include several that have valued different traits than the now-ubiquitous aroma hops bred by HBC. Bruce runs a large fruit and hop farm and is part owner of ADHA (American Dwarf Hop Association) which began breeding hops with dwarfing technologies with the attempt to lower production costs while maintaining yields by pound of alpha acid, the key bittering ingredient large beer companies were functionally buying in the 1980's. While dwarfing technologies are no longer a primary goal of the breeding program, this illustrates how farmer innovations precede the craft beer transition and illustrates how such a practice can be driven by farmer action.

> *ADHA is the name of it [our plant-breeding program]. It used to stand for American Dwarf Hop Association when we started...because we started the program around breeding dwarfing varieties for low-trellis hop production when the world was driven by the commodity side of things and the craft beer market was like nothing… [Dwarfing Technologies were about] lowering operational costs specifically so we could keep up with China. So, we embarked on that whole journey. We had one of the only, and largest, blocks of low trellis hop production. The variety we were growing on that came out of the breeding program.* [Bruce]

ADHA shows us that responsive innovation has been an ongoing practice in hop growing in the Yakima Valley. This cost saving approach mimics typical agricultures of scale and could be seen as a gamble which has paid few returns. HBC's predecessor YCR, during this same time and in recent decades took an alternative approach that hinged on the growing demand from craft beer brewers. YCR originally bred its unique aroma hops as high-alpha varietals. However, as they became popular with the few early microbreweries such as *Lagunitas* and *Sierra Nevada*, those with ownership stakes in YCR cultivated this desirability of early varietals such as Ahtanum™ and Simcoe™. These farmer-breeders were able to identify a potentially profitable way to diversify demand for the genetic landscape of hop growing early and leveraged that to make a more valuable hop, a contrasting approach to ADHA's goal of producing a less costly-to-produce hop. Their child company, HBC has continued to innovate popular varietals, including what is largely considered the most popular current aroma hop, Citra™.

While ADHA is an ongoing breeding program, this grower's story illustrates the risk of innovating as a single or small group of growers operating in a vast bioeconomic network where demand, market pressures, and material performance remain unknown quantities. It also demonstrates that responsive innovation is both risky as well as profitable. When asked if he continues growing any of those varietals, Bruce gave an answer that reflects the surprising demand trend toward small number of especially popular aroma hops despite the increasingly diverse genetic marketplace in recent years: "*We used to, we pulled it all down to put up high-trellis. Now it's all Citra" [Bruce].* While demand for other hops exists, other aroma hops do not receive the same volume demand as Citra™. Notably, Citra is an HBC varietal co-owned by Haas Inc. and YCR. It can only be planted under contract with these two entities and its highly valued bines are propagated by contracted nurseries and farmers, often by tissue culture, and

purchased by the planting farm most often as pots (see figure 2). Citra is not the only varietal being grown in Yakima, other profitable and popular varieties developed by Hop Breeding Company include Mosaic™, Ekuanot™, and recently Sabro™ while their co-owners have previously developed a range of other popular aroma varietals including Ahtanum™, Warrior™, Chelan™, and Simcoe™, among others. Their dominance in the US hop breeding landscape is unprecedented, no other farmer-driven breeding program has so dominated the plant genetic marketplace for an agricultural good.

One exception to the dominance of Hop Breeding Company and its owners is the varietal Amarillo™. Amarillo™ is legally grown entirely by one family and those who physically grow the varietal on the farm both in the US and elsewhere in the globe through their Amarillo™ program do not legally own the bines but rather contract with the farmer-owner to ostensibly rent Amarillo™ plants on a guarantee buy-back program, the farmer then works with hop buying merchants and large-scale brewers and therefore maintains price-setting power. The buy-back program represents a kind of plant-material rental program, and this otherwise unusual bioeconomic arrangement has similar models throughout hop growing. Yakima Chief Hops is functionally YCR's hop marketing and growing company. YCH serves both its owning members and a number of farms who wish to grow YCH hop varietals, which include those bred by HBS YCH's member and contract farm model is similar: YCH contracting farms are obligated to sell YCH varietals through YCH and receive a percent-share of earnings based on acreage instead of a set price as a typical commodity would function. In both the Amarillo and YCH cases, contracting farmers, those smaller entities, do not have significant leverage. However, for those few farmers who have ownership stakes in breeding and merchant programs, a significant ability to shape the biological marketplace allows them to more freely experiment on-farm and develop new genetics or implements. In short, this agriculture of scale has depended on incremental

farmer-driven innovations. Instead of corn and soy agriculture, which scales to reduce per acre costs, hop growers in Yakima have scaled while simultaneous using those earnings to mitigate infrastructure and innovation costs. For those who have been successful, a vast arrangement of people and materials create a system that continually reproduces a new hop bioeconomy: linking farms to breeding programs to the craft beer marketplace.

Participating in a breeding program has significant costs including infrastructure costs. As test varietals and small planting plots begin to scale, owners of the breeding program and affiliated farmers have a vested interest in testing and marketing the new varietal before scaling larger multi-year perennial plantings of a new varietal. Because hops have a narrow picking window and because hop picking requires significant infrastructure hop growers are met with a particular problem. To switch varietals of hops during picking, they must pause production on some portion of their picking, kilning, and curing apparatuses, thoroughly clean the vast equipment to prevent flavor contamination, and then begin picking this new hop varietal. During the month-long harvest season this is typically managed by planting varietals with varied growing times and managing plots such that the equipment is maximized.

Testing small batches interrupts this picking window and reduces the farms ability to grow at capacity and therefore to justify the large infrastructure costs and maximize production. To moderate this cost, many farms maintain or build smaller picking facilities to manage boutique varieties or to test new varieties. On Fred and Van's farm, which hosts many of the test varieties produced by Hop Breeding Company, they were currently building just such a small facility (see figure 5). As a partially built structure, it demonstrates some semblance of scale for the size of infrastructure required on these farms and though it is significantly smaller than their primary picker, it illustrates the potential cost benefits that I suggest materially encourages on-farm investment in process innovation. One such innovation is the patented de-viner, which

negates the need for frontends which strip the arms, leaves, and hops from the vine by removing the vine in the field (see figure 6). These de-viners are custom fabricated trailers pulled behind a tractor, but ahead of a storage trailer, and are cheaper from a material and petroleum standpoint than expensive fixed frontends. Hop farms in the Yakima valley are complex bioeconomic assemblies that attempt to control their eventual market opportunities by vertically integrating not only their market structure of brands, buyers, and inputs but also the vast array of social and material actors that play into this. Participating in mechanical and genetic innovations is a way of (re)producing the social and material world which allows for the unique large-scale profitability that Yakima hop growers have benefited from over the last decade. This has, as mentioned above, come with incremental environmental adaptative improvements and with many farmer benefits. However, these benefits are not equally shared, in the following two sections I describe two outliers: the large farm which diversifies into hop farming and the small farm which must find alternative bioeconomic pathways because of the onerous limitations to access for small farmers to grow the popular, proprietary varietals of large Yakima growers.

Figure 2-5: Smaller hop picker being built to allow for simultaneous harvest of boutique, test, or uncommon hop varieties without interrupting harvest of larger-acreage varieties (such as Citra™, Simcoe™, etc.). These hop pickers clean and pick hops from bines which are cut in the field and brought to these large warehouse settings for picking, kilning, curing, and baling.

Figure 2-6:Fleet of home-made, patented "de-viners" in equipment lot. De-viners are patented implements used only on two jointly held large farms in Yakima and are pulled behind tractors while cutting the hops at harvest and separate the bine from the arms, leaves, and hop material while in the field. This incrementally lowers petroleum costs as well as the expensive infrastructure costs of large, static “front ends” which otherwise clean these hops at the site of a hop picker.

Growing hops: diversifying the mega-farm’s portfolio

Many hop farms I spoke with operating in the Yakima Valley were primarily hop growers, and only produced other goods as tertiary portions of the farm portfolio, and many of these farms planned to offload excess acreage of orchards or berries so soon as their current fields became unproductive and could be more effectively converted into hop yards. However, this is not a totalizing picture, many of the large fruit farms in Yakima are primarily operations of scale, and at such scales the investment required to begin hop farming is feasible. How do these farms undertake, understand, and operate in this new agriculture of scale as part of a larger

portfolio of apples, blueberries, and other fruits? Besides asking how these farms vary, I first suggest that these farms emphasis on scale reveal a generalizable observation about Yakima hop farmers: that their self-professed goal of "decommodifying" hops is not only linked to innovation and vertical integration but also to a particular agricultural technique of scale which allows them to provide unique varieties in significant quantities for large profits. In these contexts, farmers willing to invest and grow at scale quickly are an integral member of the Yakima hop growing assemblage that enables this particular arrangement to continue and remain relevant in the global hops market.

While the scale of farms in all hop yards in Yakima are large by industry standards, those with diversified crops seemed to more consciously assess themselves according to scale. Notably Bruce is a large apple and fruit producer. These markets are truly agricultures of scale, requiring higher hours of human labor inputs than hops and longer investments in plantings. Slimmer margins in the apple industry encourages the plantings of higher value apples which conversely, are riskier long-term plantings. Perhaps because of these compounding factors apples and most fruits truly become agricultures of scale. It may come as no surprise then, that such growers who also grow hops see agency and power in the hops market as a direct function of size:

> *We have the desire to scale the business larger in all the crops that we're involved in right now. Mostly so we can remain relevant and [so] we have a seat at the table in the supply chain because in my opinion, we have... we need that seat at the table. Otherwise we become 'just a grower' and in many ways if you're 'just a grower' you're not going to receive full value for your crop. That doesn't mean you need to own every piece of the supply chain, but you at least need to be relevant so that you have a voice. [Bruce]*

For farmers like Bruce, hops may be part of a larger portfolio, but as with his large fruit operations, he sees scale as vital means for maintaining value-chain relevance in making planting, selling, or pricing decisions. While Bruce's hop breeding has not had the success of HBC, he is able to leverage scale to be recognized in an industry dominated by the vertically integrated large farm.

Other large multiple-crop farms do not mimic Bruce's method, and these hop/fruit operations remain content to grow relatively small acreage hop yards (closer to 600 acres) and either contract with another grower to use their infrastructure or maintain a smaller infrastructure. In this latter case, hop farms are methods for mitigating market risks of fruit production and utilizing ground types more effectively. While many of these cases result in little innovation, one case contradicts this standard. In the case of Bruce, there is an uncommon example of a hop farm which is over 2000 acres being run by a farm with significant holdings in other fruits. This contravenes the trends of the other especially large hop farmers which are reducing other crop holdings or abandoning them altogether.

The lesson of Bruce is that the hop agriculture of scale is not entirely detached from the constraints of other commodities even in the context of a goal to 'decommodify' crops. While Bruce did not speak about decommodifying, he did describe particular innovations including an ownership stake in a private breeding enterprise, and a decision to pelletize hops on farm as oppose to bailing as a means to increase quality and decrease merchant processing fees. These decisions mimic those interested in decommodifying, yet the need to scale to remain "relevant" suggests a particular commodity exercise, that power and agency are functions of socioeconomic status and scale. However, he did not describe scaling as a typical agriculture of scale, a requirement to break even and increase profitability, but rather as a way to have a "seat at the

table." He saw scale as a way of leveraging power in the larger hop growing supply chain. In this large operation, we see that the "decommodified" hop operates clearly as an "other agriculture of scale" which is simultaneously beholden to the socio-material arrangements that inform, constrain, and produce what we typically call commodity agriculture, but also materially linked to all kinds of other concerns including taste, social relationships, and place which operate differently than a conventional commodity agricultures of scale.

Exceptions to the large farm: Making it happen on ten acres and less

All farms are not large, and as with vegetable and grain agriculture, there are a small but growing number of farmers that are operating at smaller scales in more local economies. Hop yards are labor-intensive practices which are also highly productive, how do these small farms pay for their hop yard start-ups and what methods do they use to either become profitable or aim to stay solvent over the long-term. Do these farms use notably diverging practices and if so, do they provide lessons, contestations, or useful social science considerations for this mapping of an agriculture of scale developing in the Northwest hops industry? In many cases the small farms do not purposively diverge from the large farms in terms of sustainability practices. However, because of the constraints of scale and the active hop industry bioeconomy of genetic property rights these farmers practices do differ, particularly as they seek to reframe hop varietals as unique due to terroir and locality instead of genetic varieties. Put simply, if you can't legally grow Citra you must find some other way to convince local brewers to purchase a lesser-known hop for use in beer-making applications. For many small-time growers, this is one of the instances where food-ideals of locality can be leveraged, such as in the case of Sal and Lynn who market 'wild' varieties of hops they've cultivated from shoots found on a nearby ranch. These

unique hops are local to the city and therefore have staying power with a small set of purchasing brewers despite their bio-chemical and taste inconsistencies.

Hop farmers tend to use surprisingly analogous techniques across scales. Fourteen-foot poles remain standard, though straight-line trellising on twelve-foot poles sometimes appear on small farms while v-trellising on 14-foot poles is near universal on larger farms. Like large farms, small farms must have some implements, home-made or otherwise for vine throwing, wrapping, cutting and eventually hop-picking, and cleaning. Most large farms bale their hops while almost all small farms I spoke to pelletize or contract with a pelletizer instead of pelletizing their own. Small farmers I spoke to buy small scale equipment usually from German hop company Wolf™ or build their own as in the case of David and Linda. While many small hop farmers grow primarily land-grant university public varietals as opposed to historic European "noble" hop varietals, some did experiment with new breeds. However, without the structures and money required to produce their own breeding programs, these hop growers who use alternative varietals are often using 'wild' varietals or cross-pollinated subtypes without highly predictable known qualities. While some growers name these varietals and are successful in marketing them as a more local product to brewers, they struggle with the unpredictability of local markets. Generally speaking, one could characterize the key differentiation in technique between large- and small-scale hop growing operation to be the presence or absence of particular genetic lineages and the likelihood of their involvement in the production and maintenance of those lineages.

