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Sustainable Management and Design of North American Orchards Supplying the Hard Cider Industry

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Abstract

The hard cider industry is quickly growing in North America. In this research I investigate how apple production in North America has adapted to meet the demands of the rapidly growing hard cider industry, and whether this expansion and adaptation is sustainable. Specifically I seek to understand how orchard managers are shifting production or expanding their orchard to supply the cider market, what techniques and management practices are currently in use, and how this is impacting the agroecosystem, the surrounding ecosystem, and the landscape ecology of the region.

I chose to examine the sustainability of orchards supplying the hard cider industry through a series of five case studies conducted along the North American west coast. I applied an adapted framework of 'A Rapid, Farmer-Friendly Agroecological Method to Estimate Soil Quality and Crop Health in Vineyard Systems' consisting of surveys and analysis by the Altieri Agroecology Research Group at UC Berkeley, and conducted supplemental interviews. The surveys are designed to measure the sustainability of the five orchard agroecosystems through a participatory, comparative, quantitative analysis of synergies occurring within the system. Semi-structured interviews complement the surveys to provide a mixed-methods analysis. My research also draws on applied island biogeography theory to analyze biodiversity and habitat fragmentation at the landscape scale.

The five orchards which participated in this research are all above the sustainability threshold used. My findings suggest that the cider industry is proving to be a high value market opportunity for small scale, sustainably run orchards which could not compete economically with larger operations to provide culinary apples. This research also suggests that the cider industry has potential to effectively utilize a wide variety of agroforestry techniques. I would also put forward that cider orchards could successfully be operated as low input systems under the right conditions and still be economically viable. I conclude with a discussion on the cider industry's potential to compete with the wine industry in northern California and decrease habitat fragmentation for native pollinators in the region by increasing landscape diversity.

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Introduction

Hard cider is experiencing a renaissance in the United States. Following prohibition in the 1920s, hard cider production fell to the wayside despite a nationwide abundance of apple orchards (Watts, 2017). Riding on the coattails of the craft beer industry, there has been a new resurgence in the popularity of craft hard cider, which could be a high-value market opportunity for small orchard operations.

At the same time, in the wine industry, a growing interest and demand for sustainable food systems is leading to the incorporation of ecology based systems and design. These initiatives are influenced by prominent agroecologists and industry groups such as Stephen Gliessman, the Altieri Research Vineyards at UC Berkeley, the agroecology program at University of California Santa Cruz, and LIVE sustainable winegrowers certification and education programs in the Pacific Northwest.

This research seeks to find out whether the same principles of ecology based systems designs currently being integrated into the wine industry are also being applied to upcoming cider orchards. To answer this question I extrapolate the principles of sustainability being applied to vineyards and adapt them to orchards.

On the other side of the United States, where cider is also staking a claim in the market, industry professionals approached Cornell University and asked them to expand their cider research programs. Presently there is no discussion of systems design or ecology based landscapes in their research. The cider industry is expanding, but not yet established, which creates unique conditions allowing for both the flexibility and incentive to promote sustainable best practices.

There are many parallels between the cider industry and where the California wine industry was prior to the explosion in popularity of regional wines after winning an award at the Judgement of Paris in 1977. Will the cider industry evolve in the same manner as vineyards, which have caused a variety of negative ecological impacts (Christ and Burritt, 2013)? Or is there a new awareness of, desire to be, or pressure to become a sustainable operation that was not present during the growth of the wine industry?

Agroforestry and other conservation agriculture techniques can improve the sustainability of agroecosystems and landscapes. Trees and agroforestry practices taking hold globally have the potential to address major issues caused by and related to climate change, urbanization and hunger (“Agroforestry”, 2018). Orchards were abundant across the United States and Canada historically. As new orchards spring up and existing orchards expand or adapt to meet the demands of the cider industry; hopefully they will be designed in a way that promotes beneficial ecological function. This research will explore the realities and potential of agroecological design and management practices to improve sustainability of cider apple production.

An excerpt from Cornell cider researcher Gregory Peck explains the current economic viability of hard cider in the US marketplace: “Hard apple cider was widespread throughout the American colonies from the time Europeans began immigrating to North America until prohibition in the 1920s. Hard cider has remained popular in Europe, but it has only recently enjoyed a revival in the states. Within the past five years, U.S. cider consumption has increased by 850 percent. It’s the fastest growing segment of the alcohol industry. It’s relatively small proportionally to wine and beer, but it’s the fastest growing. All the major multinational beverage companies have cider companies now” (Peck, 2016). Peck has also stated that, “We see

this as an opportunity for diversification, which adds to sustainability. And it's a value-added product, so it's a way for farmers to make more money from their produce" (Peck, 2016).

Altieri Agroecology Research Vineyards

Miguel Altieri is an academic in agroecology. Currently he works at UC Berkeley and runs a research vineyard which studies agroecological techniques as they can be applied to viticulture. As the wine industry exploded after a Californian wine won the Judgement of Paris in 1976, most California vineyards scaled up as monocultures (Gliessman, 2006). Altieri works with only a handful of vineyards, but the hope is to promote agroecology in this economically powerful Californian industry (Altieri, 2015).

Altieri's research vineyards created a user friendly framework called "A farmer-friendly method to estimate soil quality and crop health in vineyards". It is a questionnaire that helps farmers use visual clues to assess the vitality of the system. There are of course more complicated and possibly slightly more accurate ways to do this, but the value of this framework lies in its utility. Likewise, the simplicity of the framework is ideal for participatory research. Many lists of indicators that can be used to estimate the productivity, stability, resilience, and adaptability of agroecosystems have been proposed, but few methodologies exist that allow farmers to use a few simple indicators to rapidly observe the status of their agroecosystems. Such tools would permit them to make management decisions directed at improving the attributes that are performing poorly, and thus improve agroecosystem functions (Nichols et al., 2004).

This framework was given to multiple farmers, which allowed for cross-comparison. Vineyards with high composite scores were deemed 'lighthouses' and could be used as model systems. The interconnected nature of the agroecological management system made it difficult to direct farmers towards specific interventions. Emphasis was therefore given to looking to lighthouse model vineyards to find efficient synergies which could be replicated in other systems rather than single explicit management tactics. This framework also created a very effective visualization of strengths and weaknesses in the system referred to as an 'amoeba'. The amoeba creates a visual representation of different ecosystem functions and synergies without representing the systems in a hierarchy.

Biodiversity promoted through ecology based systems were categorized into planned biodiversity (such as cover crops and corridors) and associated biodiversity (such as predators and parasitoids). The planned biodiversity is assumed to be some of the tactics other practitioners could adopt to promote a more complete biodiversity picture in the agroecosystem.

This framework was designed to be adaptable. The mathematical layout and comparative tactics used in this framework would fit any agroecosystem. For this research it was adapted to an orchard agroecosystem.

Research at Cornell on American Cider

Cornell University Extension has established cider orchards and is researching various elements of cider making. There is no published research at Cornell which displays agroecological influence as is such with the research at UC Berkeley. This research builds on the practical knowledge gathered thus far at Cornell with the environmentally focused research at the Altieri Research Vineyards (Peck, 2015) (Altieri, 2015).

The USA Cider Makers Association Members have an annual conference called CiderCon. At this conference Cornell researchers surveyed attendees on their status as producers and about areas where they needed research and extension agents to step in to fill knowledge gaps. Research needs were broad across all categories with no significant outliers, suggesting that research is needed in all categories. The knowledge gaps were broad, since the industry is composed of many people in their first years of production. Respondents made up about 20% of US and Canadian cider producers, providing a very accurate snapshot of the industry.

The research needs were as follows: (each respondent could choose up to 3)

Fermentation management: 18%
Final product quality evaluation: 15%
Storage and packaging techniques: 13%
Cultivar and rootstock trials: 13%
Cider orchard management: 11%
Juice quality improvement: 11%
Economic feasibility and consumer preference studies: 8%
(Peck, 2015)

A slightly lower desire for research in orchard topics could be due to the fact that many respondents were buying their apples. Less than a third of those surveyed were growing any apples used in their cider, and had no personal stake in orchard management. I predict that this research category will receive more support as more people expand to start their own orchards or vertically integrate with an established orchard.

Many researchers have raised concerns that the specialty apples required for cider production will not be available as their businesses grow. There is a limited supply of European cultivars with high tannic and acidic qualities, which are desirable for craft production. To address this issue Cornell is importing, establishing and researching the growth properties of Spanish and British cider trees. The Spanish trees were released from a USDA quarantine process in 2016 and the British trees will become available in 2020 (Peck, 2015).

Importantly, 91% of survey participants were interested in participating in research. There is obviously a desire for participatory research. According to the Cornell survey people are learning about cider primarily through the internet and colleagues. The desire for participatory research was evident based on the enthusiasm of the case study participants and the desire by cider makers to promote the industry as a whole.

While the vineyards in California went straight to monocultures (Gliessman, 2006), there is strong potential here for new orchardists to implement diverse sustainable productions, possibly even regenerating the agroecosystems and climate with agroforestry practices. Most survey participants who did have an orchard had small acreage (Peck, 2015). My intention, which is to compile and assess ecology based orchard practices, will arrive at a perfect time to reach many new upcoming orchardists as more cider cultivars become available in the United States.

A foreseeable potential setback in the effectiveness of providing this information is that Cornell's research is promoting top-working of cider trees to make cider cultivars available sooner to meet demand. If cider apples are primarily woven into existing large scale orchards, there is less chance of being able to install an ecology based system.

Literature Review

Agroforestry

Agroforestry practices are still on the fringe of mainstream employment in agricultural systems in the United States, despite agroforestry techniques being well documented and formally promoted by the European Union, the United States Department of Agriculture and United States Forest Service. Furthermore, agroforestry practices are not new in the United States. There was a massive agroforestry initiative to counter erosion following the Dust Bowl in the early 20th century (USDA, 2016). America's reluctance to use agroforestry practices is due to a combination of cultural, social, environmental and economic factors. Dr. Gene Garrett Professor Emeritus at The Agroforestry Center at the University of Missouri thinks that, "One major hurdle to the widespread adoption of agroforestry might be conventional thinking about trees. Families spent generations removing trees to practice agriculture. We have to stress that if you don't put them in the way, you can use working trees to benefit agriculture." (Robbins, 2011). I hope that I can show through my work that 'planting the right tree in the right place for the right reason', which is the mindset of agroforestry, can be used commercially to benefit both productivity and the larger ecosystem.

Honey bees and Native Bees

Another point of interest is the re-establishment of native pollinators. With the threat of Colony Collapse Disorder (CCD) it is important to recognize that honeybees were brought to America in the early 1600s and there are more than 20,000 species of bees in the world (Park, Ore, and Danforth, 2010). Studies on the presence on native bees in apple orchards show a significant proportion of native bees in eleven surveyed apple orchards New York State (Park, Ore, and Danforth, 2010). The role of native bees in apple agroecosystems could help to close the system by reducing the need to rent honeybees as an input for pollination, which is the current practice for many large scale orchards. Creating habitat for native bees in cider orchards is a promotion of surrounding ecosystem function and agroecosystem biodiversity (Park, Ore, and Danforth, 2010).

Pasture Grazing

Spotted orchard pigs have been a facet of British cider orchards for some time. The pigs eat fallen apples and dig up root vegetables planted for them in the rows of the orchards, at the same time digging up pests in the larval stages and acting as natural pesticides. They also act as fertilizer by returning nitrogen to soil in the form of manure. Originally the pigs were an additional source of income for cider orchardists who could sell them for slaughter at maturity. The practice dissolved in England because it was out-competed by industrial hog farms (Freeman, 2015). The only practitioner of orchard grazing with pigs in the United States found during the course of this research is Virtue Cider located in Michigan.

Heineken UK, a famous European beer company, but also a major cider producer, is experimenting with sustainable supply chain practices and has done some research with BioDiversity International on pasture grazing sheep in cider orchards in France. The push comes facing impending agrichemical restrictions for the EU (Heineken UK, 2015).

Relevance

There is an effort spearheaded by UC Berkeley to introduce agroecology into an already well-established wine industry. Meanwhile at this early stage in the development of the cider industry only essential basic research questions being addressed. The current leaders in cider science in the United States are found at Cornell University Agricultural Extension. Their research does not address issues of sustainability; instead it focuses primarily on issues of economic viability, productions of scale, and comparisons to established cider traditions in Europe (Peck, 2015).

I argue that it is easier and more effective to promote sustainable best practices in the cider industry before it becomes fully established. As farmers adopt cider cultivars, and as craft producers continue to establish themselves, this research will be available to them to inform environmentally responsible management and sourcing decisions.

Research Questions

1. How has apple production in North America adapted to meet the demands of the rapidly growing hard cider industry, and is this shift in production sustainable?
    a. How are orchard managers shifting or expanding apple production to supply the growing market, and how is this impacting the agroecosystem, the surrounding ecosystem, and the landscape ecology of the region?
    b. What are the techniques and management practices currently in use in orchards and how is this impacting the agroecosystem, the surrounding ecosystem, and the landscape ecology of the region?

Auxiliary Questions/ Prospective Analysis

2. To what degree can we anticipate to see further expansion or a shift in apple production in favor of cultivars desirable for the hard cider industry?
3. Does the cider industry have the potential to provide economic viability to small apple producers? If so, does this have the potential to change the landscape ecology away from large swaths of monoculture to smaller pockets of biodiverse agriculture?
4. Will cider production be influenced by the craft, local or slow food movements?
5. What is the relationship between apple growers and cider makers? Are cider makers and/or consumers interested in sustainable production?

Research Methods

The research questions were addressed through a series of fived mixed-method case studies about cider operations and orchards that supply cider makers. Information was gathered through interviews with cider industry professionals and researchers. Additional literature-based research draws comparisons across time and to sites that could not be reached in person over the course of this study.

There were two phases to the research. The first phase was exploratory, and sought to understand the current status of sustainability in the cider industry and establish contacts. In the second phase data for the case studies was gathered through semi-structured interviews and a participatory survey to measure crop health and soil quality. The surveys are an adapted framework of 'A Rapid, Farmer-Friendly Agroecological Method to Estimate Soil Quality and Crop Health in Vineyard Systems' by the Altieri Agroecology Research Group at UC Berkeley (see appendix #2). Additional materials such site maps and photos are included where available and relevant.

After data was gathered, it was analyzed to assess the overall sustainability and impacts on ecology at multiple scales using the same framework by the agroecology research group mentioned above. This framework creates a participatory, comparative, quantitative analysis of synergies occurring within the system (Nichols et al., 2004). Through observation of a single specific site, each metric of the survey is assessed as a 1, 5 or 10. These values are then placed into a visual representation, called an amoeba. This type of graph is also commonly known as a radar or spider chart. The amoeba graphs are produced using Microsoft Excel with the radar graph function. The amoeba shape visually represents an ecosystem and its many interrelated properties. The fuller the circle, the closer the agroecosystem is to a completely balanced self-sustaining system. The goal of the survey is not to assess how to make the circle completely full on all metrics, but instead to understand ecological relationships within the system and consider what management tactics can address any imbalances or best reflect the priorities of the farmer while maintaining sustainability and ecological equilibrium.

The interviews are designed to supplement and address any misguidances in the survey. Interviews assess ecosystem services not addressed by the survey, and inquire about specific management practices. They also compile the history of the orchard, the backgrounds of orchardists, and their plans for future expansion. Interviews conclude by gauging the participant's perspectives on the future of cider industry, the economic viability of cider, and the challenges and benefits of supplying the cider industry.

The research methods used in this thesis involve 'a participatory activity and is applicable to a wide assortment of agroecosystems in a series of geographical and socio-economic contexts, as long as some indicators are replaced by others more relevant for each particular situation' (Nichols et al., 2004). The flexibility and ease of use is a key quality of this framework which allowed it to be adapted to apple orchards and usable by people of any background.

A question was added to assess 'native pollinator abundance and diversity', based on research at Cornell titled, "The Role of Native Bees in Apple Pollination", by Park, Orr, and Danforth (Park et al., 2010). The European honeybee, *Apis melifera,* is the most widely used insect for fruit pollination. They are highly efficient pollinators because they can be moved into a flowering crop and will quickly produce thousands of foraging workers. This makes them especially important in large-scale, highly disturbed agroecosystems where native pollinators find scarce habitat, such as the central valley of California (Park et al., 2010). Unfortunately due

to a variety of factors, honeybees in North America are in serious decline. Colony Collapse Disorder, although not fully understood at this point in time, has been the result of what is likely a combination of heavy pathogen and parasite loads and additional stresses associated with migratory beekeeping (Park et al., 2010). It is also important to keep in mind that honeybees are not native to North America. The species was introduced by European colonists in the early 1600s (Park et al., 2010). Native bees play and important and underappreciated role in crop pollination. Bees are an enormously diverse group. There are over 20,000 species of bees in the world, approximately 4,000 species in North America (Park et al., 2010). One potential solution to the decline in honey bee populations in North America is to examine the role that native bees are playing in crop pollination and to develop management practices that promote and maintain healthy native bee populations in and around agricultural areas (Park et al., 2010).

Renting migratory honeybees for pollination is common amongst apple growers. In their research Park, Orr and Danforth observed a lack of awareness and understanding of both the extent and diversity of native bees in New York State and their role as pollinators for commercial fruit trees, but many farmers expressed concern over declining honeybee populations (Park et al., 2010). When inquiring about willingness to adopt practices that would enhance wild bee pollination in apple orchards they found that, "Throughout New York there seems to be an overwhelming support for the importance of wild pollinators and a willingness to make low-cost changes that will enhance their populations" (Park et al., 2010).

Other changes to the original framework worth noting was the choice not to include the metric for microbiological activity on the soil health status amoeba because of inconsistency in results when tested, and a lack of other published information regarding the conditions for, and validity of the results of the test.

Results are analyzed in two stages. Each system is first represented by an amoeba graph for soil quality and crop health. The amoeba graph is a visual tool that the farmer can use to make interventions that will impact one, or more often several, of the sustainability indicators to bring his or her results closer to full circle. For example, if the farmer chooses to put in live cover, the results for 'erosion', 'color, odor and organic matter', and 'water retention' will improve shortly thereafter.

The average of the combined survey results becomes a general gauge of the sustainability of the system, where anything greater than 5.0 is considered to be above the sustainability threshold. The case studies are then grouped comparatively in a line graph and the more sustainable systems are deemed 'lighthouses'. According the original framework used, the idea here is not for farmers to copy the techniques that lighthouse farmers use, but rather to emulate the processes, synergisms and interactions that emerge from the ecological infrastructure of the lighthouse farm, which are assumed to determine the successful performance of such systems in terms of soil quality and crop health. Simply copying the practices used by successful farmers does not work for diffusing principles underlying the performance of lighthouse farms. Agroecological performance is linked to processes optimized by diversified systems and not to specific techniques (Nichols et al., 2004).

The survey is supplemented by semi-structured interviews conducted on site and in person. The interviews are intended to provide a well-rounded perspective of all information relevant to the case study. The interview expands on the survey by probing for specific management techniques that influence soil quality and crop health and supplements the survey by inquiring about details regarding survey results and gathering information on the legacy of the orchard and the orchardists' background and perspectives on growing apples. **See appendix for interview questions and survey*

Limitations of the Research Methods Used

The methods used do not directly measure the specific factors of sustainability, resilience, adaptability, biodiversity, and productivity. They allow me to look at crop health and soil quality separately, and then infer sustainability. In the interviews I pull out more specific examples of factors of sustainability, such as the inclusion of a wetland or riparian buffer.

The surveys are based on one representative site in the orchard at a specific moment in time, but there is variation across the landscape and changes throughout the year, week, and even hour that are not represented by the results of one survey. Although the interviews and maps of the site are included to supplement the survey results, it is important to keep the limitations of the survey in mind.

The amoeba graph is a simplified representation of a complex ecology, but in a typical agroecosystem there is an oppositional effect between productivity and the other metrics. The graph does not necessarily represent the priorities of the farmer and the oppositional effects of productivity and conservation should be kept in mind as a farmer's economic viability is dependent on producing yield. It is not necessarily the goal of the farmer to create a full circle, but to use the graph as a tool to visualize and understand the elements of the system and their synergies.

Ethics

All participants were informed and consented to interviews and surveys on site at their property. All interviewees were given the option of anonymity and the opportunity to review the published work. All participants consented to have their interviews and surveys published in this work including their names, the name of their businesses, and their general locations. Interviews were recorded and password protected prior to publishing. The results of the survey will be returned to the participants to be used to better understand how their property fits into the sustainability framework used. There was no exchange of money involved in this study, all participation was voluntary. This research is registered with Norwegian Centre for Research Data (NSD).

Methodology

Applied Island Biogeography Theory

In this research I draw on the theory of island biogeography to look at elements of biodiversity and landscape sustainability. Farm borders are arbitrary boundaries, and the broader landscape plays heavily into the sustainability of an orchard (Nichols et al., 2004). One question in the sustainability survey, retained as a part of the original work by the UC Berkeley research group, rates sustainability based on the number of sides on which the orchard is bordered by native vegetation. This question is further delineated in the interview, where the details of the surrounding landscape are recorded.

The concept of island biogeography relates to agroecosystems by placing it in the broader context of the landscape ecology and recognizes the influences of fragmentation, disturbance, species migration and other elements that affect the equilibrium of the agroecosystem (Shinderman, 2015). Situating the agroecosystem in the broader landscape provides a greater understanding of the eco-region as a whole and the influence of the areas outside the orchard on the orchard's biodiversity.