Discussion:

What lessons are there from examining Washington State hop growing as an 'other agriculture of scale' which reinvests high earnings resulting from their practices in infrastructural

and genetic actors to produce value? Using this technique, Yakima hops growers have grown larger while inverting expectations, increasing price-per-pound to maintain profitability instead of increasing acreage to mitigate the lowering price-per-pound indicative of other commodity agricultures of scale. Findings from this research reveal how actors in the Washington State hop growing bioeconomy "decommodify" hops and continue to produce heterogenous meanings in response to this "decommodification." In each of the three previous cases, hop material specifically means and behaves, differently for each farming assemblage. For those in the first case, who are involved in the innovation and proliferation of new varietals, hop material is a collaborator and an enabler of new modes for profit seeking. For the large fruit and hop farms of the Yakima valley, this hop material connects these large farms to the innovative and vertically integrated hop farms that produce new varieties while diversifying their agricultural portfolio. In this bioeconomic setting, hops provide short term profitability and long-term stability by diversifying their agricultural investment. For those small farmers, the "decommodified" hop is a foil that troubles their direct-to-brewery sales specifically because these new proprietary and popular hop varietals are largely unavailable to small growers.

While the bioeconomy for hops growing remains fragmented and varied between these three cases (Marsden & Farioli, 2015) it is clear that the agriculture of scale practiced by Yakima hop growers alongside their vertically integrated breeding and marketing programs does produce a dominant arrangement within the hops growing industry. By "decommodifying" their hops, this small group of large and innovative growers reimagines the particular actor (the hop strobile) in the bioeconomy of hops growing and this disrupts both the local production systems for these large growers but also reshapes the larger industry by modifying others' relationship to plant material involved in the hops growing and marketing assemblage. "Decommodifying" hops,

again, in the emic sense of the word, is an encoded way of describing a material and ontological shift in the hops growing bioeconomy. It reveals that farmers may be self-aware of the material disruption to the larger biological marketplace for commodities they are involved in producing.

The "decommodified" hop is new, proprietary, and expensive. It is desirable for craft beer applications and its value arises from a confluence of factors including novelty, availability, and taste. It is a new actor in the hops growing assemblage, and it reshapes the possibilities and limitations for hop farmers. In the context of the fruit and hop megafarm, control over innovative "decommodified" hop material is forgone, rather these large farms aim to increase scale as a method of "having a seat at the table" with those they contract with to grow and sell these hops. For these farmers, the selling power of scale in such a small market can remain an alternative way of accessing agency in the hop growing bioeconomy. For small hop growers, however, this "decommodified" hop operates almost entirely as an outside pressure: a force which inhibits full market inclusion as they struggle to find alternative pathways for producing desirability with local brewers and hop buyers. Exploring the effects of growers' efforts to "decommodify" hops has lessons for other agricultures of scale and for disciplinary understandings of bioeconomies and agricultural assemblages: These farmers' self-conscious efforts to reshape their market reveal both the importance of material actors in the bioeconomy and the importance of human intentionality in the maintenance and disruption of this assemblage.

Conclusion

This case study yields insights into the ontologies of on-farm innovation and technological adoption, contributing to an ongoing discussion of the impacts of innovation on the world's food system (Darnhofer, 2020; Eastwood et al., 2017; Fraser, 2018; Rotz et al., 2019). Other research has already revealed that innovation arising in the input sectors onerously locks in

farmers and limits farmer agency in agricultures of scale (Comi, 2019; Kloppenburg, 1988; Rotz et al., 2019). Agricultures of scale rely on a complex bioeconomy to produce value and a distributed array of actors in order to make farming decisions. While this distribution of agency has locked in many commodity farmers, examining Yakima hop growers and their "decommodified" hops reveals three core contributions to the discourse on innovation and technological adoption in agriculture: **(1)** When a farming operation recognizes their distributed status, unique opportunities to collaborate with a range of bioeconomic actors to innovate technologies and profit-making pathways can arise. **(2)** Large scale agriculture's lock-in is contingent upon onerous pricing models and therefore pricing models that free farmers, at least in this instance, result in on-farm reinvestment and increased farmer agency in the growing bioeconomy. And **(3)** while changing practices in hop growing have concentrated wealth among only a few farmers in the Yakima valley who continue to practice chemically dependent high-irrigation techniques, these same farmer's reliance on local ecologies encourages technological and praxis innovations with incrementally improved outcomes for environmental adaptive capacity.

This research also responds to problems in applied rural development and environmental policy. On-farm innovation is shown to increase profits for hop farmers, improve environmental adaptive capacity, and result in incremental improvements in sustainability. This insight is consequential for policy makers and research groups targeting sustainable rural development. Initiatives aimed at funding farmer driven innovation and/or incentivizing farmer-driven reinvestment may both result in incrementally better environmental outcomes in the long-term while boosting rural livelihoods in the short term. One distinct problematic revealed in these findings is that positive financial outcomes continue to benefit primarily those farmers of scale

who are able to adopt quickly. Additional research is required into the inequities resulting from this bioeconomic system and potential applications resulting from this research should consider these mitigating factors. Research into the specific material character of farmers' practices of innovation would also improve understanding of the links between bioeconomies, value, and taste. Further, continued research is necessary to better map the complex relationships between Yakima farms and other hop farms throughout the US and elsewhere in the world. Understanding the relationship between Yakima and the global hops bioeconomy would help to clarify the meanings of farmer driven innovation and its impacts on industry sustainability in both environmental and financial contexts.

3. Do Farmers Know Better?

Introduction:

I left my campsite near Yakima at around 6AM, heading South along the L-shaped irrigated valley home to the lions-share of US hop producers to visit Paul and Neal's operation. Paul and Neal own two large hop yards, are brothers in a storied family in the region, and are part of the ownership structure of a hop breeding program and one of the largest hop selling and marketing companies. They are indicative of the new Yakima hop grower, who vertically integrates their operation along the entire hop value chain. I stopped at a gas station at the exit to Toppenish to wash up and change out of my shorts and sandals and into my "uniform:" thick canvas pants, boots, wool shirt, a hat belonging to my deceased grandfather advertising Alpha farm implements. I expected to spend my time in the passenger side of a farm truck, driving the many acres of their farm, walking along the large hop-picking apparatuses housed in outbuildings throughout their farm, and examining hop yards. I was surprised, however, when Paul took me to an empty tasting room above the hop curing floor in a large warehouse. The floors were smooth hardwood, with wall-sized windows looking out to the warehouse curing floor on one side and over a large hop yard to the other (see figure 1). A thick slab of wood from the original hop picker on their farm is repurposed as a bar running the length of the room to my right and a large family style table sits on my left. The space had the feel of Napa Valley tasting room and my 'uniform' suddenly felt out of place. Paul poured me a few test beers, made by a contract brewer to showcase new hop varietals and told me that this room is where they bring brewers from companies like Lagunitas and Sierra Nevada to sample lots, buy whole bales of hops, and give feedback. This room and its goals reflect the unique world of new hop growing, driven by taste and demand from the craft beer industry, the new "craft" hop market reflects a collaborative

effort of hop growers, brewers, and plant material to co-produce novel hops in a market that hinges on novelty and an adaptive system for monetizing the specific taste associated with craft beer and the hops that help make it. None of these hops are more notable than one developed by Paul and his associates through Hop Breeding Company (HBC) in 2007: Citra™.

Employing Citra™ as a case example this qualitative study uses participant observation and interview data to explore US hop growers' practices and to map the unusual value chain these innovative growers have collaboratively produced. Drawing on scholarship on biological economies and innovation in agriculture settings (Bronson, 2015; Marsden & Farioli, 2015; Pyka & Prettner, 2018) alongside relational approaches in agriculture (Carolan, 2008; Darnhofer, 2020; Forney et al., 2018) I take a more-than-human approach to studying Yakima hop growing where actors are shown to generate value through the innovation and proliferation of new genetic varieties. This arrangement makes visible the relational tension between discursive ontologies and material outcomes, as farmer/breeders work to identify cultural trends in taste, 'brand' their varietals, and retain sustainable portfolios of diverse hop materials on their farms. These farmers produce and rely upon both discursive and material technologies and their practices yield insights into environmentally sustainable pathways forward for farmer-driven innovation in other specialty agricultural goods.

Figure 3-1: Hop yard as seen from hop farm sampling room. Photo taken in May, hop bines are visible at base of trellis.

Background:

American hop growing's value production assemblage is closely linked to farmer-driven breeding and innovation. Yakima hop growers are largely a vertically integrated industry and farmers are often in some way involved in breeding, propagating, growing, and marketing hops to buyers. Some farmers even have ownership stakes in hop merchant companies. This arrangement arises from responsive development to socio-economic pressures throughout the twentieth century and unique collaborations between a variety of actors including farmers, local ecosystems, hop material, and beer makers. In this section I outline the structure of the hop growing marketplace, the historical contours of hop growing in Yakima, and the recent development towards boutique and expensive "big juicy" hop varieties alongside the surprising

emergence of Citra™ a hop varietal which exemplifies the hop breeding and growing ontologies of Yakima Valley hop growers.

From alpha to aroma hops in the Yakima Valley

> *A guy named Vinnie Cilurzo [from Russian River Brewing] shows up and says, "Hey man. I love your Simcoe™." We don't know who the guy is, where he's from, or what he's doing, but more brewers would come in, like people from Founders and people from Lagunitas. We actually, for a short time there, began to do some direct business with them, and we'd have the work done at Yakima Chief. [Paul]*

Hop growers have long been farmers who sell almost the entirety of their crop for a single, value-added good, beer. This single-market focus produces unique pressures and opportunities in the hop growing industry. Broadly, there are two categories of hops used in beer making: "Alpha" and "Aroma" hops. Alpha hops are grown for their high content of alpha acids. This chemical compound is a preserving agent that produces a bittering effect which is ubiquitous in beermaking applications. To fully extract alpha acids, alpha hops are utilized at the beginning of the boil process in beer making, meaning that the aromas, volatile oils, and other compounds present in the hop cone evaporate, leaving only the bitter taste and antiseptic qualities. The vast majority of beer production by volume today remains standard and premium lagers, which utilize almost exclusively alpha hops in low concentrations. Aroma hops are selected for a variety of volatile oils and beta acids which produce desirable flavors in beer. These hops are popular in "craft" beer styles today and are added at the end of the boil or following fermentation to prevent volatile oils from being off-gassed before bottling, kegging, and distribution. Historically alpha hops represented the primary share of the hop market, with aroma hops being used in relatively small quantities and making up less than 30% of the total acreage grown.

Throughout the twentieth century, prohibition and the consolidation of the beer industry impacted hop farmers much as buyer-consolidation has in other industries: fewer larger buyers with more power depressed hop prices and decreased farm profitability (Cabras & Higgins, 2016; Howard, 2016; Marketline, 2015b). This in turn, decreased the number of farmers and the size of the market, decreasing engagement from land-grant universities in Washington and Oregon as the share of farmers also decreased. With greater buying power, these large beermaking companies negotiated new contracts. Instead of buying hops by the pound, a multigenerational farm owner, Paul, describes how hop merchants would estimate the quantity of alpha acid present in each lot of hop material and purchase hops from growers based on the weight of alpha acid present.

> *We had markets into some of the bigger brewers through that system, and it was a matter of getting the highest alpha you can get per acre to try to maintain that commodity market. There were years where there was some [demand] here, and the price would boom up for a year or two, typically no longer than two or three years at the most. We would live through those cycles…We were probably 80 per cent alpha and 20 percent, we called them, aroma hops. That's kind of inverted. [Paul]*

In the absence of vibrant LGU activity and facing poor economic outlooks, farm operations in Yakima began breeding new varieties of hops to try and increase profit margins. One widespread approach targeting the development of hop varieties with higher concentrations of alpha acids to increase per-acre profitability. One farming group, Yakima Chief Ranches (YCR), began breeding varieties which are now well known, such as Ahtanum™ and Simcoe™ with this goal in mind. During this same time, craft brewers became aware of these new varieties of hops and began experimenting with them in beer styles that were then considered unusual, but which now

seem commonplace including pale ales and India Pale Ales (IPAs). Long-time growers who pioneered these high-alpha varieties report that craft brewers realized that these new hops happened to also have high quantities of volatile oils that produced more flavorful beer when utilized as aroma hops. From the 1980's to the early 2000's the small segment of craft brewers continued to grow, and many of the larger craft brewers built relationships with hop farmers to buy off-contract hop varietals that were then difficult to find. Because of this unique arrangement, hop growers were increasingly aware both of the developing use of their high-alpha varieties and these brewers' willingness to pay premium prices for these varietals as well as the higher volume of hops required in craft beer applications despite the segment's relatively low volume of beer production.

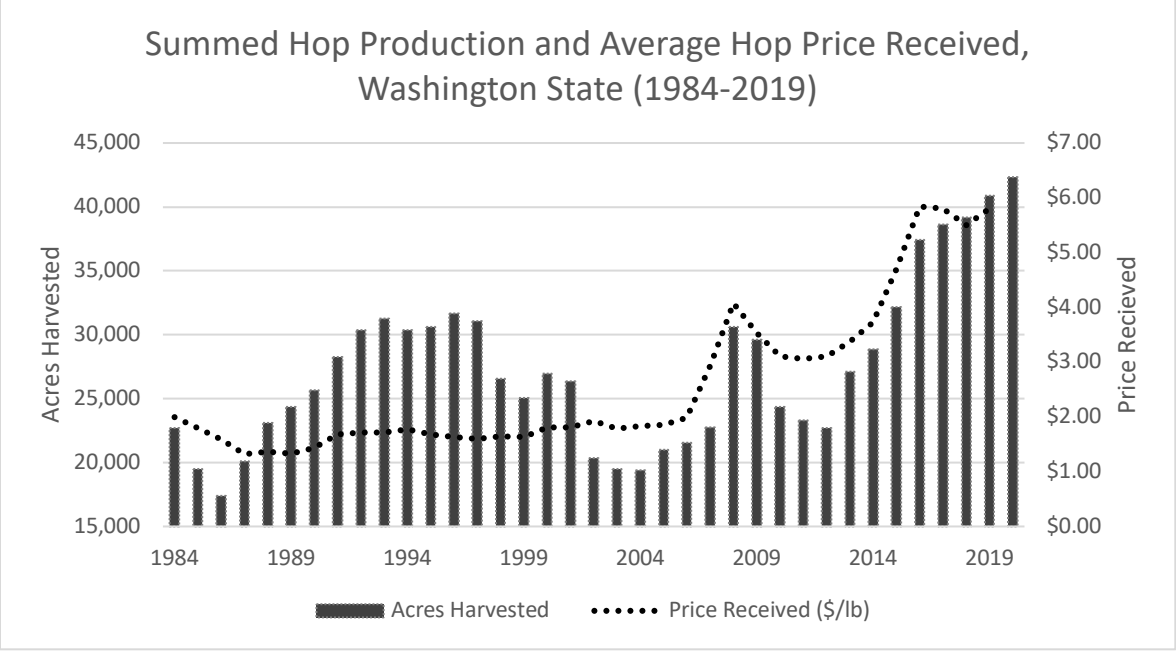

Figure 3-2: Total hop production for Washington State charted against average price received as reported by USDA NASS. Rising total acreage and increasing profitability are linked to the revised model for hop growing, which emphasizes aroma hop varietals with applications in craft beer instead of alpha varieties with applications in standard lager or "big beer."