In the theory of island biodiversity, the larger islands closer to the mainland are expected to have higher rates of biodiversity and recover more quickly from disturbance. This theory can also be applied to terrestrial landscapes within agricultural areas. Biodiversity hotspots within a large monoculture agricultural landscape are akin to islands, and can therefore increase their biodiversity and resilience by increased size or by allowing for more proximity to another biodiverse zone (Shinderman, 2015).

This ecological theory was applied by David James, who used it to study the impact of planting native species in vineyards (Shinderman, 2015). He looked at habitat enhancement within vineyard agroecosystems and how this could be viewed from a landscape ecology scale to test biodiversity and resilience in vineyards. His research showed that proximity to the next patch of biodiverse landscape improves the biodiversity of the area in question. Isolated patches of biodiversity are still biodiverse, but serve more as a habitat enclave or refuge than an effective habitat corridor within the broader ecosystem. The farther away a patch is from a like patch, the less likely that patch is to harbor various species of the region. This is expected based on what we know about species dispersal characteristics (Shinderman, 2015). Furthermore, the borders of an agroecosystem show higher ecological functioning than the center of a managed property, implying that habitat patches need to be installed within and throughout a larger managed property (Shinderman, 2015).

Measuring Sustainability: Importance and Challenges

Agriculture is a major contributor to global climate change (Gliessman, 2006). Sustainability in agriculture seeks to mitigate the negative environmental impacts of growing food. The concept of sustainability can also be applied to the economic vitality of a business to maintain consistent profit. Sustainability is difficult to measure because it is an attempt to measure something that is not there rather than something that is. It is simpler to recount negative environmental impacts and declare something unsustainable than it is to take into

account damage not being incurred and declare something sustainable. For example, it is much simpler to measure the amount of agrochemicals applied to a system and observe the impacts than it is to assume any impacts which have occurred as a result of not putting chemicals into the system. Despite these challenges, there are several emerging tools to assess sustainability qualitatively and quantitatively.

In this research, the metric for measuring sustainability is based on 'A Rapid, Farmer-Friendly Agroecological Method to Estimate Soil Quality and Crop Health in Vineyard Systems', in which sustainability is defined as the "productivity, stability, resilience and adaptability of agroecosystems" (Nichols et al., 2004). Productivity refers to the ability of the system to produce a desired output. Stability refers to a resistance to disturbance and a relatively stable degree of productivity. Redundancy in ecosystem structure and function often infers stability on a system. For instance, if there is more than one (redundant) population of microbes that convert ammonium to nitrate and a disturbance wipes out one population, that function (nitrification) will continue to be performed by the remaining populations (Gliessman, 2006). A concept related to ecosystem stability is the Intermediate Disturbance Hypothesis, which states that the highest levels of diversity are supported at intermediate levels of disturbance (frequency or intensity). Diversity is usually defined in terms of species demographics (such as species richness or the number of species present in a given area). Ecosystems experiencing intermediate levels of disturbance, will have the highest diversity, the greatest redundancy, and, therefore, the greatest stability. In other words, stability can apply to the number of species in an area or the number of functions performed (Gliessman, 2006).

Resilience is defined as the ability of the agroecosystem to recover from disturbance. An ecosystem disturbance can be a natural or human-induced stress. Examples of natural disturbances include hurricanes, tornados and wildfires. Examples of human-induced, or anthropogenic, disturbances would be tillage or pesticide application (Gliessman, 2006). Because agroecosystems have reduced structural and functional diversity, they have less resilience than natural systems (Gliessman, 2006). The expected outputs from the system (the yield) cannot be sustained without human inputs, therefore humans are an integral part of agroecosystems. Resiliency can refer to the ability of a single tree to overcome damage or the entire orchard. It can also occur on a larger landscape or even global scale. Our macro-scale concept of resilience is changing as we come to understand and deal with the realities of climate change as a force of disturbance in agriculture.

Adaptability refers to how the system responds to immediate and longer term changes, such as changes in management. Examples of this include shifts in production, changes in the amount or types of inputs, and variations in seasonal weather patterns and climate.

Sustainability issues did not have a strong cultural foothold during the explosion of the wine industry. There are strong comparisons between the current cider industry and the wine industry prior to its first global accolade. Cider may also make its mark on the global stage, and if there is an awareness of sustainable practices and a desire throughout the industry to produce a sustainably made product, the supply of cider could evolve in a manner much less impactful on local ecosystems than the wine industry is.

Results

Case Study 1

Tod Creek Cider, Victoria, British Columbia, Chris Schmidt

Overview of the Business and Location

This small scale orchard is located on a former dairy farm on the island of Victoria, British Columbia. It is in its second year of production. The owner, Chris, has other business dealings in apple production, which made a venture into the craft cider industry a natural extension. Agrotourism is also an element his business because the orchard is located near other major tourist attractions, most notably the Butchart Gardens.

In regards to growing practices, their website states that, "Tod Creek Craft Cider's apples are grown following Good Earth practices; we minimize or eliminate our use of chemicals and fertilizers where possible. Our integrated pest management program follows organic and holistic practices, as a few bugs here and there are ok. Live and let live. We purposely do not aim to achieve 'organic' status as it can be an expensive burden on a small cidery, but we love the earth our trees grow on and look after it accordingly. Fertilizers are kept to a minimum as nitrogen-deficient apples are better for craft cider. Since our apples are destined for the crusher, apple scab is not a concern" (Tod Creek Ciders, 2018).

One of the most notable features of the Tod Creek orchard are the trellised trees, a variety called M9 dwarf stock. The trees are small and grow in rows, much like a winery. This technique produces apples with greater frequency, higher yield, faster ripening, and the design allows for easier picking in the fall because there is no need for ladders. Also, if a tree is lost to canker (a common disease) it is easier to replace than a full sized tree.

The orchard is surrounded by forest or wetland on all sides. They do rely at least partially on pollination by native bees. Production was low this year because of an extended rainy season which caused the bees to stay dormant longer, so next year they will buy a hive of Mason bees (a native North American species). In regards to pests, they have issues with mice. Mice avoid wide open spaces, so currently they keep the orchard ground un-vegetated so that the mice have no place to hide.

Chris considers his biggest challenge being pressed for time to accomplish all the work that comes with this venture. If he hadn't already owned the land he would have never started this particular business. Although cider apples go for a higher price than a non-cider apple, the cost of owning an orchard, particularly a young orchard, detracts from the economic benefit. Chris's business has grown a fairly consistent 20% per year, but he notes that other cider businesses, such as Schilling Cider in Washington, have exploded in growth. Furthermore, Chris takes into consideration that the beverage market cyclic, and doesn't think cider will always be popular. He more interested into diversifying into soda production than further investing cider.

Agroecology and ecological implications at the agroecosystem and landscape scales

Converting this land from a dairy farm to an orchard led to a variety of ecological changes. The manure from the dairy farm added organic matter to the soil, and the constant tread of the heavy animals led to soil compaction, which results in low vegetation (Brady and Weil, 2012). Following the introduction of trees, roots stabilized and aggregated the soil to reduce erosion caused by compaction and accelerated the rate of decomposition of biomass on the orchard floor, improving humus formation (Brady and Weil, 2012).

Chris also observed an increase in birds after establishing his orchard, indicating an increase in habitat for wildlife and improved agroecosystem biodiversity. The presence of birds in the agroecosystem improves multiple metrics of the crop health status amoeba because they are natural predators to many common diseases and pests found in apple orchards.

The craft movement allows for variation in flavor, which mitigates pressure for the agriculturalist to manipulate the product to maintain consistency. To this end, Tod Creek Cider states that, "As a small batch cider, you'll notice that each year the ciders will vary slightly, much like a good wine does. Our apples will be influenced by the sun, the amount of rainfall, and other factors, so each year will yield a slightly different taste" (Tod Creek, 2018). The lack of pressure to provide consistency means less pressure to use pesticides, herbicides, and fungicides to keep the produce consistent.

Cider apples are best for making cider when they are slightly nitrogen deficient; this reduces the need for nitrogen fertilizer as an input to the system, reducing manipulation of the nitrogen cycle. There is still a slight risk of chemical leaching from this orchard considering the proximity to a water source and the fact there are still some fertilizer and pesticide inputs. Decreased nitrogen inputs in cider orchards will not contribute to decreased eutrophication of water sources unless phosphate use is also decreased. Phosphorous is the limiting nutrient causing excessive algae bloom, not nitrogen (Schindler et al., 2008). Therefore the use of both phosphorus and nitrogen in the system would need to be studied in order to reach a conclusion on the ecological impacts of the orchard on nearby water sources.

Agrotourism is a major element of the business. Agrotourism creates some additional pressure to provide an aesthetically appealing orchard, possibly influencing a slight increase in herbicide usage to control weeds. Other potential repercussions of agrotourism include wildlife disruption caused by crowds, which may decrease the overall biodiversity and presence of natural predators in orchard. Decreasing biodiversity and natural predators can lead to an increase in disease and pests, leading to the need for additional agrochemical inputs.

Case Study 1 is the only case study which scored a ten in regards to the amount of surrounding natural vegetation. Fruit trees are more contiguous with the surrounding forest than the environment created by a dairy farm, therefore likely reducing habitat fragmentation for wildlife.

The surrounding forest habitat is sufficient to harbor some degree of native pollinators. Additionally, the choice to purchase mason bees, a bee native to North America, may prove to be beneficial to native bee populations. There is a potential here for additional research on the broader ecological impacts of the choice to diverge from the standard honeybee.

One of the most notable impacts of Tod Creek's orchard is the trellis design. This design, although it improves safety and productivity of the orchard, may diminish the orchard's agroforestry potential. The root system of a dwarf tree is shallower than a standard apple tree, decreasing the tree's ability to aggregate the soil and reduce erosion (Brady and Weil, 2012). The

lack of shade would not decrease the ground temperature and improve water retention like a forest canopy would. Because of the distinct size and shape of the trees, the ecological impacts of this orchard may be more like those of a winery.

Although some of the restoration potential of the orchard is diminished by the trellis system, the presence of trees is nonetheless proving positive for reclaiming the soil from a more degraded state. The roots have improved soil quality, the local bird population has expanded its habitat range into the orchard, and native bees are using the apple blossoms as a food source. Furthermore, the value added to cider apples allows the orchard to subsist on a smaller scale, causing less overall impact on the landscape ecology.