While the new Yakima hop farm that prioritizes hops for the aroma market has been financially successful, it has not been immune to other market fluctuations which inform the general trendline for agriculture in the US and in Washington State (see figure 2). The US housing crisis of 2008 produced a generalized economic downturn which shuttered farms and caused the US hop growing industry to significantly contract. Following this recession, remaining hop growers in Yakima and elsewhere in the US saw the buoyant craft beer economy as the way forward and began a profound reversal in their growing practices(Peter Adam Kopp, 2016). In the last fifteen years, Yakima hop growers have inversed their hop portfolios, replanting thousands of acres of perennial alpha hop bines with these new aroma varieties. While much of the world still grows primarily alpha hops at low profit margins and a small number of aroma hops at higher profits but less predictable demand, Yakima growers have vertically integrated and developed robust marketing schemes alongside diverse portfolios of aroma hop genetics specifically catered to craft brewers. These expensive hops now make up over 70% of the hops grown in Washington state and have radically reshaped the pricing of hops grown in the US (USDA NASS, 2020).

Co-production and the "big juicy" hop value chain

> *We called them aroma hops… [Now] we call them craft. Some of our popular proprietary varieties we call "big juicies", because that's essentially what they do. They have a higher alpha, so they can't really be called just an aroma hop. [Paul]*

American hop growers' emphasis on profitable aroma hops grown for craft beer applications have reshaped the global hop growing market. Much like agricultural products produced for other value-added goods like wine and cheese, the value of hop material has become linked to

assessments of taste (Alons & Zwaan, 2016; Dougherty, 2012; Forney, 2016; Paxson, 2013). Like both wine and cheese, much of the perceived value occurs at the consumer level of the value chain, where wine, beer, and cheese makers use cultural markers to emphasize their craft. At the growing level, products like wine and cheese have well known cultural links to terroir: where value is linked to the place of production (Dougherty, 2012). Similarly, hops have particular links to the few regions where significant production occurs: the Yakima and Willamette valleys of the US Northwest, for example. However, unlike these products, particularly wine, where long genetic lineages of heirloom grape varietals are culturally valued: Yakima hop growers have instead proliferated large portfolios of new aroma hops and varieties, linking novelty, taste, and innovation to the production of value. Similarly, because drinkers primarily identify and seek out craft beer based on brewers/makers, the maintenance of aesthetic value primarily occurs between grower and maker prior to final consumer. This creates the need for the proliferation of branding materials, new categories for flavors, and new ways of describing hops as desirable. As Paul reports, he no longer thinks of his hops as being simply "alpha" or "aroma" but rather thinks of them as operating with application ends and flavor categories. Notably "craft" hops are identified as his largest category of hops grown, with "big juicies" being the most notable and profitable of that subcategory.

American hop growers and breeders have used traditional breeding techniques to proliferate new "big juicy" or "craft" commercial plant varieties and retain value in what was previously a financially precarious industry for US farmers (Comi, 2020a). Examining these operations reveals that physical attributes and normative values of hop growers, merchants, brewers/buyers, and hop material converge to co-produce paired socio-material outcomes (Jasanoff, 2010). Hop breeders have proliferated new trademarked "big juicy" or "craft" hop

varieties which can be observed as both commercialized plant material resulting from proprietary genetic lineages as well as robust discursive ideas glossed as “brands” like Citra™, Sabro™, and El Dorado™. By pairing innovations both in the form of new varieties (plant technology) and new brands (discursive technology), large hop growers have been able to take advantage of increasing market-demands for novel quality hop varieties while also exerting influence over how hop novelty, taste, and quality will be assessed by buyers. This study examines how multiple actors in the hop breeding and growing assemblage are involved in the coproduction of “craft” or “big juicy” hops and how this sociotechnical apparatus impacts the hop-growing value chain in a US context.

Plant technologies, like other forms of scientific inquiry and innovation, result from the triangulation of multiple actors relationally involved with one another and the resulting materials have been shown to have multiplied socio-material meanings (Jasanoff, 2007, 2010; C. J. Rosin et al., 2017). While, much attention has been paid to biotechnology in modernist agriculture observable in the robust interest in transgenetic techniques involved in commercial research and development over the last 40 years (Carolan, 2010b; Comi, 2019; Kloppenburg, 1988, 2010) less attention has been paid to more traditional breeding techniques and the way actors in these practices are also involved in co-production and innovation. Research in other industries like apples (Legun, 2016), strawberries (Guthman & Zurawski, 2020), and wine (C. J. Rosin et al., 2017) have revealed that aesthetic qualities of taste are both political and material and that breeding goals, market demand, and labeling all have rebounding impacts on resulting agricultural arrangements. Particularly, Legun’s (2015) work on dwarfing technologies in apple orchards demonstrates how the pursuit of specific technologies in fruit production entrench

actors in a neoliberal marketplace while also revealing that alternative assemblings of these relationship may result in more sustainable, profitable, or otherwise beneficial ways forward. Similarly, Rosin's work on sustainable wine production reveals that again, a material assemblage of objects and actors are relationally involved in co-producing agricultural goods and the socio-political meanings that help to maintain such agriculture regimes (Rosin et al., 2017).

In each of these cases, contemporary, and more specifically modernist, agriculture is undergirded by robust control over plant material as an ontological precondition (Campbell, 2020). Put differently, the notion that plant breeding is replaceable by tightly controlled transgenetic techniques is a specific ontological stance about what plants and plant genetics actively *are,* that results in particular modes of co-production involving plant-scientists, hybrid pairs, bacteria, and other actors who are involved in innovating and controlling plant genetics. Hops growers show a "third way" forward for plant agriculture, that is neither heirloom agriculture as in wine production, nor the tightly-controlled transgenetic technique indicative of modernist commodity agriculture. Examining co-production in hops growing and breeding reveals the links between material-technical worlds experienced and impacted by farmers alongside the ontologies about what farming is and what plant materials mean. The resulting hop materials in these local breeding programs which occur on farms, in places result in the proliferation of new plant genetics and new plant materials that are co-informed by a wide range of actors which together co-produce novel hops. As Fred, co-owner and operator of a large breeding program reports:

> *What it really boils down to is GBEI, genetic bio-environmental interaction. That's really what's driving selection. It's how do our genotypes respond to our environment? And one of the original drivers of variety development in a new area of course is for example, we*

> *can't take a variety that's developed in Germany and expect to grow it here successfully. We can grow it. We can try. We've seen time and time again that those are not necessarily going to be economically viable. So that's where probably 100 years ago they started trying to develop varieties specifically for the Pacific Northwest [Fred]*

This study takes this environmental-relational attitude as a theoretical starting place. Drawing on this principle of genetic bio-environmental interaction, I address co-production as arising from material relationships between humans and environmental actors involved the act of breeding. The interconnected relationships operate as an assemblage which is able to create value and stabilize ideas about agricultural goods (Carolan, 2013; Darnhofer, 2020; Sutherland & Calo, 2020). This assemblage reveals that a range of material and social relationships in the ecosystem are responsible for the maintenance and reproduction of these farmers' breeding operations and the plant materials they select and grow. Further, as farmers market and "brand" their hops they are engaging in an ontological reassessment of what plant material is, and this reshapes their relationship to such plants as growers, breeders, and sellers (Sutherland & Calo, 2020). This loop reveals the complexities which occur when farmers engage at multiple levels of the crop value chain and how the resulting messy assemblage subsumes a conventional value chain. Hop farmers' on farm direction of plant breeding and marketing is a case example that shows how ontologies about plants and self have rebounding impacts on the co-production of new crop varieties and the demand for those varieties in the hop growing marketplace.

Methods

I use mixed qualitative methods to *gather* together the social worlds of hop growers (Law, 2004). Through on-farm participant observation and interviews with hop growing professionals (n=21) I examine the unusual world of US hop production. While my interviewees almost always identify

as “farmers” in some sense, it is notable that the large hop farms of Yakima in particular are often diversified operations of scale. Even on those farms which grow only hops, farm owners, managers, and laborers identify by a variety of roles. This data draws from those with ownership stakes or managerial and are therefore explicitly involved in direct, broad decisions about planting and harvesting. By especially targeting farm owners, I was able to explore decisions about multiple levels of these vertically integrated operations, and interviews discussed a broad range of aspects from decisions about material purchases, to involvement with merchants, buyers along with input concerns including propagation, input purchases, implement innovation, and plant breeding. In the following three sections, I report on information gathered from farmers, with an emphasis on three farmers who are extensively involved in both farming and breeding hops. Drawing from this data I assemble the social and material worlds surrounding these farmer breeders and the hop materials they collaborate with to co-produce novel brands

Results:

The following section is divided into three subsections. First I outline the range of proprietary hops grown in Washington State and the breeding programs that develop them, including Hop Breeding Company, developer of Citra™. Second, I explore how farmer growers and hop materials are co-involved in both breeding and “branding” hops and how these paired processes yield insights into the contemporary value chain for hop growers in Yakima. I particularly examine the tension between hop materials and hop ontologies and the links between innovation and value in hop growing. In the third section I compare two HBC varieties, Citra™ and Sabro™ to explore how branding works to both benefit diversity in the hop-growing assemblage by coproducing and maintaining desirability for a variety of genetics while also contravening this very outcome through the maintenance of desirability for monolithic varieties.

Citra™ and the proliferation of "big juicy" hops

Hop growers today do utilize the results from some public breeding efforts that have received new attention, notably at Oregon State University. However, the hop growing marketplace in the US primarily relies on a range of proprietary hop varieties produced by individual farms or farmer/merchant-owned breeding programs. The proliferation through traditional breeding methods has resulted in a diverse portfolio of farmer-bred US hops with a strong emphasis on fruit-flavors which are marketable in a US and global context for craft beer. While US hops have arisen from a variety of breeding programs and farms, many of the hops grown in the US are controlled through two merchant operations: Yakima Chief Hops and Haas Inc. In 2003, the owners of Yakima Chief Ranches (YCR), along with other farmers and owners of Haas Inc cofounded Hop Breeding Company (HBC). HBC is farmer driven and the youngest large breeding operation active in Washington. It has effectively replaced the breeding operation conducted by YCR and has, since 2013, come to dominate the US hop growing bio-economy in terms of proliferation of new genetics adding six new varietals to the market during this time (see table 1).

US Grown Proprietary Hop Varietals (Brands) Available through Yakima Chief Hops (YCH)

Brand	Origin/Breeder	Flavor Profile (reported by YCH catalogue)
Ahtanum™	Yakima Chief Ranches	Grapefruit, Floral, Cedar
Amarillo™	Virgil Gamache Farms	Grapefruit, Orange, Lemon, Melon, Apricot, Peach
Azacca™	American Dwarf Hop Assoc.	Grapefruit, Orange, Lemon, Mango, Papaya, Pineapple, Grassy, Citrus, Tropical, Pine

Bravo™	Hopsteiner	Orange, Vanilla
Citra™	Hop Breeding Company	Grapefruit, Melon, Lime, Gooseberry, Passionfruit
Ekuanot™	Hop Breeding Company	Orange, Melon, Mango, Lime, Berry, Green Pepper, Apple
El Dorado™	CLS Farms	Apricot, Grass, Citrus, Wood, Mint, Watermelon, Cherry, Pear
Idaho 7™	Jackson Farms	Peach, Mango, Pineapple, Pine, Resin, Black Tea
Jaryllo™	American Dwarf Hop Assoc.	Orange, Grass, Spicy, Fruit, Banana, Pear
Loral™	Hop Breeding Company	Floral, Lemon, Citrus, Pepper, Fruit
Mosaic™	Hop Breeding Company	Papaya, Blueberry, Tangerine, Rose, Bubblegum
Pahto™	Hop Breeding Company	Floral, Earth, Herbal
Palisade™	Yakima Chief Ranches	Floral, Apricot, Grass
Pekko™	American Dwarf Hop Assoc.	Floral, Lemon, Melon, Pineapple, Mint, Pear, Herbal, Cucumber
Sabro™	Hop Breeding Company	Citrus, Tropical, Herbal, Stone Fruit, Coconut
Simcoe™	Yakima Chief Ranches	Citrus, Pine, Passionfruit, Berry, Earth, Bubblegum
Summit™	American Dwarf Hop Assoc.	Grapefruit, Orange, Pepper, Anise, Tangerine, Incense
Warrior™	Yakima Chief Ranches	Resin

Table 3-1: US Grown Proprietary Hop Varietals available through merchant company YCH

The market for craft hops and so called “big-juicies” is, as a rule, reported to be driven by taste and this taste for craft hops and craft beer has been driven by perception of novelty and quality. However, within this framework, one HBC varietal has emerged as a unique force, Citra™ (see figure 3). Developed in 2007, Citra™ is the prototypical “big juicy” varietal. As seen in table 1, it has many hallmark flavors common among US proprietary hops. However, as shown in qualitative empirics, its rise is not the sole result of material novelty, but the combined success of the material and discursive technologies co-produced by farmers who operate breeding and marketing programs in the Yakima Valley. Through the first six years on the market, Citra™

operated as a popular but typical craft beer variety. It was planted as part of diverse portfolio of hops grown on the farm, and until 2013 it accounted for less than 2% of the total acreage of hops grown in Washington state. However, in the last seven years, the increasing popularity of Citra™ in IPA applications and effective marketing of "big juicy" varietals by Yakima Valley hop growers has reshaped the agricultural landscape in the region. It is now the most popular single variety among Washington state growers and accounts for roughly 19% of the region's hop production which accounts for roughly 5% of the globe's hops production (see figure 3). Understanding the links between Citra™'s rise to popularity alongside the otherwise diversified hops growing practices for craft aroma hops reveals a unique market that hinges on local breeding and reveals avenues towards farmer autonomy and profitability through local innovation.