Figure 1: Crop Health Status
Tod Creek Ciders

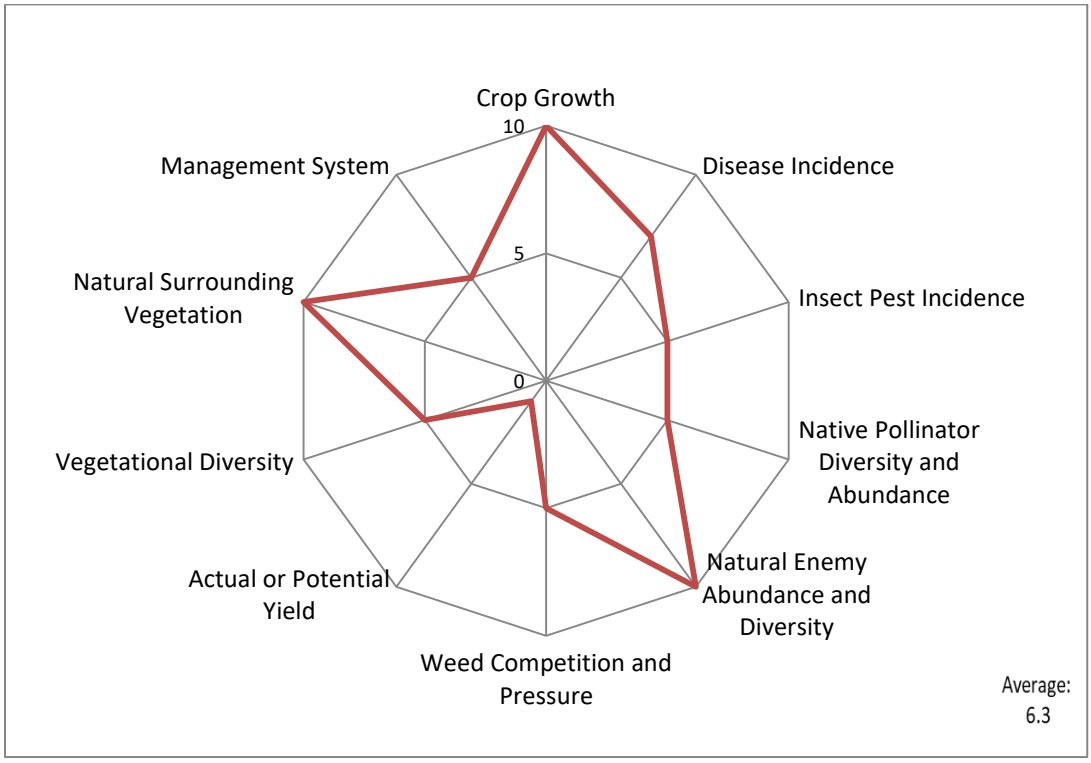


Figure 2: Soil Status
Tod Creek Ciders

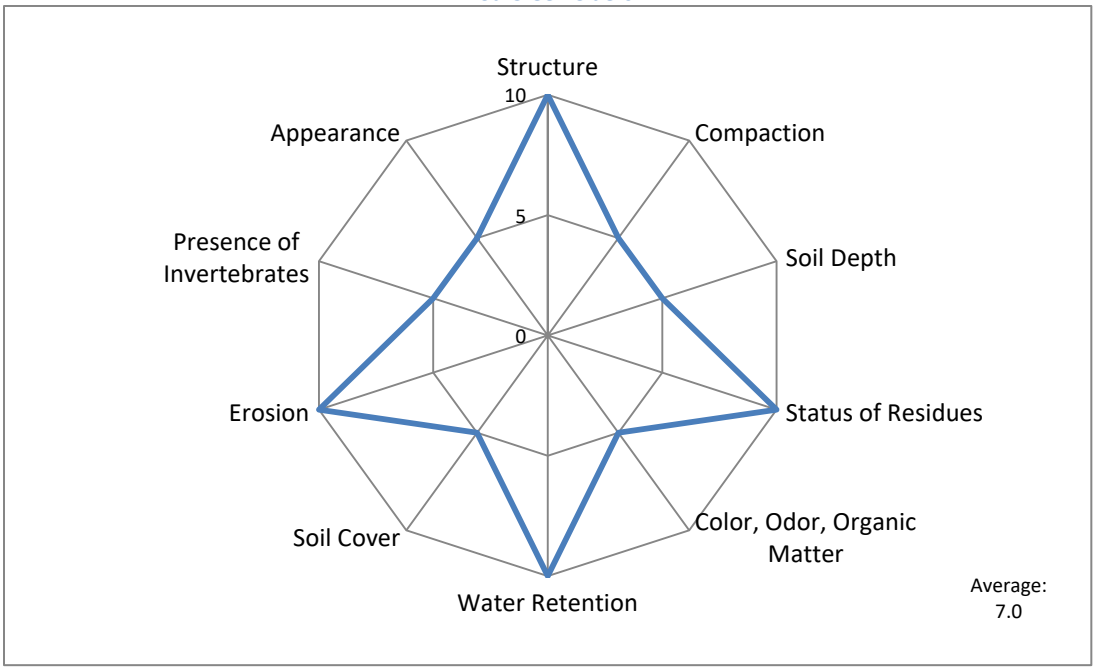


Figure 3: Trellised trees improve safety and productivity, but because of the distinct size and shape of the trees, the ecological impacts may be more like those of a winery. Shallower root systems have a decreased ability to aggregate soil and reduce erosion. Reduced canopy size increases ground temperature causing greater evaporative water loss.

Figure 4: Tod Creek Cider is the only case study which scored a ten in regards to the amount of surrounding natural vegetation. Fruit trees are more contiguous with the surrounding forest than the environment created by a dairy farm, therefore likely reducing habitat fragmentation for wildlife.

Figure 5: Image of survey site used to determine crop health status and soil status.

Case Study 2

Upper Valley Farms LLC, Mount Hood Parkdale, Oregon, Ed Salminen

Overview of the business and the location

Upper Valley Farms is a small-scale family run apple orchard. They grow mainly dual purpose (both culinary and cider) Jonagold apples. They first purchased the orchard in 2007 and immediately transitioned it to organic. They are listed as a supplier on the Pacific Northwest Cider Association webpage and are very involved in the blossoming cider industry. They are actively expanding to include some rare cider varieties (Upper Valley Farms LLC, n.d.).

Expanding into the cider industry makes economic sense for Upper Valley Farms, but that ultimately depends on the price of cider apples. Jonagolds were the 'hot apple' 20 years ago, but now the price is low. Ed considers selling apples for $300 per bin to cider makers preferable to what they have been selling them for as fresh packed. Ed started making his own cider, but now he sells most of his apples to the other cider makers who have recently started production in the Hood River area. Ed is hoping to create a symbiotic relationship with the cider makers in this area in the same way that winemakers and viticulturists have networked.

Their newly planted cider variety orchard just produced its first apples. They planted 300 cider trees in the new section of their orchard. They use trellised trees for most of the new plantings. Aside from the standard practices involved with achieving organic status, they also use crimson clover as a cover crop for the orchard floor, (although the cover crop does not extend past the orchard) they didn't initially fertilize, but now do some fertilization with pelletized composted chicken manure. They also rent honeybees. Ed Salminen's background as a hydrologist helped him design a system that evenly and efficiently distributes water throughout the orchard. They use a micro-drip irrigation system, and the property also features a retained central wetland.

In terms of pest management, codling moth is the main issue. Upper Valley Farms works with a representative from a local chemical distributor, who happens to be a neighbor, to treat the area with another virus *Cydia pomonella granulovirus* (CpGV), also known as codling moth granulosis virus. The commercial product name is Cyd-X (Witzgall et al., 2007). Additionally, they deal with fire blight and scab. Fire blight is a virus that can enter through the flower and ultimately kill the tree. Apple scab is merely an aesthetic blemish, but scab is a concern because they also sell culinary apples.

Agroecology and ecological implications at the agroecosystem and landscape scales

There is a deliberate focus on best environmental practices. The property is surrounded by natural vegetation on every side, primarily temperate pine forest, with a conserved natural wetland in the middle of the property. They also use crimson clover on the orchard floor, a nitrogen-fixing legume. Cover crops improve several metrics of the crop health status and soil health status amoebas.

The design element of the central wetland space has a large impact on the agroecosystem. It provided an additional habitat for improving wildlife biodiversity, and serves as an additional corridor to maintain continuity of habitat between cultivated and uncultivated land. The wetland includes a variety of native trees species. The inclusion of non-apple tree species provides

additional plant biodiversity. The wetland cleans and filters as well as distributes water throughout the soil and improves the water holding capacity of the soil (Brady and Weil, 2012).

The environmental conditions in this region are excellent for agricultural productivity. There are also conservation agricultural practices at this orchard which promote long-term soil health. The organic management and cover crop, as well as no-till practices and leaving biomass on the orchard floor all contribute to a high soil organic matter content (Brady and Weil, 2012). The production of cider in the area is a natural extension of an already well established fruit tree industry. The soil is good for agriculture, and there is normally no water shortage in the area, so fruit production does not greatly stress resources as it might in a more arid climate.

In terms of wildlife, there are lots of birds and the occasional cougar, bear, deer, and elk. They have not noticed any changes in wildlife since beginning their operation, likely because the orchard was already in place. The elk cause some problems in the orchard because they are heavy animals and can compact the soil, regardless, they choose not to ward off animals. When Ed was formulating his organic plan and he was asked what he planned to do about birds in the orchard, his response was, "share". The promotion of birds in the agroecosystem improves 'the presence of natural predators' metric in the crop health status amoeba. Since birds are natural predators of codling moth and other apple pest insects ("Pest Management Options: Birds and Bats for Pest Suppression", 2011) their presence can also improve the metric of 'pest and disease incidence'. Although notably, the ecological impact of renting bees is a current area of research which may impact native bee populations (Jepsen, 2015).

They have observed less elk travelling through the orchard this year, and Ed suggests that there may be some change in patterns of elk migration caused by fencing in the area. Their original orchard isn't fenced, but the new section of apples does have a fence around it. All of their neighbors like the elk, and want to keep them around, but there is no comprehensive plan to keep a route open for them. There is potential here for an ecoregional approach to managing agriculture and wildlife migratory patterns to increase biodiversity across the landscape.

The natural enemies of the codling moth include birds, spiders, insects, nematodes, bacteria, fungi, protozoa, and viruses. Of these, birds are the primary natural enemy. They can eat the codling moth in the larval or the adult stage. Woodpeckers are one of the primary species which prey on codling moth (Falcon & Huber, 1991).

Cooperating with neighboring farms provides a large area of quarantine for the codling moth virus, and is necessary to reduce the risk of introducing new untreated mating partners into the orchard (Witzgall et al., 2007). Notably, pear is the other major host of codling moth (Falcon & Huber, 1991) and another major fruit tree crop cultivated in this area. This is a consideration for cider orchards looking to expand into perry production. Current research suggests that pheromone mediated mating disruption improves codling moth natural enemy populations because of the reduction of insecticide use, which can be harmful to birds and other animals. Codling moth did become resistant to other methods of chemical control, most notably to DDT. The drawbacks of insecticide use were a major factor in the development of this control method (Witzgall et al., 2007).

Figure 6: Crop Health Status
Upper Valley Farms LLC

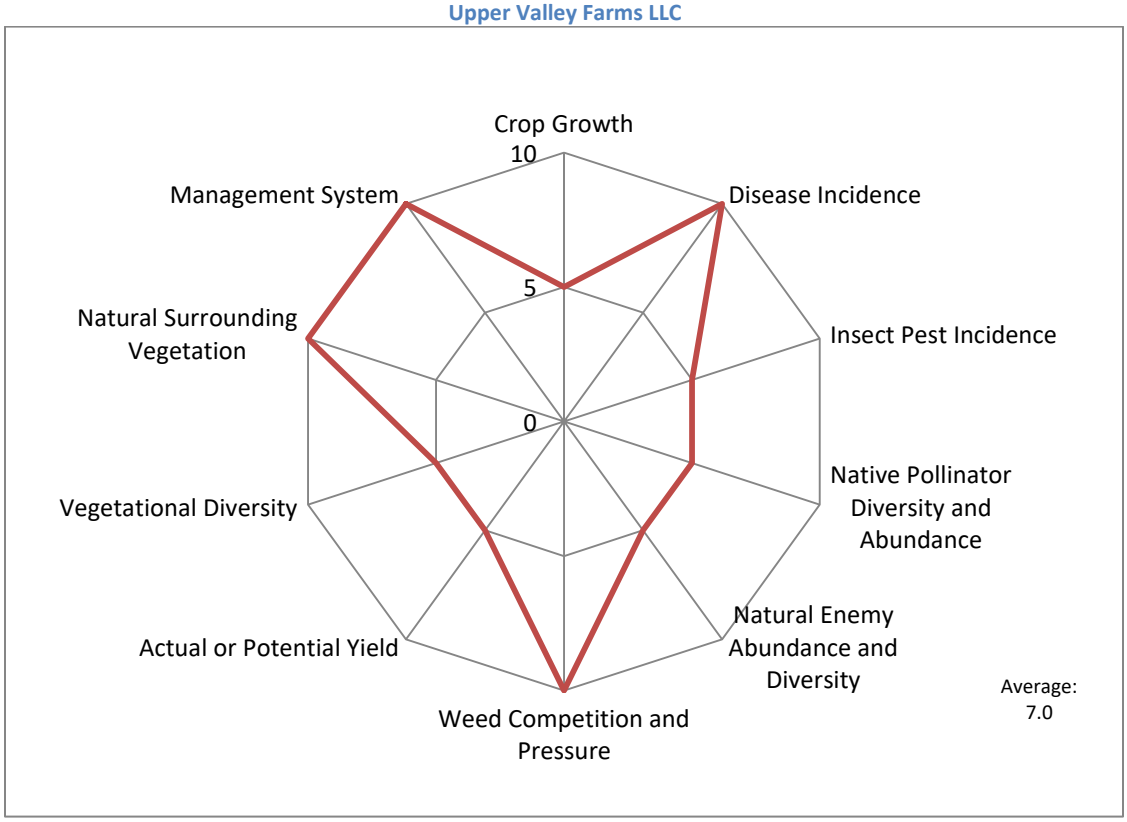


Figure 7: Soil Status
Upper Valley Farms LLC

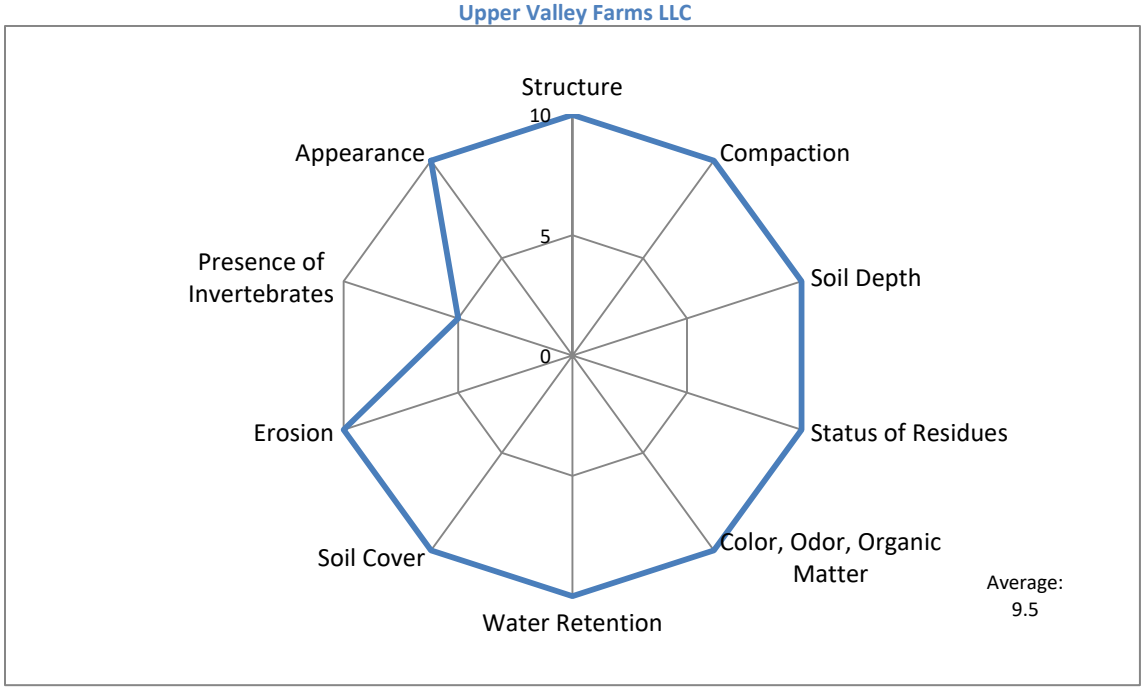


Figure 8: The central wetland space serves as a corridor to maintain continuity of habitat between cultivated and uncultivated land, improving biodiversity as described in applied island biogeography theory (Shinderman, 2015). The wetland cleans and filters as well as distributes water throughout the soil and improves the water holding capacity of the soil (Brady and Weil, 2012).

Figure 9: Orchard expansion of 300 cider trees, most of which are trellised. The ecological impacts of trellised trees may be more like those of a winery than an orchard.

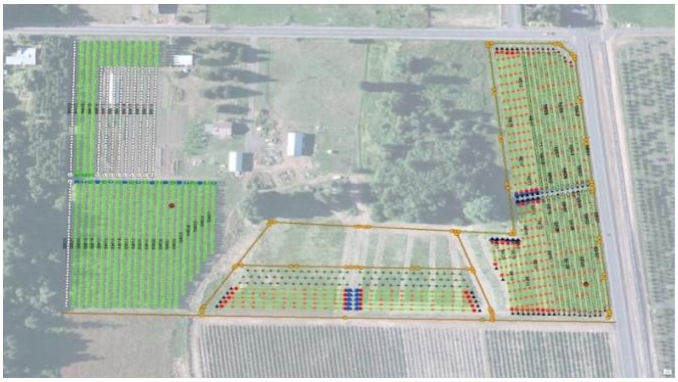


Figure 10: Orchard map of Upper Valley Farms LLC showing orchard expansion and bordering landscape with a mix of agriculturally developed land and native vegetation.

Figure 11: Image of survey site used to determine crop health status and soil status with a close-up of soil.

Case Study 3

Santa Cruz Cider Company, Santa Cruz, California, Nicole Todd

Overview of the business and the location

The orchard is described by Nicole as an old orchard with new elements. The older portion of the orchard consists of mature Gravenstein trees planted back when California was a major producer of apples. The new parts of the orchard are a mix of desirable cider apple varieties. The owners of this property used to work for Martinelli's, a very popular US apple juice company, but are now retired and lease the property to Nicole and the other operators of the Santa Cruz Cider Company.

The old orchard was planted in 1880. Its heyday was from around 1910 through 1950. It stopped being managed around 2000. Since Nicole and her partners took over in 2015 they have put in about 100 new trees, 60 of which are cider trees. The remaining trees were Fuji so they can continue to sell to Martinelli's. They will also be grafting cider varieties onto some of their existing trees.

The owners are very interested in sustainability, and are taking many steps to improve the function of the agroecosystem with new techniques and management strategies. The property is under intense development pressure and has been placed in a land trust to remain an apple orchard. As part of this transfer, it is undergoing a transition to a more sustainable system.

Nicole explains that while there is economic potential in cider, there's not much money in growing apples. They consider their work in the orchard to be a labor of love unless they decide to scale up to the level of the Mann orchard (their neighbors, who are detailed in case study 4). Currently The Santa Cruz Cider Company has two lines of cider, a more affordable entry level version using purchased juice, and a higher quality line made from local apples.

Nicole mentions that Santa Cruz is a great area for the craft movement. Nicole thinks cider is riding on the coat-tails of the craft beer movement, and predicts the industry will continue to grow.

Agroecology and ecological implications at the agroecosystem and landscape scales

Many of the prominent ecology-based design elements of the orchard are a direct result of the resources and requirements of the land trust and the local conservation district. For example, this property received state funding to build a wetland space with a pond and a variety of native vegetation designed as a habitat refuge for the native red-legged frog. The work being done with the conservation district makes this property an important case study to showcase the potential of an orchard to serve as a biodiversity hotspot in a landscape shifting from rural-agricultural to rural-residential.

The wetland space provides multiple ecosystem services. It is developing as a habitat refuge for a threatened native species, the red-legged frog. The inclusion of non-apple tree species provides additional plant biodiversity, and improves overall biodiversity by providing habitat for other organisms. The wetland cleans, filters, and evenly distributes water throughout the soil (Brady and Weil, 2012). Wetlands also improve the water holding capacity of the soil

(Brady and Weil, 2012). The wetland is a new addition to the property, but as species begin to establish themselves this design feature will continue to improve the ecological balance of the system. The inclusion of wetlands and riparian buffers improves multiple metrics of the soil health and crop health status amoebas.

Like multiple other case studies, this orchard is not certified organic because the process is expensive and overly burdensome; regardless, they never spray agrochemicals, nor are their management practices intensive. They have some issues with codling moth and the occasional aphid, but overall have few problems with disease. Currently the orchard floor is sparsely vegetated, but they are in the process of installing a cover crop. Cover crops improve several metrics of the soil health status and crop health status amoebas.

Irrigation is currently done by hand with hoses. Their current irrigation practices to do not take salinization into consideration. They are charged a residential rate for their current water usage, and because of frequent periods of drought, water is an expensive resource. Nicole's response when asked about the biggest challenge of operating an orchard and a cider company is the high price of water. The previous year, the cost of water was higher than the value of their trees. To combat this problem they dry farm the older orchard and have recently installed one of what will total five rain collection tanks. They have also received funding through the land trust and conservation districts for a more efficient irrigation system.