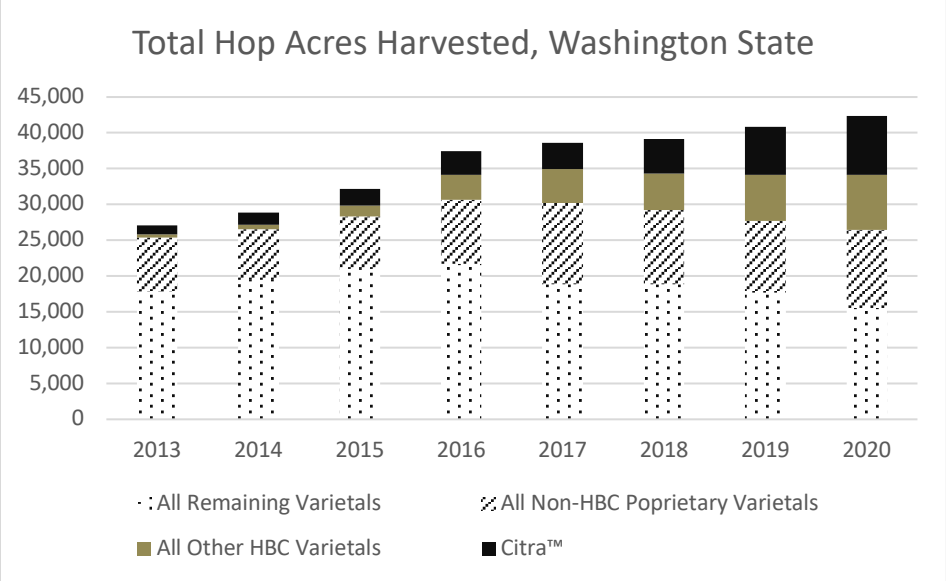

Figure 3-3: Hops harvested by Acre. Citra depicted separately from all other HBC Brands and other proprietary brands. Notably, in market defined by genetic diversity and development, Citra™ is a newcomer and has quickly grown from a ~2% (2013) share of total harvest to a ~19% (2020) share of total hop production. Note the shrinking acreage of open/non-proprietary hops. Retrieved from USDA NASS.

Assembling Citra™: What makes a hop varietal value-able?

> *So our breeding program is partners in a joint venture called Hop Breeding Company. We're [YCH] 50/50 partners with Haas in that. So between YCH and the partnership with Haas and HBC, our brands, as we call them rather than varieties, have access to two of the largest marketing outlets in hops right now. So right now- those brands, they're reaching the market through those two very large markets. So that kind of drives what we're going to plant. Now in terms of what we're going to select, a lot of that is driven by what we perceive as being in demand. Obviously it's going to be driven by basic economic pressures. Whether there's the need for pest resistance, yield, things like that. But then also being driven by what's demanded in the market at the time and whether that be alternatives to existing flavors and aromas in hops or maybe more efficiencies in terms of health of production. Or something new and unique that's never been seen in terms of aromatics and flavor but fits really well with what's in demand. For example, IPAs, hazy IPAs and things like that. [Fred]*

Yakima Valley hops growing has generated a profitable arrangement through the proliferation of hop varieties which are perceived as desirable by craft brewers and drinkers. The production and maintenance of these varietals' desirability hinges on material/genetic innovations. This produces an unusual arrangement where the development of new varieties produces an aesthetic value of novelty, and this novelty is desirable to craft brewers who will pay higher prices for hard-to-find unique hops From a bioeconomic perspective, these varietals do not operate along the same value propositions as typical commodity agriculture. Issues such as scale, size, and efficiency that are paramount in other industries, are subsidiary concerns to taste and perceived

marketability. Because hops are both bred and marketed by farmer owned or farmer driven companies, the methods for breeding are in more flexible and tolerant of unpredictability. Fred is a member of a multi-generation hop farming family and besides being part owner of HBC, he is also the primary operator of the breeding program. Fred Describes their breeding program as characterized by linked efforts of intuition, observation, and patience:

> *[Breeding is] Equal parts art and science. Intuition drives a lot of the breeding effort. Just that inherent knowledge of the plant and then of course, that has to be backed up with solid data analysis, population genetics and so on. Helping you drive the direction you're taking the program. Fred*

In this instance Fred reports HBC to be a flexible program, one that involves plant material, breeder/farmers, and environmental actors in the co-production of new hop varietals. This is reinforced by long-held breeding principles that Fred also ascribes to, such as an emphasis on GBEI. While much of HBC's geographic focus in hops production is a way to delimit total acreage and maintain a profitable ratio between supply and demand, Fred does point out that there is a material function to this action: popular hop varieties like Citra™ are untested in other environments and their quality, resilience, and aesthetic properties in other regions such as humid Michigan are unknown.

Innovation on the hop farm and in hop breeding is a collaborative effort. However, developing new genetics in plant material is informed by multiplied ontological forces. Taste in the form of brewer and drinker demand dictates this arrangement, where value arises from perceptions of novelty, quality, and scarcity rather than quantity.

> *From a breeding standpoint, what's really going to drive that selection is what's in demand at the time and what moves forward. And we really look to the industry to pull*

> *things into the market rather than us having to push them. So that's kind of the philosophy behind that, is to make sure that something's being pulled and we're not trying to force something new in a market that doesn't want it. [Fred]*

In this instance Fred reports that an apparatus of brewers, buyers, and drinkers coalesce to determine what hops are valuable and so HBC and other breeding operations are bringing multiple varieties to market which they as breeders and growers believe will be individually desirable. However, this is also a method of hedging, scaling up varieties which may have short term viability before investing in larger long-term growing operations. Like any perennial, the initial investment to scale, grow, and harvest is high and so this approach does not come without cost.

Demand, though, like all parts of the hop growing value chain is also not monolithic. Hop growers such as Fred are vertically integrated even in the ontological sense. As part owners of hop merchant companies Haas and YCH, they are involved in the production of marketing materials for the hop varietals they select. Producing the discursive world surrounding the genetic material of a particular varietal and the aesthetic outcomes resulting from that varietal. Put differently, they describe their varieties as brands, and this ontological shift produces material outcomes both by maintaining and coproducing the demand for tastes available in a particular variety, and by dictating the material selected, encouraged, and grown in the hop growing world. In this sense, though Fred and other growers with breeding stakes report a level of dependence on the buying market, this report is contradicted by their own large marketing apparatus which while unable to dictate the exact demand trends, has large power to control the discursive worlds surrounding the materials bred, grown, and sold by these farmers. Consider how Fred reports that eventual commercial plantings are entirely market driven, but their synergy

with their directed and co-owned breeding program allows a high degree of influence over that eventual "demand":

> *In terms of deciding which hops to grow, that's driven by demand. It's not something where we sit back and go, we want to grow this just simply out of our desire to grow it. It has to be something that can sell. Particularly meaningful with craft beer being our major target market right now. We're going to grow whatever is in demand for those. We are particularly focusing them on the varieties coming out of our breeding program. [Fred]*

Perhaps no hop has been as successfully marketed as Citra™ whose identity as a "big juicy" hop ideal for craft IPA beer production has become an increasingly fixed point in the quickly changing novel hop landscape. The demand for Citra™ is high among craft brewers and this demonstrates the rebounding effects of this vertical integration. A sort of feedback loop results: successful marketing and breeding of Citra™ produces demand by brewers that dictates what gets selected for larger plantings by both Fred and for the direction of future experimental varieties in their program and this material shift then rebounds throughout the Yakima Valley. Growers with breeding operations that have been successful, but less so than HBC are obligated to respond to these changing demand dynamics as well:

> *[ADHA was focused on] Lowering operational costs specifically so we could keep up with China. So we embarked on that whole journey. We had one of the only and largest block of low-trellis hop production. The variety we were growing on that came out of the breeding program…we pulled it all down to put up high-trellis. Now it's all Citra. [George]*

HBC's marketing of Citra™ has been enormously successful. And that has allowed its unprecedented growth, those with access to doing business with YCH and Haas inc. have switched models, George reports that they used to plant dwarf hop varietals from their own breeding program and operate as their own merchant. However, contracts with YCH or HAAS are required for growers to have access to Citra™ and other popular YCR and HBC hop varietals and this has required them to contract a majority of their annual hop sales through Haas or YCH. They report this change in the landscape and their hop varietal portfolio:

> *Two years ago we were probably 80 customers and 80% of our product going over our sales desk. Now we've shifted that to probably 70% or 60% or 70-some percent merchant and the remainder over our sales desk. That's because we didn't have access to—we couldn't grow and sell the genetics that were the most popular in the industry, being Citra. So if we were only bound to our grow/sell model that we were accustomed to then we were going to cut ourselves off from a huge potential market. [George]*

In this model of hops cultivation proliferation is key, however, according to growers such as George, the arrangement that results actually produces remarkably rigid hierarchies of in- and ex-clusions centering around only a small selection of the wide range of available novel "big juicy" hop varieties. Citra™ and the HBC catalogue are at the center of this aesthetic hierarchy and their efforts concentrate wealth among this small group of farm owners by pursuing too seemingly contradictory ontological goals in their genetic innovation and breeding: to develop the stability and aesthetic demand for existent hop varietals as well as to proliferate and produce both additional novel varieties and the demand for those new hops.

From Citra™ to Sabro™: Proliferation of brands and the future of the hop-genetic marketplace

While Citra™ has been enormously successful over the last seven years, how long Citra™ will maintain market dominance in the brewing industry remains a question, and the process by which Citra™ was brought to market relies on concepts of novelty, taste, and quick development cycles. The production of new varieties has remained an important component of HBC's business model and considering the relationship between Citra™ and more novel hop development reveals insights into the relationship between innovation and ontologies of value in hops growing and selling. Particularly, considering Sabro™ reveals the particular human-nonhuman character of the hop-breeding/hop-growing system.

> *So last year we officially released Sabro™. …The variety is HPC438. The brand we're selling is Sabro™. So we released that last year as a commercial variety, but it had gone through a number of years of testing. In fact, I made the cross for Sabro™ in 2004.It was a cross of a wild neomexicanus plant that was given to me. Humulus lupulus neomexicanus is a taxonomic variety native primarily to the Western US. But anyways, it was given to me by my mentor and predecessor. It was in our breeding plots and I decided to cross on to it one year and then got these resulting progeny from that. The male I do not know actually, because what I did was I took a collection of pollen from our top males, mixed it and pollinated the females. [Fred]*

(Carolan, 2007; Comi, 2019). Sabro™ is an example of human/plant co-production and the resulting technology is both discursive (a brand) and material (a set of predictable chemical compounds produced by a hop cone). In this statement, Fred reveals two key components to hop-growers approach to genetic innovation. Fred clarifies that these growers rely on complex

relationships with plants to co-produce new genetics and therefore to retain value in the hop growing industry. Second, it points out that this process is variable and expansive, and therefore the selection of future commercialized varieties is reliant on discursive and ontological practices of control (branding) which happen continuously. HBC produces a diverse genetic catalogue, and guided by previous successes they experiment to coproduce in-demand aesthetic outcomes.

The chemical/material makeup of Sabro™ is as important as its unusual origin in the branding and marketing of this varietal. The proliferation of varietals is both an effort to continue to produce more valuable and expensive hop material as well as to secure against demand changes should popular varieties such as Citra™ be displaced. HBC's method for making value and meaning within the craft hop market is self-reproducing, and continued experimentation with popular varieties create new outcomes, such as Talus™ a recent HBC experimental variety arising from Sabro™ cross which will be available to the market for the first time in 2020. This technique for genetic innovation requires the production and maintenance of wide catalogue of hop materials and this material alongside strobile samples are preserved in cold storage both for the production of future crosses and to preserve potential re-plantings should desirability in the market shift to match already existent crosses in the HBC program (see figure 4).

Figure 3-4: Cold storage HBC varietals, each trash bag is filled with pressed 'bricks' of test hop varieties to preserve some aroma quality. Less than 1% of these varieties will eventually be scaled to commercial production.

Sabro™ shows the importance of this branding effort and their vital need for vertical integration along the hop growing and breeding value chain. Fred Reports that:

> *I would consider us very vertically integrated. My dad, along with [other farmers], started what is now both Yakima Chief Hops and Yakima Chief Ranches. Yakima Chief Ranches of course, was the breeding side supplying the varieties into the supply chain. And YCH being that connection directly to the brewers. So being founding members in both those companies, yeah, we definitely have vertically integrated across that entire value chain.* [Fred]

This integration allows them to set the ontological bounds for new hop materiality. Descriptions of Sabro™ for brewers also rely on the narrative Fred told to me: emphasizing the novel origins

of an unlikely cross between a *neomexicanus* variety, and that this unlikely pairing has produced novel results: linking aesthetic/taste components of the hop strobile in beer making applications to is unusual origin.