They leave all biomass on the orchard floor for decomposition. They are surrounded by other orchards on all sides, one is conventional, and the other has gone fallow. In terms of wildlife, they have plenty of birds; including hawks, turkeys, vultures, owls, barn sparrows, blue jays, and scrub jays. They also see bats, stray cats, coyotes, raccoons, skunk, gopher, and deer on the property.

They have issues with deer and gophers destroying the trees. They have installed a deer fence around the property. Gophers residing in the orchard have caused significant root damage to trees. They have six or seven snakes permanently residing on the property which feed on the gophers. Part of the rationale for not spraying any pesticides on the orchard is that they worry the snakes may be killed through bioaccumulation, and they have been very successful natural predators in the system.

They haven't rented bees but their productivity was too low this year, so they are looking for a solution. Given that the orchard did not have enough native pollinators for sufficient productivity suggests the need for an ecoregional approach for the conservation of native pollinator habitat. There is little native vegetation immediately surrounding the property, and the surrounding area is increasingly developed. It would require collective action to decrease habitat fragmentation for native pollinators. It is preferable from a landscape conservation perspective for agroecosystems to serve as habitat corridors rather than a habitat refuge in a developed landscape. This concept relates back to the idea of applied biogeography theory to agricultural landscapes as a strategy for conservation (Shinderman, 2017).

Lastly, the baseline price for apples in this area is set by Martinelli's. Martinelli's recognizes that the cider apples are worth more per pound, so they pay extra for dual purpose varieties used in their blend. Likewise, Nicole pays more for the cider apples her company purchases. There is price competition for select varieties of apple and the higher price allows for the supply side to exist on a smaller scale, leading to less extensive ecological impacts.

Figure 12: Crop Health Status
Santa Cruz Cider Company

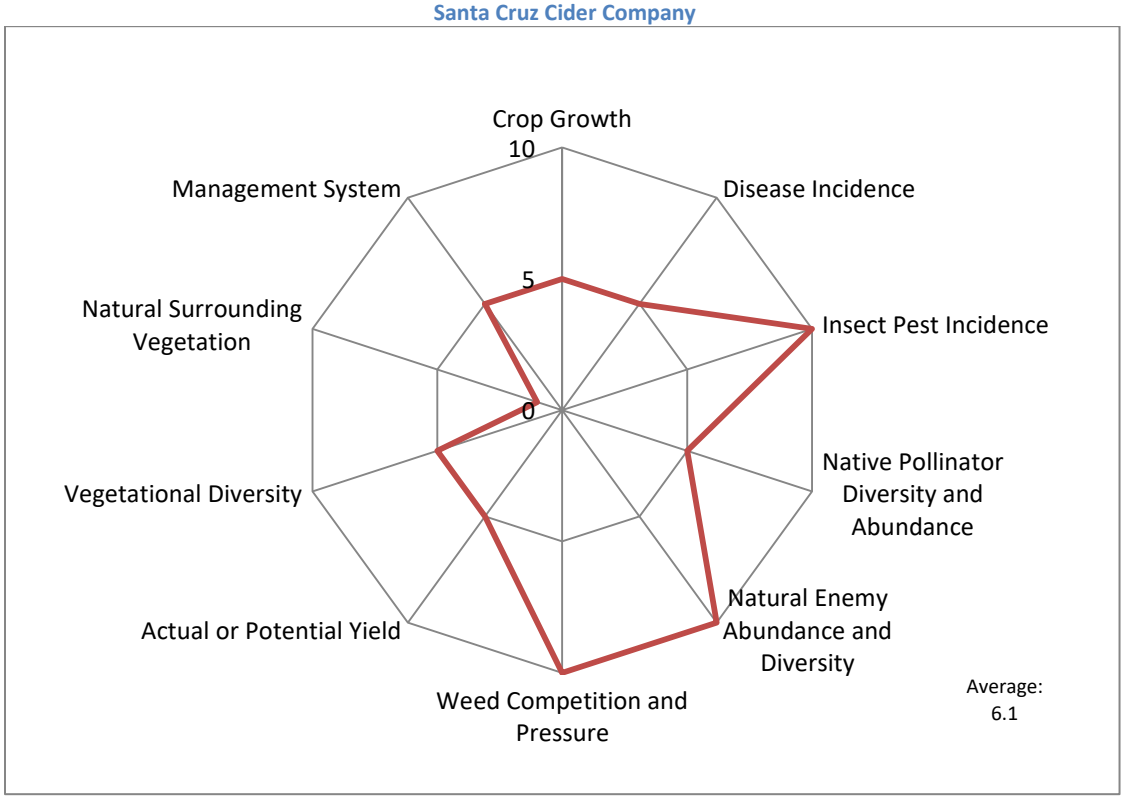


Figure 12: Soil Status
Santa Cruz Cider Company

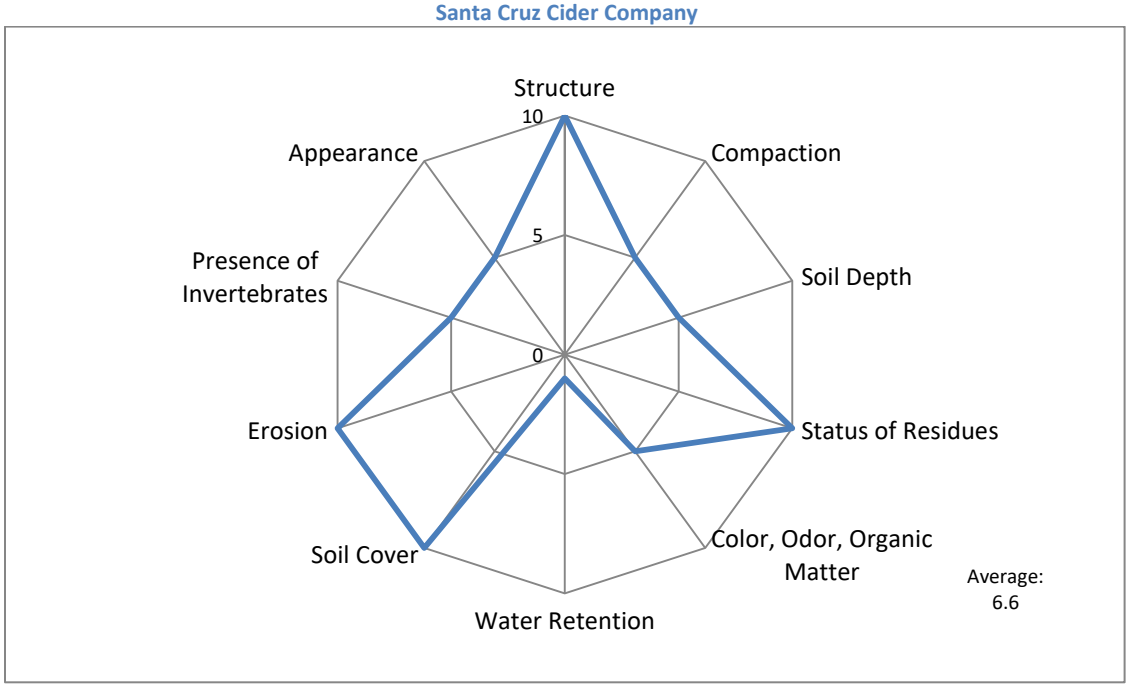


Figure 13: Mature Gravenstein trees planted back when California was a major producer of apples. The old section of the orchard at this site was planted in 1880 and its heyday was from 1910 to 1950.

Figure 14: The newly installed wetland provided by the conservation district serves as a habitat refuge for the red-legged frog, a threatened native species. The wetland is a new addition to the property, but this design feature will continue to improve the ecological balance of the system. The inclusion of wetlands and riparian buffers improves multiple metrics of the soil health and crop health status amoebas. The work being done with the conservation district makes this property an important case study to showcase the potential of an orchard to serve as a biodiversity hotspot in a landscape shifting from rural- agricultural to rural-residential.

Figure 15: Image of survey site used to determine crop health status and soil status with a close-up of soil.

Case Study 4

Mann Family Ranch, Watsonville, California, Jake Mann

Overview of the business and the location

The Mann Family Ranch is a large-scale orchard that has been in the family for five generations. It produces many varieties of apples for culinary uses, apple juice, and more recently cider. The Mann Family Ranch is a longtime producer of Newtown Pippin apples. The Newtown Pippin trees on the property are 75-80 years old, and the trees growing at Jake's parent's property are approximately 100 years old. There is a lot of conversation about Newtown Pippins in the cider world because it's a distinctly American apple.

Jake is very involved in the cider community and the sustainable food movement. He serves as a judge for the Good Food Awards, which promotes sustainability in food production, and annually attends CiderCon, a nationwide conference of cider industry professionals.

Currently, the wine industry has a big spread in the quality of fruit they buy, and Jake thinks cider might evolve in a similar way. From a business perspective The Mann Family Ranch is looking to supply the middle ground in the marketplace. From Jake's perspective apple growers will need a higher value for their product in order to survive, and in his words, "he'd be silly not to get involved (in cider) and he's excited to be part of the conversation."

The Mann Orchard plans to start incorporating more cider varieties like Kingston Black that can be sold to cider makers for a premium. They will do some of this expansion through grafting. Unfortunately, there aren't many cider-variety grafting materials or nursery trees available to purchase. The availability of cider cultivars is a limiting factor to expansion for several case studies. Jake anticipates harvesting two bins of cider apples this year, which is their third year of production.

The management across the property varies widely, the larger part of the orchard is run conventionally, but one segment is undergoing the conversion to organic, which takes three years. The organic segment consists of dual purpose Newtown Pippin apples that will be sold to cider makers and also to Martinelli's apple juice, who requires Newton Pippins for their apple juice blend.

Jake Mann was raised and educated in a different era of agriculture and food production than his parents were, so he brings a slightly different attitude to managing an orchard, choosing to take a more holistic approach than some of the super tidy commercial operations nearby.

Some of the trees are irrigated and some are dry farmed. They use a variety of irrigation types, and adapt their irrigation practices to the weather. Unlike their neighbors in case study 3, the Mann property uses well water rather than city water, which is shared by a few other farms. Agriculturalists in California are generally cautious and aware of water shortage. As of yet there have not been any water conflicts amongst neighbors in this area. That said, the water needs of apples are far less than the needs of berries, and because of their high market value, a large part of the Watsonville landscape, including the bordering farm at one of the Mann orchards, has converted to blackberry production.

The orchard is actively managed. The trees don't experience an overwintering period. Prunings are raked into the middle of the row and shredded. They primarily just mow grassy areas but occasionally disc. They leave biomass in the center of the row, then prune and shred it which will increase the rate of decomposition and improve the topsoil (Brady and Weil, 2015).