While Fred reports their involvement at multiple levels of the value chain as a simple function of vertical integration. This explanation, however, does not account for the way this vertical integration results in these multiple kinds of intersecting innovations, and bioeconomic interventions. Material, discursive, and ontological shifts about what hop material is, how it can be valued, and how it will be described in the market are influenced by these farmer owners. However, HBC's varietals are not equally diffuse throughout the market, and the predominant value of a handful of varieties (HBC and otherwise) are reported by many farmers to be key market drivers that are only obfuscated by the "noise" of novel varieties. George operates the largest acreage hop farm in Yakima and is part-owner of a breeding program ADHA, and when asked about their plantings and trends in hop varieties they report:

> *The demand trend has been for the last 5-6 years is anything I can get and shove into an IPA but its been greatly rooted in Cascade, Centennial, Citra™, and Mosaic™ probably. And then there's been variations of that but those are the drivers. Mostly because Cascade and Centennial have been around the longest and they're kind of what hops earlier homebrewers used and earlier craft brewers used. Then Citra™ and Mosaic™ because they were something new that were sitting there ready when the thing took off. So a lot of the recipes that were driving the industry, driving the growth were based off those 4 varieties…I consider a lot of this other noise around new varieties just noise when the main drivers have been Cascade, Centennial, Citra™, Mosaic™, and maybe a*

few others, Simcoe™ um. But really that's the bulk of it and people will use CTZ [Columbus/Tomahawk/Zeus] on the bittering side of things. [George]

This report contravenes the attitudes of proliferation described by Fred and many other breeders and growers in the US. It reveals that tension between ontologies about hop varietals at different levels of the value chain and within grower populations remain despite the small number of growers and the tight vertical integration of large-scale Yakima Valley hop growers. Further, it shows that hop material and its meanings remain contested spaces in hop growing and the dominance of Citra™ while it may be temporary remains stable largely because of continuous ontological fixing originating with growers decisions to plant greater acreage and their marketing decisions to continue to promote its value and primacy in the craft brew assemblage.

In/exclusions in the "big juicy" value chain

While genetic diversity in hops has increased and adaptive capacity increased as a result, it has not produced fully equitable value chains or truly diverse plantings. What actually results from these multiple farmer-driven innovations in the co-production and branding of novel hop varietals in the craft hop growing regime and what lessons can be gleaned for interventions in other kinds of agriculture? Three key considerations complicate the otherwise positive environmental outcomes of farmer-driven breeding in the hop growing industry and the (in)equitable ways value is shared in the hop growing assemblage: 1) access to the largest portion of the most popular varieties is delimited to a small number of owners and licensed growers which concentrates earnings and expands exclusions 2) many growers with large operations rely on other avenues for producing novelty or on single varietals in the absence of breeding programs and 3) value accrued by farm owners and managers in hops growing has generally resulted in marginally better labor conditions but labor remains an inequitable partner

receiving little compensation and remain targeted for reductions by innovation to reduce 'inefficiencies.'

Access to varieties is based on scale and geography with almost the entirety of YCH and Haas contracts in Washington, and smaller contracts in Oregon and Idaho. Michigan is the largest hop producing state outside of the US Northwest and a manager for a local operations in Iowa described the challenges they face marketing their hops in local contexts because of the inaccessibility of popular genetics:

> Oh, absolutely. I mean, Citra™, you know? Like, I love a Citra™ beer, but we can't grow Citra™, we can't grow Mosaic™, we can't grow Amarillo™… and, you know we're starting to see some other options like from Great Lakes Hops having Mackinaw and some of these other ones, but we're still not going to have the marketing behind those that Simcoe™ does, you know what I mean, and some of those others, so I think that is certainly a challenge. [Karly]

Value produced by the ontological changes about hops have enriched Yakima-area farmers and produced incremental gains in adaptive capacity and farmer agency but their efforts to maintain these profits exclude farmers of smaller scale and outside this geography from accessing these same gains. With less developed marketing infrastructure, these growers and their grower-associations have attempted to mimic Yakima's vertical integration and ontological/material shifts in their own hops production, such as Michigan's Mackinaw variety, which is meant to compete with Yakima growers' "big juicy" varieties. But without the powerful branding action of Yakima's merchant companies, Michigan growers struggle to communicate this hop material's like chemical compounds to brewers interested in Yakima Brands.

For large Yakima Valley growers, not having a breeding program doesn't preclude farmers from success. Many farmers face slightly lower levels of earnings but are able to turn significant profits simply by contracting to grow YCH and Haas varietals. Within this model, there are further exceptions as well: Norman operates one of the largest hop farms in Yakima, and they have a fairly strong program surrounding a patented varietal they've grown on their farm for the last decade developed from farm-driven crosses but without a robust breeding program. Though single farm origin crosses are not uncommon in the US and especially elsewhere, their model is unusual because it relies heavily on their ability to grow a single reasonably popular variety Amarillo™. In order to gain security and to remain agile in an unpredictable industry, they diversify and experiment. They access and experiment with novel hop varietals for the craft beer vanguard but they do it using public repositories and seek non-commercial varieties that could be scaled up and grown effectively.

> *Yeah, I look at our portfolio and what people are trying to create and I go through and I try to find the best version. The best hop that would deliver that. That already exists, because I don't have a breeding program. I'm not looking for it by combining DNA I'm looking for it by looking through the germplasm repositories and seeing what already exists. [Norman]*

Value produced in this novel bioeconomic arrangement is not readily shared with smaller farmers or farmers outside of Washington, Idaho, and Oregon, which maintains both a scalar and regional dominance over the hops marketplace, made more complete by their control over the most popular and profitable varieties in the global hops marketplace. Value is also not equally shared with labor. The reduction of which remains a central consideration in the innovation of implements and the proliferation of new varietals. Jeff is a co-manager and co-owner of a large

operation. Their labor practices are unusually equitable for the larger ag industry, resembling what would be considered normal in many other workplaces: requiring applications, documenting worker assignments, and providing actual HR support for workplace safety complaint. They see this as investment but even they see labor as part of wider set of issues subject to changes based on finding regulatory and financially efficient 'solutions.' When asked about labor on the farm more broadly, Jeff reported:

> *There's multiple issues and it's a constant endeavor I think in any industry, but ag's kind of been highlighted in the past. So just recently we've got there's several state bills right now that we're facing. Further taxation on waste use and whatnot. And then we conform by workplace safety issues, not only just for OSHA, but also for migrant farm workers. There's a whole other set of rules that L-and-I sets forth. And in that there's notifications that you have to give to employees…There's farm labor contractor issues that come into play with H2A program. There's a whole other set of issues from Department of Labor. There's several different entities that monitor that. Like any industry, it's heavily regulated…Which is fine but it's just another thing that you have to look at as far as employment. [Jeff]*

When examining the (in)equitable distribution of value within the novel hop growing arrangement it remains clear that labor remains excluded from the lions share of earnings and targeted for further remediation by increasing levels of automation. However, unlike fruit industries in the Yakima Valley and elsewhere in the US, the immediacy of value gains from genetic proliferation and ontological branding has taken pre-eminence and the demand for "quality" hops in this changing industry has increased the demand for quality agricultural

laborers, generally improving (marginally) the quality and conditions of hop farm labor by comparison to the low quality conditions in neighboring fruit operations.

Conclusion and Further Research

The co-production the "big juicy" hop along with Citra™ specifically and the resulting big juicy hop value chain has lessons for a range of agricultural goods produced in the US and elsewhere alongside critically engaged inquiry on agriculture, innovation, and technology. First, this mode reveals that farmer direction in farm-level innovation or applied science results in different bioeconomic arrangements than in innovation or applied science that results from input companies or other outside financial actors. In the instance of hop growers, farmer-driven science is revealed to be more collaborative, flexible, and adaptive from social, material, and environmental standpoints and this increases the resilience of the agri-food assemblage that results. This result, however, does not contravene an overarching neoliberal tendency to fix genetic meanings and concentrate wealth amongst early-adopters in agriculture.

In the case of hop growers early adoption is further constrained by the tight control these few farmers have over *who adopts* these new genetics and how these new genetics are considered. While onerous legal control and fixed meanings for vibrant plant genetics has become commonplace in US agro-chemical industries (Aoki, 2008; Carolan, 2008; Kloppenburg, 1988) genetic branding has generally been restricted to specific traits and interactions, such as the popular Agrow-Dekalb RoundupReady 2 Xtend® soy beans (Comi, 2019). The complex qualities encapsulated in the discursive technology of a hop brand is a far more holistic encapsulation. Instead of attempting to fix trait-level identities such as herbicide resistance, hop breeders use brands to ontologically contain ideas about the lineage, character, and aesthetic properties of a particular hop, which is further controlled by that hop's specific growing region.

Innovation in hop breeding materiality has required innovation in the ontological practice of branding and its interaction with vibrant, living matter. This practice has shown how farmer-driven innovation successfully relocates power, financial sustainability, and adaptive capacity with innovating farmers. However, it also shows how ontological control over genetic technologies continue to strain relationships in the agri-environmental assemblage and delimit the possibility for more socially and environmentally just outcomes.

Further research is required into international contexts where Yakima hop growers and breeders impact is more diffuse and less totalizing than in a US context. A history of vibrant hop breeding has been successful in smaller markets especially in southern hemisphere contexts like New Zealand, Australia, and South Africa. To better understand the impact Yakima hop growers have on the global hops industry a comparative qualitative assessment of these grower/breeder operations would be required. Understanding the situated context of Yakima in a global context would help to illuminate the extent to which co-production and farmer driven innovation in particular localities affects the ontological and material worlds elsewhere in the globe, an effect which would have important lessons for other agricultural practices. Despite distinct and problematic inequities in the distribution of earnings in the hops growing industry, this inquiry into the innovative practices of US hop farmers and their co-production of novel hop varieties reveals an agriculture with greater adaptive capacity and higher farmer earnings than many other cognate industries. This in turn has distinct lessons for scholars and policymakers aiming to produce more autonomous farming classes and more sustainable farming practices in the 21st century.

4. Farmers who tinker: Alternatives to Incrementalism and the Growth Imperative

Introduction

Technological innovation in agriculture over the last half century has become a contested and politicized domain that, when directed by large agri-chemical and pharmaceutical organizations, has been shown to often produce environmental and social harms in pursuit of immediate gains in productive capacity (Bronson, 2015; Esteva, 1996; Jasanoff, 2007; Kloppenburg, 1988). However, gains in farmer-autonomy and involvement of large farmers as directors of breeding programs and other technology innovations has resulted in case-specific incremental gains in environmental adaptive capacity and farmer profitability (Comi, 2020d; P. V. Stock et al., 2014). Hop growers in the Yakima Valley are one such group that have directed their own breeding programs and produced a more profitable and environmentally sustainable model for an agriculture of scale in their region. However, this change has also had rebounding impacts on an industry that was previously dominated by small, low-earning farms obliged to sell on the commodity market. While this new arrangement has many benefits, hop farmers' innovation show that farmer directed involvement does not contravene many of the problematics involved in the neoliberal marketplace, most notably, farmer innovation in hop growing has exaggerated the already-dominant growth imperative in US agriculture.

Within this landscape, a small group of medium-size hop farmers and small-to-very-small growers contravene this trend. Studying this group is a lesson in diversity of farming operations. In my results I examine the governing values and material relations of a variety of these farms, specifically, I examine how medium size farms "tinker" with hop material and emphasize alternative values in the resulting hops to increase profitability on a hop market governed by novelty and aesthetic value. I also examine small farms, who negotiate local relationships to

carve out niche opportunities in a brewing segment with commitments to sustainability and locality. The resulting study fuses theoretical traditions of food and culture, and materialist traditions drawing on science and technology studies to describe how these tinkering framers rethink their agri-environmental worlds and re-value the materials they interact with to produce new farming opportunities that don't emphasize growth do result in the opportunity for improvements to environmental justice outcomes.

Background

Tinkering: Small Scall Innovation not Incrementalism

Tinkering is a direct, social engagement in the material world to produce more beneficial outcomes for the tinkerer. Tinkering is also an act of care (Mol et al., 2010; Winance, 2010). Tinkering is improvisational, local, specific, and necessarily small. Tinkering involves paired social and material interventions into the immediate technologies and arrangements with whom stakeholders (both humans and nonhumans) interact (Donati, 2019). This process is relational and involves direct relationships between implements, technologies, plants, and other materials involved in the farm in the production of food and other agri-environmental outcomes and externalities (Alarcon et al., 2020). One central component of tinkering relationships is that plants and other actors involved in agriculture are the recipients of *care* and that *care* is produced by both affective and material action. This socio-material arrangement of care is the subject of widening discourse in agri-food studies on how care in agriculture settings (re)produces new outcomes and possibilities (Alarcon et al., 2020; Stock, 2016). This idea explains how positive outcomes from agriculture, including rural/agricultural pleasure, enjoyment, health outcomes,

and autonomy are possible for farmers, human rural inhabitants, and a variety of nonhumans including plants and animals (Donati, 2019; Stock & Forney, 2014).

This study borrows the concept of tinkering to explain how socio-material *assemblages* of agriculture may be engaged with by people (e.g. farmers) in ways that do (or do not) support more sustainable or environmentally just outcomes. Assemblages are sets of socio-material relationships that reproduce outcomes—they are flat and messy hierarchies that eschew traditional social science categorical domains (Deleuze & Guattari, 1987; Müller, 2015). When the farmers of this study are shown to *tinker* they are improvising new material arrangements for the farms and markets with which they interact. By revising how they trellis, or whether they cover-crop, or by finding and saving wild hop bines, or building their own hop picker, they are introducing and modifying the material actors in the agri-environmental assemblage and reshaping the relationships in their specific agricultural assemblage. This directive work involves care-level decisions—obliging farmers to make directive technical interventions based on their values (Alarcon et al., 2020). This idea has implications for other social science research on small farming operations, such as on grape growers for wine operations, who also have the freedom to improvise novel engagements with plant material on the farm (Alarcon et al., 2020; Parga Dans et al., 2019). It is not necessarily true the large farmers *cannot tinker* and some of the farmers in this study do have fairly sizable operations. Rather, small farmers who lack systematic autonomy are more able to tinker, and reshape the material arrangements in direct, *care-ful,* and improvisational ways with greater consistency and success.

This draws on a range of literature that examine farmers as actors in diverse sociomaterial landscapes who are engaged in (re)arranging assemblages of agriculture to produce new outcomes, possibilities, and futures (Carolan, 2008; Darnhofer, 2020; Goodman, 2001). For

example, Carolan's work comparing the ontological and material worlds of seed banks to the Seed Savers Exchange in Decorah, IA reveals how diverging ontologies over what seeds are and how one should interact with them produces dynamic and alternate agri-environmental futures. Notably, by recognizing that other materials are active in the system, the Seed Savers Exchanges collaborates with their own seed stock, maintaining lineages of seeds that are planted and replanted—undergoing subtle genetic variation that continues to adapt and respond to a range of environmental actors. Tinkerers on the farm are like the Seed Savers Exchange, engaging with other actors on the farm but these farmers are either unable or opt not to engage in politics of control within the agri-environmental assemblage.