They are starting a cover crop this year although it is difficult to establish and maintain full ground cover growing through the hot, dry summer. They will plant bell beans and add in clover after discing. The older orchard at the Mann property has strong turf, but achieving that has been the result of 20 years of work.

They are using this newest plot of trees to test out incorporating organic production. For now, they aren't strictly organic, so they have the benefit of being able to use chemicals if an issue suddenly gets out of hand, but prefer not to unless it's necessary.

Pests and diseases are addressed through a variety of strategies with an IPM (Integrated Pest Management) plan. To prevent codling moth, they use codling moth pheromones. They currently do three sprays throughout the year. The product they use is designed so that over time less and less of the pheromone can be used as the pest population becomes eliminated (Witzgall et al., 2007).

Scab is another issue for the orchard. Currently they treat scab by spraying a fungicide. Because the fungus which causes scab decreases the tree's overall productivity, Jake is inclined to continue containing its spread among his cider trees even though the aesthetic blemish caused by scab is irrelevant for apples which will later be pressed. Sulfur is the organic alternative for fungicide, but Jake notes that this is still a very harsh material.

They use an herbicide on the rows, and manually weed some sections. Jake states that he does not like the effects of Glyphosate (Roundup) on the environment (Casteel, n.d.), so they limit its use and are seeking alternatives. Previously, they prescriptively sprayed Lorsban, an aphid spray, but have been laying off in recent years. Following the reduced application of Lorsban, they have seen an increase in ladybugs. Jake has noticed natural predators returning to the orchard, but in his words, "sometimes it takes a moment of patience".

They rent bees for pollination. They get about one box per acre. The bees that come to the property rotate between almonds and apples in California, and clover in North Dakota. They are not aware of any native bees in their area but are interested in looking into it more.

The use of the pheromone for codling moth is a biocontrol which avoids the use chemical sprays and associated negative effects (Witzgall et al., 2007). As mentioned in the previous section, a reduction in the use of the commercial aphid spray Lorsban (Chlorpyrifos) may be leading to a return of ladybugs, a natural predator to aphids.

In terms of wildlife, the orchard hosts jack rabbits, red-tailed hawks, barn owls, and other birds. Birds are natural predators to many common pests. They also have gophers and ground squirrels, both of which are problematic in the orchard. They are wary of these animals because they tunnel through the roots of the trees, causing them to topple. They have done shootings in the past, but are hesitant to use poison bait because of secondary poisoning of the birds. Owls and cats are both seen in the orchard occasionally and are predatory towards gophers. Gophers are also a pest at the neighboring orchard (case study 3), indicating that there may be a larger regional ecological imbalance, such as a low population of predator species which could be addressed through an ecoregional approach.

There is a ditch at one of the orchards which is planted with oak and other varieties of grasses which serves as a wetland and windbreak. They left some oaks growing in the ditch and consequently noticed fewer weeds because they were being outcompeted by ferns, so they decided to expand it along the length of the ditch. According to Jake this vegetated ditch keeps spray off their neighbor's properties and blocks the undesirable view of endless berry production. This agroforestry technique provides an additional habitat for improving plant and wildlife

biodiversity. The wetland cleans and filters as well as distributes water evenly throughout the soil and improves the water holding capacity of the soil (Brady and Weil, 2015).

Recently they have seen more intense heat waves in September that cause sunburn on the plants, so they hope the oaks will eventually provide more shade. There are also a few old tall non-apple trees on the property for this purpose. For agrotourism purposes, which aren't currently happening but may in the future, Jake thinks that some of the older trees as well as the oaks will improve visitor's experience.

Agroecology and ecological implications at the agroecosystem and landscape scales

This case study serves as an example of a larger scale producer shifting towards more sustainable practices. Although there is no baseline measurement, based on the interview, the ecological impacts of this orchard seemed to have changed significantly over the years. The shift towards sustainability does appear to be slightly influenced by demand from cider makers for sustainability, but occurred primarily out of a sense of environmental responsibility on the part of the apple grower.

According to Jake, not many cider makers are concerned about getting apples from someone with an organic certification, but they are concerned about responsible growing practices. This implies that there is a sense of environmental responsibility across the network, although further research would need to be done to understand the full extent of agricultural chemical use among cider orchards. That said it is worth noting the use of agricultural chemicals has not been totally eliminated at this orchard, and each chemical will alter the agroecosystem and broader ecosystem in specific ways.

Based on his experience, Jake recounts that the standard orchard method used in large scale eastern Washington orchards is to rip out trees every twenty years after their peak productivity, fumigate the field, and replant for maximum productivity per acre. The Mann Ranch doesn't have the economics to do that, and retain their trees for much longer periods of time. The well-established roots aggregate soil and decrease erosion (Ontl and Shulte, 2012). The implementation of ground cover, which is currently underway, is a single management change which will improve all metrics of the soil health amoeba. Ground cover improves topsoil through decreased erosion and improved decomposition and aggregation of soil (Brady and Weil, 2012).

The implementation of the wetland space is another deliberate agroforestry technique that has an overall positive impact on the agroecosystem. More specifically, this design feature is considered a riparian (streamside) forest. The wetland space adds to the biodiversity of the system with the oaks, which creates additional habitat for ferns and other species of insect and smaller animals. The oaks over time would provide shade, decreasing ground temperature and sunburn to the apple trees. Wetlands serve as a filter for agricultural water. Riparian forests act as living filters, and play a significant role in improving water quality by filtering sediment, nutrients and pesticides ("Benefits of Riparian Forest Buffers", n.d.) . Considering that agricultural chemicals are occasionally used on the property and are used by surrounding farming operations, the wetland space is a valuable management tactic for mitigating potential environmental repercussions of agrochemical use.

At the broader landscape level, Martinelli's is acting as a force of conservation for apple orchards in the area. In regards to the supply and demand of apples in the Watsonville area Jake states, "If you have apples you can sell them. But no one is converting land from berries to apples because berries get much higher rent. Martinelli's are concerned about maintaining

orchards carrying Newton Pippin because they would rather have a local supplier than pay shipping on apples from somewhere far away." The Mann orchard is maintaining a degree of biodiversity in the larger landscape by continuing to grow apples rather than shifting to the highest market price crop. The orchard could be serving as a habitat refuge for species that cannot survive in blackberry fields, and the presence of trees may be improving carbon sequestration and air quality for the region, but broader scale research would need to be done for conclusive evidence.

Given that blackberries are self-pollinating, it is possible that native pollinator populations are already decimated in a landscape with a high degree of monoculture blackberry production, which means that not renting bees could result in major productivity losses to the Mann orchard. Research on crop pollination from native bees at risk from agricultural intensification found that organic farms near natural habitat harboring native bee communities could provide full pollination services without the intervention of managed honey bees, even for a crop with heavy pollination requirements; while other farms experienced greatly reduced diversity and abundance of native bees resulting in insufficient pollination services from native bees alone. This research concluded that landscape diversity is essential for sustaining the ecosystem service of pollination by native bees. Continued degradation of the agro-natural landscape will destroy this "free" service, but conservation and restoration of bee habitat are potentially viable economic alternatives for reducing dependence on managed honey bees (Kremen et al., 2002). In regards the Mann Family Ranch, shifting to any degree of native pollination would require the creation of habitat for native bees within the agroecosystem or a larger ecoregional approach to reducing habitat fragmentation for native pollinators.

As mentioned earlier in the case study, Jake has been noticing more intense heat waves in September, and is hoping the oaks planted in the riparian forest area will mitigate that. It is probable that as farmers adjust to climate variations associated with climate change, agroforestry practices will become more favorable. The FAO promotes agroforestry practices for this purpose (Graziano da Silva, 2016).

The results of the survey for this site are indicative only of the section of the orchard surveyed. Given the scale and range of management techniques of the orchard, multiple surveys would need to be done to fully understand the sustainability and ecological impacts of the property. Although much of the broader sustainability of the orchard can be qualitatively assessed through this interview, the survey site was chosen based on the parameters of the research, and the limitations of the survey should be kept in mind.

Figure 16: Crop Health Status
Mann Family Ranch

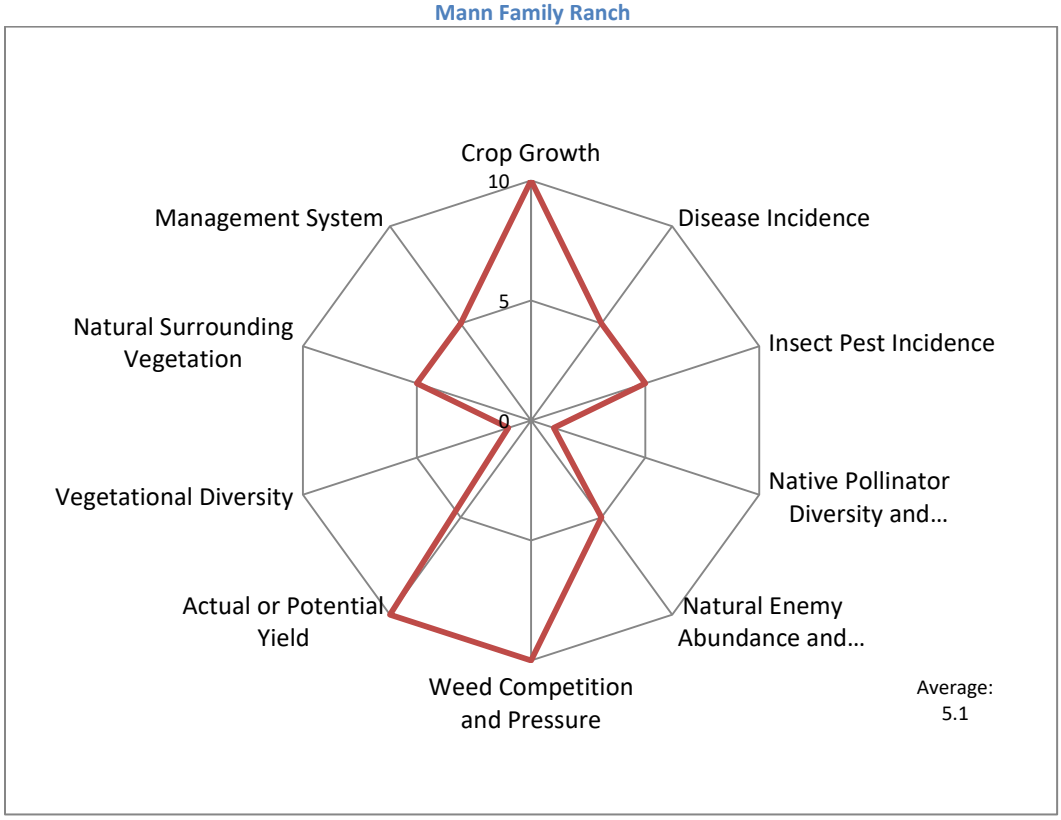
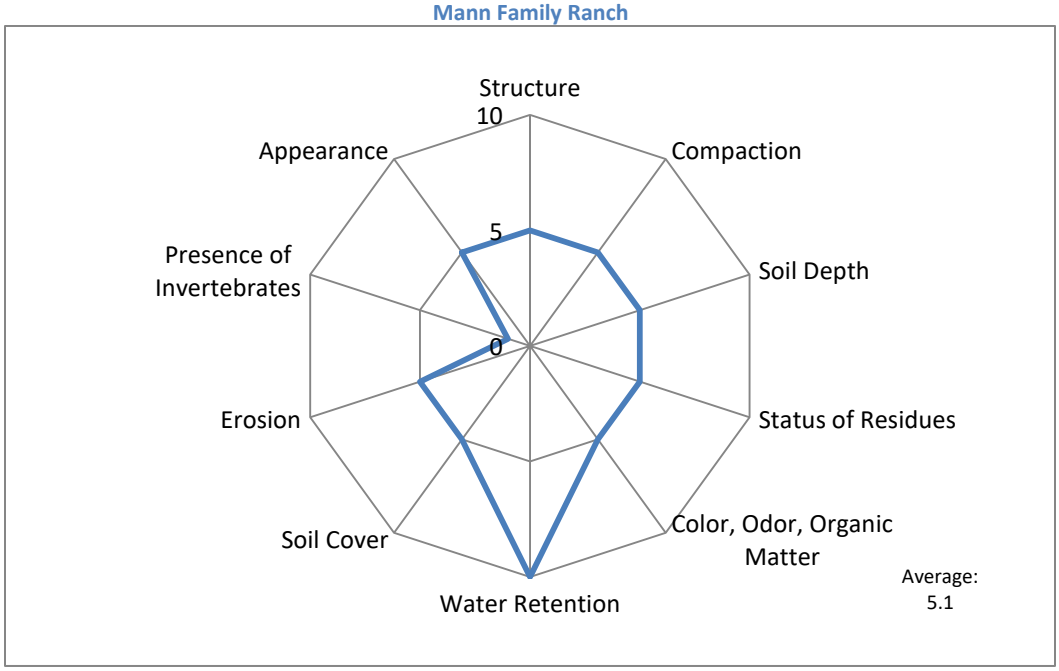