Tinkering as applied to farmer-innovators also pushes forward a small but important thread of literature on farmer-inventors and farmer innovators. Very little work has been done on the politics of farmer driven innovation but what little there is shows that scientific communities and agri-business interests have responded hostilely to the innovations and open-source ethos of many farmer-inventors (Carolan, 2017a; O'Flynn et al., 2018; Shutes, 2003). Tinkerers are not always systematic, drawing inputs and resources from heterodox sources. At times this means tinkerers draw on natural and applied plant science, but at other times improvisation and *en situ* knowledge prevails—meaning that the innovations of specific tinkering farmers as described in this article have not been widely adopted as standard practice and are unlikely to be adopted as standard practices—this is partially the point of tinkering solutions though—to produce situated and heterogenous solutions to particular problems through mobile and grassroots innovation instead of top-down governance.

The arrangement of tinkering contrasts with the material/social/economic arrangements indicative of neoliberalism. The latter flexibly takes up materials, commodifies those materials

and translates their value into a range of social worlds (Carolan, 2017b; Centeno & Cohen, 2012; Stock et al., 2014). It is well known, that as with capitalist structures, this neo-liberal model results in a growth imperative that emphasizes unsustainable economic expansion and material extraction (Moore, 2017). This differentiation from a technocratic capital-focused approach to innovative systems changes sets tinkering approaches apart from the more top-down biological innovations imagined by eco-modernists over the last three decades (Asafu-Adjaye et al., 2015; Spaargaren, Gert & Mol, 1992). Instead of a theory for innovating our way out of ecological disaster, I suggest that tinkering shows how grassroots and grounded innovation developed by and for farmers and other stakeholders can be a useful "tool in the toolbelt" when considering suites of policy and social alternatives for more just futures. Put differently, tinkering is one improvisational and immediate way that more sustainable futures may be possible as part of a diverse and heterodox field of innovations that encourage a more just future.

To better situate how tinkering contributes to a range of approaches for considering and working toward more socio-ecologically equal and sustainable futures I place this concept in relation to two key responses to our current environmental and agricultural crisis—a focus on environmental justice with the goal of direct remediation of unjust distribution of environmental harms (Pellow, 2017; Reed & George, 2011; Taylor, 2000) alongside a diverse discourse on growth imperative alternatives which take a variety of approaches to rethink or ecologize economic futures (Callon, 2015; Kallis & March, 2015). Further, as shown in Stock and Szrot's (2020) theoretical exploration of justice in agri-food contexts, care, whether conceptualized as stewardship or through directive action, is an integral component in the development of more just and inclusive agri-environmental arrangements.

Environmental justice scholarship accounts for the vast disparity in environmental harms that remain/accelerate in our neoliberal world regime (Chiro, 2008; Pellow, 2017). Ideas of resistance, movements, coalition building and just transitions are key considerations in EJ framework (Chiro, 2008). This brand of social science consideration looks for just transitions, and in this way, EJ is a close cousin of de-growth scholarship, which seeks to solve the problem of neoliberalism's unsustainable growth imperative. Seeing how small farmers tinker with inputs to make ends meet demonstrate a formal resistance to growth-imperative agriculture and so far as these farmers succeed lessons can be drawn for other agricultural settings. Just transitions in agriculture require inventive rethinking of the agri-environmental arrangements and if farmers who tinker are able to become fiscally sustainable their improvisational approach to reshaping the socio-technical landscape of local markets and agriculture techniques could be instructive for the formation of more just and sustainable agricultural futures.

Departing from the trend, differentiating kinds of hop farms in the US

Hop farms in a global sense are in flux, and in the US the rapid concentration of hop farms is no such exception (Comi, 2020d; Cordle, 2011). Calling one kind of hop farming a norm is a contested and political statement. For the purposes of this paper, I look at hop farmers who depart from a major trend toward concentration and growth in the US in some sense. Because a small number of farmers are responsible for this large amount of production in the US, I avoid referring to these growers as the norm. Rather I consider this as a trend towards concentration in farming operations and plantation style agriculture techniques. Those who grow small farms are necessarily *resisting* a marketplace increasingly concentrated into fewer growers' hands.

While over 70 operations report area harvested for hops, only fifty-two growers are registered with the Washington Hop Growers Commission and large growers estimate that less than forty farmers make up over 90% of the state's total production, which accounts for upwards of 70% of the total annual US output by acreage (USDA NASS, 2020). Other states reflect this trend, with large growers in Idaho and Michigan reporting that less than nine and only two large operations make up the lions-share of those states' production respectively. Many of these small reporting operations are relatively young, for example, in Washington state, less than forty operations were reporting hop acres cultivated in 2003 (USDA NASS, 2020). Every small operation (<10 acres) interviewed during this study was less than ten years old. Because of their short tenure in the growing community, evidence of long-term viability/sustainability is difficult to assess. However, how these young and small growers engage with (re)imagining local hop foodways and market value remain an interesting case example in searching for sustainability as a small farmer.

Large hop growers in the US have pressured the global hop marketplace of growers to re-assess historically conventional growing models. Yakima Valley growers have concentrated not just the acreage of their farms, but have tended towards vertical integration—with many growers having ownership stakes in hop breeding or hop merchant companies (Comi, 2020d). This allows these large farmers to exert a remarkable amount of power over the hop material that gets selected at the research and development stage alongside the eventual hop flowers that are selected at the brewer side. The large marketing apparatuses controlled by these large farmers help identify and define the chemical compounds which brewers use to assess flavor and offer the qualitative tasting assessments along with harvest-season farm visits to promote new varietals, concentrate interest in large-acreage and profitable varieties, and to reduce and divert

interest from varieties which these growers feel have become redundant, underproductive, or less worthwhile than other hops.

Methods

This project uses mixed qualitative methods including on-site interviews which include on-farm participant observation (n=16) who identify as (one of) the primary decision maker(s) for hop growing operations. Further research using distance methods due to covid-19 targeted key stakeholders in other markets outside of Yakima (n=6). These participants' inclusion was limited to interviews only because of health concerns. Because these operations range in size and scope, these individuals were usually either owners or employed/contract hop-yard managers (or both). Data collected from these participants include interview transcripts, field-notes, and photographs. This group of participants includes a significant segment (n=14) of hop growers in the largest hop growing region of the US, the Yakima Valley, where roughly 40 large growers produce over 30 percent of the globe's total annual hops-by-acre. This inquiry, however, relies primarily on the diverging experiences of outlying participants (n=9) who do not grow in this region and/or whose methods do not conform to the prevailing model for hops growing as laid out in recent research on the contemporary hop-growing industry (Comi, 2020d). I take an exploratory approach to this data that emphasizes *gathering* over *sorting* (Law, 2004) and aims to describe the multiplicity of socio-material arrangements outlined by these farmers' experiences.

Findings

These findings are reported in three sections. In section 4.1 I outline how small farmers tinker with their infrastructure, tools, and implements—I show how these ultimately technical engagements with material actors re-shape outcomes for these farmers and result in a wider range of financial autonomy. In section 4.2 I outline how small and medium farmers tinker by identifying, describing, and re-imagining the meanings of wild, found hop varieties and use this to produce a market niche with brewers. This action is compared to the programmatic farmer driven breeding programs of large Yakima growers, such as Hop Breeding Company (HBC) and is shown to be a useful example of plant-human tinkering relationships. Building on section 4.2 I outline how medium size farmers in the Northwest and some large farms are engaged with rethinking how plants and agro-ecosystem health is assessed. Using the case example of Sap Analysis, a newly popular technique that is growing in popularity among a small group of hop growers as an alternative to petiole analysis, farmers try to more responsively adjust soil nutrition. I show how Sap Analysis operates as yet another plant-human tinkering relationship that results in more beneficial agri-environmental outcomes.

When you can't afford a hop picker you build one: Tinkering on a tiny farm

Tinkering is a complex and multifaceted task. It involves improvising with the material world in a collaborative way: responding to immediate problems to care for the participants that surround you. One of the most obvious ways that small farmers in this study *tinker* is through modifying, building, and re-thinking the on-farm implements and infrastructure required for hop growing. Because hop growing infrastructure is expensive both as an initial investment and in continued petroleum costs, small hop farmers can accrue significant financial benefits by identifying and pursuing alternative infrastructure solutions. This has led some small hop farmers

to DIY solutions for otherwise expensive materials. Patrick for example, is starting a small two-acre operation in Eastern Washington, outside of the primary Yakima Valley growing region. Without a real deal on a used hop picker available to him, he found the pricing of new pickers or competitively priced out-of-town used pickers to be unsustainable financially. Instead, he opted to build his own picker (see figure 4-1)—an approach he's used with much of his infrastructure from his micro-kiln to his home modified pelletizer and harvesting stand.

Figure 4-1: Homemade Hop Picker, Patrick removes plywood cover to show interior picking teeth and belt mechanisms. Manufactured hop pickers for 10 acres or less often cost ~$10000 and up. Patrick Reports building this picker for less than $1500.

Tinkering also involves the repurposing of other goods—as with Patrick's operation, startup costs are a large inhibiting factor for other small growers, Hannah and Jason address

some of this startup cost issue by forgoing telephone pole trellising and logging their own trellis (see figure 4-2). Hannah and Jason did not rely on home built implements like Patrick, and were able to find inexpensive pelletizer and contract picking services. This mirrors Levi who also found secondhand small hop equipment for well below the market value. For all three of these growers, one key commonality is that the hop field is not currently their primary source of income. Patrick and Cheryl envision their hop field as a retirement hobby. Turning a profit is important, but only as subsidiary income—Patrick notes that if they don't turn a profit in 5 years he plans to quit.,

> I think for at least five years and if we can't make a profit I'm going to sell it or lease it, because my back's starting to go bad and I don't have [good] health. It's so painful. I can't explain how painful it is to go out [crosstalk 00:16:01] back and do that stuff that has to be done and I'm not getting it all done, but it's starting to happen. It's slowly coming and people find out about you slowly. And it takes three years for the hop to be matured in the first place. So last year was our third year and we had our first sales. [Patrick]

Floyd also operates a brewery and fruit farm which are both profitable, and their hops operate as brewery-supporting experiment more than a particularly profitable endeavor. Hannah and Jason do claim they hope for this to become primary part of their income, but this remains aspirational. Like many small growers there is a time limit on this endeavor and each of these three operations face significant obstacles to achieve their goal of long-term sustainability. This is particularly true as they try to responsively adapt to market demands for the local brewers they seek to supply.

Figure 4-2: Trellis made from unfinished, felled lumber. This row of hops is a "wild" variety found in the Palouse Hills and propagated by the growers Hannah and Jason.

For these small farms, tinkering with infrastructure is a method to provide locals goods at a low cost. This responsive involvement on the farm is a method for being able to provide responsive market-service arrangements. Many small growers see their niche as being able to provide a high level of service to local small brewers that don't have access to direct-to-grower contracts elsewhere in Yakima or high levels of influence over merchant company sales desks.

> One of the biggest things was with the brewers here, they're smaller brewers, right? So one of them had a contract with Yakima. They're the only big enough to do that. So the other ones just buy on the spot market. They don't always get what they want and that's kind of what triggered a lot of this too. One of the brewers

> said he ordered something, he was going to Yakima to pick it up. And they called him when he was driving there and said, "We don't have your hop anymore. We have this one if you want that." And I go, "Aren't you guys... You kind of base your beers off what kind of hops you're getting, right?" And he was like, "Well yeah." And I said, "So you really get dumped on, you get hops, whatever you can get." And they're like, "Yeah, that's how it is." I said, "So what if we grow you what you want every year on a smaller scale?" [Hannah]

By building small these growers aspire to offer a more flexible kind of growing arrangements. However, these small growers continue to face difficulties arising from high labor and financial costs associated with perennial plants even after accounting for cost-lowering with tinkering solutions. Additionally, while they may be responsive in many ways to local growers' needs, they struggle to produce desirable hops for the ever changing craft-beer marketplace. This requires a second kind of tinkering, one that occurs with and between members of the agri-environmental landscape as well as at the mechanical and technological level.

Finding Free Hops and New Soil: Tinkering with what you grow on small and medium farms

> *We're competing against fifth and sixth-generation farms that have been growing since the Civil War and things like that. So, although we can't match them on price, we're trying to figure out other ways that we can stand out or be alluring. Yeah. I mean, we're really focusing on our brand, all of our graphic design work, and then trying to figure out different ways that we can offer our products. So, the Kanook rebranding, which people do the same thing in Michigan, they call it Michigan Chinook or whatever, but for us, the biggest issue was not wanting to grow something and then delivering it to a brewer thinking that they were going to get traditional Chinook, so we just put a little twist on it just to kind of display that it's a little bit different when grown here in Kansas.(Wade)*

Large farms in the Yakima valley control over 70% of US hop acres and are both historical hop growing entities and at the vanguard of hop growing trends and new techniques in the industry (Comi, 2020d; Larsen, 2016). How to compete against these vertically integrated growers who also involve themselves in the co-production of taste and desirability in the brewing industry is a vital problem for small, local, and/or emerging growers trying to carve a niche in an industry transitioning from conventional commodity dynamics to craft desirability dynamics. Wade responds to this by seeking novel hop varieties and by rebranding public varieties. He describes that regional differences between the US Midwest and US Northwest produces predictable variations in the aroma profiles of other varieties, especially the popular public variety Chinook. Like big brewers and breeders who simultaneously produce a brand along with a new genetic profile, this small brewer skips over new genetic profile and instead uses branding to make a compact container for local, unique hop aroma profiles singular to their isolated midwestern hop farm—a variety they call Kanook™ (a contraction of Chinook and Kansas).

This farm has likewise explored unique public varieties such as Southern Brewer and wild Neomexicanus varieties (which are the source of many popular new aroma varieties, such as HBC's recent release of Sabro™).

> Okay. So, Southern Brewer…was a pretty low-yielding plant…we decided to rip that out after, I think, three years. Then the other Neomexicanus varieties, native to the Southwestern United States, mostly grown in New Mexico, kind of at really high elevations, 7,000 or 8,000 feet, traditionally found growing in the wild kind of alongside creek beds. So, obviously, here in Kansas, completely different growing environment, much lower latitude, heavy clay soils here, and tried to do that for about three years, two or three years on those, got some really cool harsh

> citrus notes out of those varieties. One was more kind of lemon-lime. The other one was more like orange and grapefruit. Just the same as the Southern Brewer, it just didn't yield very well…From an agronomic standpoint, they were really hard to grow for us, so ended up pulling those out as well. [Wade]

Unique soil qualities and regional differentiation produces obstacles as well as opportunities. It foreclosed this Midwestern farmer from accessing a genetic lineage of wild hops that has been a profitable avenue for other growers seeking fruity flavors in their hop output that are desirable for craft beer applications. It also produces potential benefits. The branding of Kanook is in many ways a way to tinker with the wide and complex interaction of soil chemistries and plants to quantify the resulting flavor, or terroir. This practice is common among many local growers seeking to carve out a niche in the craft beer market whose demand for hops is often linked to novelty and flavor compounds more than locality or regionalism.

> Hannah: It's a low soil. We've dug down five feet and we haven't hit a rock yet. So we have just... It's pure soil, no rock, very filled with nutrients. I mean it's a good quality soil and I think that's what Walla Walla is touted for. It's well known for our soil here.
>
> Jason: Yeah, that's our slogan. It's all about the dirt. That's kind of what we're setting ourselves apart from Yakima in our soil is...
>
> Hannah: And with the soil and stuff, we're hoping we get to see a little... Everybody touts the grapes and the terroir where they're growing this stuff. So I've read a couple articles on... People have written about the hops in terroir and so we're hoping we get to see a little different results from our area than other

people do. And even in our, I believe it's in Tettnang, we had some higher alpha readings then what's normal.

This husband-and-wife operation seeks to maintain relationships with local brewers in a way that mimics Southeast Washington's relationships between vineyards and vintners. These relationships are more tightly connected than hop growers are to individual beer makers. Often growers may also be wine makers and in cases where growers contract with wine makers the relationships are often more tightly maintained and long term. This is somewhat more intuitive in an industry where taste is culturally linked to terroir, tradition, and consistency more than novelty—as the hops industry has become over the last ten years of craft beer innovation and growth. Hannah and Jason seek to alter this trend in a local sense—tinkering both with what genetic lineages they plant and with the market-end relationships they sell to by investing in this sense of terroir and by identifying novel ways of integrating brewer investment in the farming operation, borrowing in this case from agritourism and winery contracts to market brewers' local investment in small hop growing operations

Hannah: I'll always give you [the brewers] what you want. And so that's kind of how that all start too. So end of the day brewers picked out what we planted.

Jason: Well, and it's similar in the vineyards, the wineries will have their name on a row. And so granted, we're not big enough to have a name of a brewery for a whole row.

Hannah: Well that's our plan.

Jason: Yeah, they know that that's theirs.

Hannah: One row is going to go to two breweries, we'll have both their names on the post. So all our posts will eventually have all the breweries...

> Jason: And they can come out anytime and check on them
>
> Hannah: Yeah, because they want to come out too so they can bring people and be like, "Hey, here's our rows and here's our..." That's how the vines are treated in the wine scene. And everybody loves that. So I want to do that and it's not done anywhere else that we know of, so.

Tinkering with what you grow is in many ways the simplest kind of on farm modification a grower can make—but in this case the practice is complex. Small growers are tasked with something of an impossible demand—taste drives the craft beer hop selection process and unlike wine grapes where taste is assessed by long-held ideals about quality that largely center on history, consistency, and terroir—hops are assessed for novelty, creativity, and rarity. This approach which favors either the trendy popularity of well-known new varieties or the cachet of novel relatively unknown varieties presents a problem for small growers of an expensive perennial plant. While hop growers might be able to be immediately responsive to brewer's self assessments for demand, most brewers are hesitant to enter into long-term contracts and without such backing brewers are likely to adjust their demand for particular hops between years and even within years—this presents a real difficulty to growers. Hannah and Jason are attempting to reshape an aesthetic valuation tinkering with what they grow and how the aesthetics of their hops are assessed: they are trying to convince brewers to consider terroir, locality, and ownership as important attributes that supersede novelty. In this way, they tinker with what they grow as well as how that product is assessed, the cultural values which inform their hops.

> Hannah: We gave them a list of what we could source and we said, "Here's what we can do. You tell us what you want." So that's kind of another unique thing

> where, same with the second acre we said, "Hey, here's what we can get. You tell us what you want."
>
> Jason: Yeah, we want to sell out. That's our goal is to...
>
> Jason: Basically your small, I'm small, we could do this.

Tinkering with hops is a practice on larger farms as well, Karly and Kyle run a larger Yakima farm and run smaller informal breeding program or contract with breeders elsewhere to produce experimental crosses. This small farm is the original grower of El Dorado™ which is technically an “open” unpatented variety that arose as part of a portfolio of hop varieties this grower maintains.

> We have a... I don't know, what I would say is a breeding-like program, and so, we worked with a couple of different people. It's a variety we had. There's lots of different varieties out there that are fairly easy to acquire. So, it's a variety we had since 1998, but we just kept it kind of in the background. It was meant to also be an alpha variety… And so, when craft came, we just brought it forth because we knew it had unique aromas. [Kyle]

Craft beer is a quickly changing marketplace, however, and growers who do not have systematic breeding programs often seek alternative methods for maintaining relevance with a buyership whose aesthetic for taste has largely been driven by a sense of novelty in the last ten years. To identify and maintain control over potential new varieties, this grower has to keep El Dorado alternatives on hand. They work with contract breeders and catalogers to keep a portfolio of potential new varieties viable so they can identify and grow “the next thing.”

> But we also worked with a gentleman down in... we have a large Neomexicanus collection, which is a different species, actually. And so, we worked with a gentleman down... in New Mexico, and bought his whole collection. He had 80 different unique varieties. So, we have a bunch of those in the wings, we have several others that we could bring forth; recently, there's lots of private breeders that have showed up. We're working with a private breeder out of San Diego that's doing some crosses for us, as well. So, we don't have a big standalone breeding program, no, but we have access to new varieties. And so, at this point, the growth of El Dorado and some of our Neomexicanus is kind of more than we can almost sustain at this point. So, we're really trying to just focus on those, you know? [Kyle]

Tinkering on medium and large farms: The case of Sap Analysis and Regenerative Agriculture

Tinkering is small—an effort of care—but it is not exclusive to small farms. Medium and large farms in Yakima and elsewhere borrow care-based modes of restructuring sociomaterial relationships to produce more financially and environmentally sustainable outcomes that free actors in the agri-environmental assemblage. One grower I spoke to operates a mid-sized (less that 1000 acre) hop growing operation in Idaho and has sought to improve their long-term sustainability in both financial and environmental sense by tinkering with a variety of growing techniques ranging from cover-cropping and inter-grazing along with other regenerative agriculture techniques as well as through the marketing of wild hop varieties and smarter methods for testing nutrition and plant health. One space where these farmers *tinker* is by re-

thinking their primary way of testing plant-health. Industry norms for plant health testing involve pedial sampling, however, these growers identify jokingly as being part of a “secret club” of growers who believe that sap analysis provides a more accurate sampling of what actually moving in the plant and what farming decisions need to be made to improve plant health more immediately. Another large farmer whose considering switching from primarily Petiole sampling to Sap sampling reports:

> I think we're trying to decide whether tissue or sap makes more sense. I'm kind of the opinion to say sap makes more sense but we need more data points to make that...Intuitively it's a better representation of what's flowing in the plants: I don't want to look at a sink I want to look at what is actively happening, what is actually flowing in the plant. Because a sink can be misleading. You might have 5% nitrogen in a leaf that's accumulated but that doesn't tell you like you know what is actually moving in the plant. So tissue analysis could tell you your fine but you could be deficient in the sap movement. [George]

This large farmer sees sap analysis as a different, precise way to “know” their plant which in this case more accurately considers the plants dynamic positionality as a living organisms that is responsive, adaptive, and active. Drawing on the work of Atchison and Head, Sap analysis could be described as an approach that cares about hop bine’s plantiness (Head et al., 2014; Head & Atchison, 2016). A different farming operation that promotes sap analysis saw this approach of tinkering with how they “know” their plants as part of larger re-thinking of their farming operation. They operate a larger farm (one of the largest in Idaho but mid-sized by Yakima Valley standards), they are women operated and have academic and professional training in regenerative agriculture practices which they bring to their farm. Notably, this approach

emphasizes farming better, with long-term sustainability in mind and diverse profit-making as an outcome instead of short-term growth as an immediate goal.

> Yeah. Well, another thing too that we started doing ... My sister, Sam, went to graduate school for plant and soil science at Colorado State in Fort Collins. That's where they have their main ag campus. And at that, she took a bunch of courses on regenerative ag just because that was one of the focuses that we knew, coming in, with her coming back to the farm, we wanted to start to pursue. We just didn't know what we were doing at all. She recommended a book by Gabe Brown called *Dirt to Soil* and I read that. And then years go by, whatever, they actually put on a Soil Academy, Gabe and his fellow colleagues in the same field. We went to that last December. And we had already been doing cover cropping and had already had some direction in that but it really helped us to figure out what we needed to do and how to do it, gave us the right tools and mindset. [Susan]

Starting cover-cropping, switching to organics for pest control and fertilizer, or producing systematic grazing plans is a complex task on a large farm (or small farm for that matter) and it requires a distributed network of actors to enable this kind of "tinkering" approach. This obstacle arises as the tinkering approach gets scaled up—while this is a difficulty in one sense it provides a range of opportunities for those able to leverage local resources to develop a strong team that enables regenerative agriculture or de-growth alternatives in their farming models.

> In the Soil Academy, they talk about sap as well and how it works and why you should do it. And with that arsenal of knowledge, we just found our fertilizer company or chemical company, Simplot, here. We contacted them and were like, "Hey, this is the direction we want to go. You guys have tons of organic products,

> let's ... " because we have a great field man that we work with there, and really progressive and forward thinking. A lot of guys just want us to lay fertilizer. And they're like, "Don't worry about anything else." And he definitely sees the big picture of why that's not always ideal. We've used them and then we also work with a super generatively based company in Washington called Soilcraft. And they've done a ton of regenerative, ton of organic. And they're an offshoot or a competitor to John Kemp, who runs his own consultancy firm and has his own line of products as well. But it's all within the auspices of regenerative ag.

In some ways this “novel approach” is actually the result of a long practice of tinkering and long held agroecologically sustainable practices. Such practices are not exclusively or normatively “good” but rather tinkering provides a more improvisational and collaborative method by which farmers’ human values and the socio-material assemblage of actors involved in agriculture more directly relate to and inform one another in the co-production of farming outcomes.

> I mean, even dad and great-grandpa, he used to have sheep. I think there's always been pieces and bits regardless of the generation. And we want to be good stewards to the land want to have a nice, tidy farm, we want to grow exceptional hops. And that's been through generations is our goal. And now we just have a few different tools in the toolbox than what maybe prior operators had because of science. We've had advances in technology that my grandpa never would've dreamed that we could figure this stuff out.

Discussion: What Tinkering teaches about Environmental Justice and Sustainable Transitions

These findings demonstrate how small farmers necessarily engage in mutual relational approaches to making ends meet that indirectly improve environmental outcomes. These approaches can be achieved by medium- and large-scale farmers but the effort requires a more self-conscious or policy governed imperative. This is primarily because in the absence of direct interaction with a range of material actors—care relationships become overly mediated. Rather, large farmers tend to focus on incremental and top-down systematic approaches in many ways. Such as one large-growers self-imposed metrics for assessing environmental friendliness.

> We also have some type of an audit to kind of see how sustainable we are, so that's through a Yakima Chief program called GreenChief®. My nephew, Tyler, kind of oversees the information on that data. They're working on our pesticide applications with the … They've worked with one app, but now they're using a different type of application called Ag World.

This approach doesn't really tinker with inputs or technologies but rather provides an interpretative frame for understanding the environmentally (un)friendly practices of large plantation style hop farms. This character shift is useful for considering the differing outcomes of these two practices. Tinkering on small hop farms is an act of care that reorients socio-material actors in relation to the farmer to maximize benefits for the farm and farmer themselves. The results are not always environmentally friendly. However, the approach differs fundamentally in character and result from the above incrementalist approach often employed by large farms to demonstrate environmentally friendly efforts.

Both cases can result in more environmentally sustainable outcomes. However, the key difference between these two examples is that tinkering represents a small shift that reorients the farming practices in total. This differs from the incrementalist approach, which sets limits or otherwise addresses the margins of a practice but leaves the farming practice in total largely intact. This characterization is helpful for considering how immediate steps can be made toward more environmentally just arrangements for vegetable, herb, and fruit agriculture. It provides particular lessons for transitions toward the more just arrangements of agroecology and growth-alternative business models.

Agricultural models which eschew growth imperatives vary widely but have not typically lent themselves toward incremental approaches to such transitions—representing ideologically and materially different approaches than conventional commodity and/or neo-plantation style agricultures. Because of this, policy interventions and scholarship on just transitions have difficulty imagining pathways from contemporary conventional farms to alternative agricultural practices which could include agro-ecology, perennial agricultures, small-holder farming, etc. However, by translating the findings on small farms to those large farms engaging in regenerative agriculture in particular, this study sheds light on how *tinkering* provides an alternative model to *incrementalism.*

Consider Sarah's particular practices which emphasize regenerative agriculture. While Sarah operates a medium-sized hop farm, her approaches borrow from the small farmers' who tinker in direct ways. Like those farmers who build out implements, rethink trellising, and experiment with novel hop varietals, Sarah is engaged with rethinking the material arrangement of her farm. She is not 'thinking big' for such a transition, but rather 'thinking small.' What I mean by this is that she engages in regenerative agricultural transitions as a matter of everyday

care and involvement in her land. She doesn't begin grazing as part of an over-arching plan to eventually end up as a maximally sustainable farm, but rather as a stepwise plan. Tinkerer's engage in immediate care by reorganizing material actors for immediate term benefits and experimentation. Sarah might get many aspects of regenerative agriculture 'wrong' but these mistakes are not particularly worrisome because she scales at an immediate, improvisational level.

For small farmers such as Saul, the impacts of tinkering may be riskier because of the low financial overhead but the impetus is also higher. Tinkering does not necessarily result in more just outcomes or more sustainable farms in every instance, however, its orientation toward care and experimentation with relationships between actors produces more flexible, responsive, and adaptive outcomes. This generally lends tinkering approaches to produce more resilient farms and opens the door towards many policy and extension interventions that encourage sustainability. Tinkering shows us that large scale transitions may be achieved in the aggregate at the grass-roots. However, for this to occur, cultures of innovation and safety-nets for mistakes should be considered at a policy level. Put differently, more just sustainable pathways toward a more equal agri-environmental practices and a more resilient food system should consider that adaptive and beneficial frameworks can most easily be cultivated by those directly involved in specific ecosystems. As such, policy stakeholders, applied researchers, and networks of ag-supporting infrastructure such as LGU systems should consider interventions which support small and medium farmer experimentation. This experimentation, tinkering is an essential component alongside a suite of other environmental and agricultural policy and research in pursuing more sustainable and just food futures.

5. Conclusion

What does an improved sociological understanding of hop growers offer for our shared understanding of the intersection of people, environments, and food production? Hops do not fulfill the caloric needs of a fast-growing population on a quickly warming planet. I want to also be clear that hops do not provide a model example for future innovation in such crops. Hop growers are a natural experiment—a window into the kinds of innovations large and small farmers pursue when they have the latitude to explore such outcomes. The lessons from these three articles should not be considered exemplars nor as neatly translatable but rather as lessons for how to consider engaged or future-oriented research in critical agri-food studies. Broadly, these articles contribute to an interdisciplinary conversation around the character of, and possibility for, sustainable transitions in agri-food and agri-environmental regimes. By understanding hop farmers innovate in response to their specific environmental and market pressures we can draw some conclusions about the potential for, and character of, such adaptation in other industries as the planet warms and agri-food adaptation becomes a prerequisite for agriculture instead of a mild benefit. The simultaneously narrow agri-environmental niche in which hop growing occurs alongside its global market make it an ideal case example for this kind of study.

In this short conclusion, I consider the impacts these articles have for three core disciplinary conversations: environmental sociology, rural sociology, and science and technology studies. Following this, I suggest avenues for further research on the social dimensions of innovation in agriculture. Specifically, I offer three key questions that remain unanswered by this project which I expect to respond to in my future research: **1)** What avenues for encouraging

farmer-directed or responsible innovation practices exist in commodity agriculture? **2)** How can adaptive and inclusive value chains for more sustainable novel crops or novel genetics be encouraged or developed in other agricultures besides hop-growing? **3)** What attributes would characterize a more politically and socio-technically *adaptive* agriculture? How would such a transition be sustained from a policy and praxis standpoint?

Before going further, I think it is also worthwhile to pause to reflect on the obstacles caused by the Covid-19 crisis. This public health emergency resulted in mortality and mental health crises many magnitudes greater than any obstacle posed to this project. However, in the scope of a project whose data collection was interrupted—some interesting results did occur. Primarily, I was obligated to use a leaner dataset that relied on both in person and targeted distance interviews. While these distanced interviews were few and limited in scope—they did allow a wider geographic picture of the hops growing practices in the US. While a larger dataset may have been preferable at the outset—I do also see in hindsight that such a larger dataset would have offered me very little to improve the range or validity of my findings. When considering whether I had "enough" or had "reached saturation" to complete the articles in this dissertation—I found that I had—and that additional interviews guided by the same interview protocol and seeking the same answers to the same research questions would have ultimately been extraneous. A key lesson for me drawn from this experience is that I should be as ruthless with my methods and with the research questions I pursue—what I mean by this is that this interruption provided me the opportunity to more thoroughly pursue my research questions with the data I had—revealing that continued data collection would be beneficial only with revised interviews targeting new research questions. In the future—I expect to conduct earlier analysis to

better assess at what point I reach saturation especially when conducting exploratory work such as in this project.

Lessons for Environmental Sociology

These three articles are primarily positioned to contribute to discourses in environmental sociology. Together, they complicate the dichotomies between ecological modernization and treadmill theories while furthering a trend toward bringing on relevant STS literatures to environmental sociological debates. In "Farmers who tinker" I make the case that small scale interventions into matters of innovation can make improvements to environmental futures in an improvisational and grassroots way. This contravenes and complicates the large-scale climate solutionism that eco-modernists have tended to pursue (Asafu-Adjaye et al., 2015; G. Spaargaren, 1997; Gert Spaargaren et al., 2006). It also demonstrates a "way out" or a way beside the often-fatalist critiques of treadmills and extraction offered by eco-Marxists (Gould et al., 2004; Levins & Cochrane, 1996).

This "third way" as suggested by this article could be re-thought as plural—*third ways* when taking each of the articles in this dissertation into account. While there are multiple take-aways from both "Other Agricultures" and "Do Farmers Know Better?" key implications from these articles also reveal how big-agriculture and corporatized, vertically integrated food production as the capacity to co-produce alternative sustainable futures even in the absence of robust policy governance—working to "decommodify" the hops they grow to increase profitability and improve long term adaptability. These outcomes do not fit neatly into eco-modernist or treadmill narratives and push forward my previous work on the distributed agency of farming operators in the digital ag era (Comi, 2020c) (see below).

The specific contributions of these articles aside, my work together pushes forward literature in environmental sociology by using the US food production system as a case example that reveals the multiplicity of development and transition pathways that are left out of the normative examples supplied by conventional dichotomized debate in US environmental sociology. This contributes to a growing literature in the food system and elsewhere that shows how sustainability narratives and transitions are contested, variable, and multiplicitous spaces which require sustained specific engagement for identifying more environmentally equal, just, or fair transitions (McCumber, 2021; Reisman, 2020; Scoville, 2019). Considering transitions to better farming futures, and by extension better environmental futures is an exercise that requires continued ontological (re)consideration of the actors, relationships, and engagements that make up environmental actions and interventions.

My work also pushes forward environmental sociological literature by keeping in mind paired interests of environmental justice and human-nonhuman relationships in the consideration of sustainable transitions. In contemporary environmental sociology there is strong scholarship on environmental and critical environmental justice (EJ) alongside strong research in human-nonhuman relationships (Čapek, 1993; Dietz & York, 2015; Larkins, 2018; McCumber, 2021; Pellow, 2017). While others scholars do "take on" these approaches in specific inquiries, these approaches remain under-adopted in environmental scholarship which is not centered on that topic. As a thought experiment, it would be quite absurd for an immigration scholar to ignore intersecting considerations in understanding immigration phenomena such as race, class, justice, and inequality. However, environmental sociology has been slow to adopt (EJ) or human-nonhuman relationships in the same way, even though these are building block consideration when examining socioenvironmental worlds. While my work does not study human-nonhuman

relationships or EJ outcomes as a direct research objective—my work does push forward environmental sociology by contributing to and incorporating a robust intersecting discourse in a conversation that is often oversimplified.

Lessons for Rural and Critical Agri-Food Studies

The articles in this dissertation offer multiple contributions to the theoretical understanding of farmer involvement in innovation, technology transitions, and sustainability in food systems and rural landscapes alongside an improved disciplinary understanding of hop growers among the wider global food system in contemporaneity. Hops, as noted at the outset of this dissertation, and hop growers have received little critical agri-food attention and especially little qualitative assessment(Cordle, 2011; MacLean, 1909; Parsons, 1940; Stratton, 1883). From a disciplinary and basic research perspective, these articles offer the first holistic qualitative social assessment of US hop growers in over 100 years. When considered in relation to the author's ongoing projects with collaborators in Europe and New Zealand, this research further scopes the international marketplace and aesthetic regime (Legun, Comi, and Vicol 2022). By improving our basic research understanding of this industry, these articles widen our knowledge of the diverse agricultural practices of quality agricultural goods production in the US and value-added goods supply chains. Without overstatement, its fair to say that social scientists curious about practices of hop growers only had industry produced materials, pop news outlets, and a small segment of applied agronomic extension research conducted primarily at Oregon and Washington State Universities to report "whats going on." This research provides a window into the novel agricultural practices on large neo-plantation style hop farms and small hop growing startups. It complicates simplified agronomic narratives of linear success over the last 16 years

and inquires about the socioenvironmental ramifications of the particular techniques and technologies employed by US hop growers.

From a theoretical Rural Studies perspective—these articles push forward how rural food producing regions are (co)impacted by changing agricultural practices on a warming planet. I push forward how farmers are able to improve their agency by enrolling a range of actors across vertically integrated operations. Put differently, in my previous work I've shown how US Midwestern farmers experience distributed agency—meaning that a wide array of actors make up farming actions and farmer identities and this, in the case of commodity precision agriculture limits individual autonomy (Comi, 2020). In these articles—I show how farmers as members of a distributed collective remain able to meaningfully impact the rural spaces in which they live and work to make systemic change possible—resulting in the "decommodification" of hops or the co-production of "big juicy" hop genetics. Besides offering insights into pathways forward for improved rural livelihoods this research also clarifies how agri-food regimes as socio-material apparatuses can be reorganized to promote expanded farmer autonomy, increased financial sustainability, and improved environmental adaptability.

Lessons for Science and Technology Studies

This dissertation pushes forward an intersecting literature on scientific innovation, expert knowledge, and the future food system on a warming planet. It intersects with classical STS scholarship on the politics of knowledge making (Jasanoff, 2010; Latour, 1996; Latour & Woolgar, 1986; Mol, 2002) and the materiality of socio-cultural networks (Callon, 1999; Müller, 2015; Pellizzoni, 2015). It also contributes to a specific interdisciplinary conversation in STS and food and agriculture systems that explores whether new knowledges produced by a range of

actors actually do or do not disrupt the unsustainable conventional agricultural global food system (Bronson, 2015; Fairbairn & Guthman, 2020; Gugganig, 2021; Guthman, 2017; Reisman, 2020). Broadly, these articles frame out the "lessons" hops growing has for other formations of agriculture and other kinds of innovation. Specifically, my exploration of how farmers produce differential kinds of new genetics through on-farm breeding practices reveal how different kinds of actors produce different kinds of knowledge when positioned as *experts* or as *researchers.*

In Chapter 3 "Do Farmers Know Better?," I show that farmer directed breeding programs like hop breeding company engage in the ontological politics of "branding" hop genetics and thereby coproduce aesthetic dimensions of desirability. This is the nuts-and-bolts, so to speak, of the "decommodified" hop farmers report pursuing in Chapter 2 "Other Agricultures of Scale" and the very same hop that is shown to put undue pressure on small farmers in Chapter 4 "Farmers who tinker." Put succinctly, the control pursued by HBC is interesting because on the one hand—it is a grassroots and farmer driven kind of innovation—a market cycle for new genetics and "craft" varieties with novelty. However, by vertically integrating a knowledge-producing industry—they exert control not only on the varieties being bred, but also how they will be described and on what metrics brewers will assess their varieties. In this way—within this niche market—hop farmers are shown to be producing both cultural and biological technologies with their novel hop varieties and by controlling paired techniques large hop growers in Yakima retain outsized market clout that results in some anticompetitive dimensions particularly for small growers and US growers outside the Yakima and Willamette regions.

This pushes STS literature forward by providing case-example insights into the co-production of knowledge, human-nonhuman relationships in applied plant science, and by demonstrating how farms and farmers can operate as analogs to laboratories and scientists within

frameworks that position such farmers as experts. This results in some parallel results but with many different *flavors*—all informed by the differential goals, positions, and identities that define farmer-driven inquiry as opposed to conventional *scientific inquiry.* Specifically, it reveals that farmers pursue a politics of knowledge production that is more collaborative while simultaneously also steeped in the politics of control in much the same way as other basic and applied science conducted at the university/commercial level. In this way—farmer driven innovation and farmer directed science is an avenue for more sustainable innovation *however* smart policy governance is required if an open scientific and commercial community is considered a goal.

Avenues for Future Research

This research illuminates three key avenues for further inquiry which I expect to take up in my future projects. They are guided by questions that are raised by this research and which this current project is either unable to answer or only able to answer partially. Each is intentionally broad and are guided by the realization that while farmer directed innovation is shown to produce differential outcomes including some positive benefits, there are significant gaps regarding the translatability of these practices to other industries and the governance of such practices to encourage adoption and protect low-SES individuals from unequal exposure to environmental and financial harms. These questions include **1)** What avenues for encouraging farmer-directed or responsible innovation practices exist in commodity agriculture? **2)** How can adaptive and inclusive value chains for more sustainable novel crops or novel genetics be encouraged or developed in other agricultures besides hop-growing? **3)** What attributes would

characterize a more politically and socio-technically *adaptive* agriculture? How would such a transition be sustained from a policy and praxis standpoint?

I look forward to parsing these questions by transitioning to research in additional industry sectors, thus widening the range of my research. I expect to consider agricultural problems relevant to the US Midwest and South—particularly I hope to look at the way innovation and adoption differentially impacts diverse groups of farmers and laborers. By keeping in mind where identity may be located within the sociotechnical and socioenvironmental questions I suggest in the previous paragraph, I think that a more engaged and effective sociology of agri-food may be possible—one that actually encourages more equitable agri-food systems for farmers and rural communities of all backgrounds—not simply white rural farmers and diverse urban farmers. Put differently, the impacts of innovation *will* be felt in rural places and significant research already shows how changing socio-technical dynamics in all spaces have differential impacts based on a number of factors relating to individual identity and background. However, little rural sociology considers the diverse groups of individuals who occupy rural America while also considering robust impacts of socio-technical innovation. My own study is guilty of leaning away from identity-level factors and by working with hop farmers I was limited to a homogenous group—considering animal agricultural and small-holder rural farms for a future study would be one sector where innovation could be studied with a more diverse group of agricultural professionals. These considerations will inform the trajectory of my work at the intersection of agriculture, environment, and technology in society.

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