Figure 17: Soil Status
Mann Family Ranch



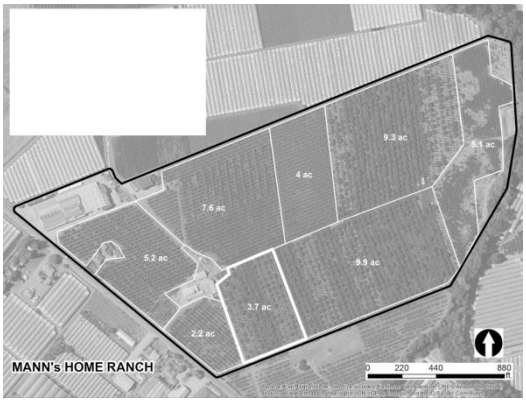


Figure 18: Orchard map showing total acreage. This case study serves as an example of a larger scale producer shifting towards more sustainable practices.

Figure 19: A riparian (streamside) forest buffer improves biodiversity, provides shade, filters agricultural runoff, acts as a windbreak, and blocks views of endless berry production seen here in the background.

Figure 20: Image of survey site used to determine crop health status and soil status with a close-up of soil.

Case Study 5

Nana Mae's Organics, Paul Kolling, Sebastopol, California

Overview of the business and the location

Paul Kolling leases and operates small apple orchards on patches of land spread across the north San Francisco Bay area. All of the orchards are organic, but the management of each orchard varies slightly, depending on the conditions of the lease. His preferred management style is organic and dry farmed with minimal intervention.

Paul and his brother bought a 25 acre property and eventually worked their way up to leasing an additional 500 acres, but have since scaled back. Competition with other types of development have made things more difficult and now he is looking toward retirement. He and his brother have run about 100 different orchards scattered all throughout north San Francisco. They call themselves 'nomadic apple farmers'. They need such high acreage because dry farmed trees are lower in productivity. When they began acquiring properties, apple prices were at an all-time low, so they went around knocking on doors and leasing orchards or collecting the fruit from people looking to get out of the apple business. They saw it as advantageous to take over the entire market for apples.

They converted to organic from the beginning. They then started to make their own juice, and soon after their own applesauce and apple cider vinegar. They sold these items under Nana Mae's Organic, the company they started in 1994. Paul has been making his own hard cider for years, but started making it commercially after they had a bumper crop. Their cider is now sold under the name Specific Gravity Cider.

The survey site was at a dry-farmed, organic, low input, well-established Gravenstein orchard in Sebastopol. He uses the perspective of a forester or an ecologist to evaluate the orchard system. Paul refers to it as a wild orchard because it is designed to mimic a forest, with deliberate focus on the ecological function of the system.

The surrounding area of the survey site is classified as rural residential. The two properties which bordered the survey site were emblematic of the impact of differentiating agricultural management styles on the landscape. One bordering property was a second orchard leased by Paul. At this property the owner preferred that the orchard be more actively managed. The other adjacent property was a small, intensively managed, young vineyard typical of northern California's wine country.

Agroecology and ecological implications at the agroecosystem and landscape scales

Since Paul does not irrigate this orchard, he works to maintain conditions for a high degree of moisture retention. He maintains full ground cover for this purpose. Ground cover also significantly decreases soil erosion (Brady and Weil, 2012). The mature trees provide a broad band of shade which reduces ground temperature and maintains soil moisture. Overall productivity is reduced during the dry season.

There is an understory in the form blackberry bushes. There are some oak trees in the survey orchard as well as a large redwood on the adjacent property. The trees are widely spaced

in a non-uniform pattern. The trees are not pruned and left to develop their own patterns of growth.

There are several animals on the property. There are a number of birds; while on site we witnessed woodpeckers and a family of quail which resided in the blackberry bush. There is no IPM plan. Paul used to rent bees but has stopped in recent years. He has witnessed native pollinators visiting this orchard and also believes that many bees from neighboring beekeepers migrate into this orchard.

Gravenstein is a dual purpose apple and a traditional cultivar of the region. Today, most Gravenstein orchards in the region have been converted to vineyards. During the past six decades, Sonoma County's Gravenstein orchards have declined by almost 7,000 acres and are currently down to 960 acres. There are only six commercial growers remaining in Sonoma County. Together, their crop totals 15,000 tons of Gravenstein apples a year (Slow Foods USA, 2018).The Slow Foods Presidio project and Slow Foods Foundation for Biodiversity are working to promote the Gravenstein apple and support local farmers in the Sonoma area to preserve the cultural heritage of the Gravenstein (Slow Foods USA, 2018).

Gravenstein apples are valued for their excellent juice making qualities, and this translates into a quality cider. The growing conditions of the fruit impacts the final product after fermentation. Consistent characteristics of fruit of a specific origin are referred to as *terroir* in the wine industry. There is discussion and debate as to whether *terrior* is a factor in producing North American ciders at this early stage in the beverage's resurgence in popularity. According to recent data from the research firms IRI and Nielsen 'big cider' has decreased in sales by volume while sales of 'regional/local cider' have escalated, increasing 50% from 2015 to 2016 (James, 2017). Jonathon Carr of Carr's Ciderhouse, interviewed for an article in the magazine Cidercraft about identifying regionality in cider states that "Cider does not deserve to be taken as seriously as wine until it consistently produces magnificent place-based ciders from specific superior varietals carefully grown in favorable locations" (James, 2017). As cider develops as an industry, *terrior* will develop with it.

Regionality in cider, particularly in the case of the Gravenstein could help to preserve the legacy of this apple variety. Sebastopol is already a premiere region for pinot noir and has the potential to provide that same status to cider. The Gravenstein is well adapted to the Sonoma climate, and would not be as successful in other major apple growing regions such as eastern Washington due to hot summers.

This system is well balanced and receives and overall high score on the metrics used for this research. Sustainability of the system comes from the deliberate focus on minimally invasive practices. This approach does sacrifice productivity for sustainability, but financial value is added through the price of organic fruit and value added products.

When questioned, Paul stated that he doesn't believe in the concept of an orchard going fallow, rather a decrease in productivity is a normal side effect of decreasing intensive management and moving towards a system that mimics the ecology of a forest. He stresses that individual organisms (such as the apple trees) and the system as a whole, have the capacity for resilience. Resilience to stress is key part of the overall function of the system.

The blackberry bush is providing multiple ecosystem services; a sellable product for the farmer, a niche habitat for quail, and improved soil water retention. Blackberries only grow where there is sufficient moisture. According to Paul, pulling the blackberries out would dry up the area where they were growing, making dry farming harder. The blackberries also provide habitat which improves the overall biodiversity of the system. While on site we observed a

family of quail residing in the bush. Paul harvests and sells the blackberries, using them to improve the financial viability of their operation.

Other wildlife present in the system included deer, fox, coyote, spiders, wild turkey, woodpeckers, and other birds. Woodpeckers are a natural predator to codling moth, a common orchard pest. This is an example of how improving biodiversity can improve multiple metrics of the crop health status amoeba, in this case improving both insect pest incidence and natural enemy abundance and diversity. Paul reported a very low incidence of disease and insect pest incidence likely because of the presence of natural predators in the system.

The spacing of the trees in this orchard mimics a forest's non-uniform pattern of spatial distribution. The trees are not densely planted into rows, which decreases the likelihood of rapid disease spread through the agroecosystem.

The presence of orchards improves landscape biodiversity. The Gravenstein trees have been designated as an apple that will maintain agricultural crop biodiversity and agricultural heritage by the Slow Foods Foundation (Slow Foods U.S.A., n.d.). The system is less likely to serve as a corridor for wildlife because the bordering landscape contained no wild spaces, but may be serving as a refuge among the vineyards and housing development for some species, and provides food sources for native pollinators since grapes are not pollinated by bees.

Dry farming is another important element influencing the sustainability of the system. The dry farming technique functions well in this system because the trees are well established with extensive roots systems, allowing them access to more water deeper in the soil. The roots of trees and ground cover are serving to aggregate and stabilize soil which allows for better percolation of water (Brady and Weil, 2012). This improves water retention by decreasing water runoff and soil erosion. The vegetative ground cover improves the humus layer, providing improved water retention and decreasing soil temperature which decreases evaporative water loss from the soil (Brady and Weil, 2012). A dry farming system functions differently depending on the crop and location, but is more complex than simply not irrigating. It requires attention to developing the necessary conditions for which irrigation can be removed as an input ("Dry Farming California Agricultural Water Stewardship Initiative", n.d.). Removing irrigation in drought prone, highly populated California conserves valuable water resources. It also drastically reduces any risks of soil salinization caused by insufficient amount of irrigation water (Brady and Weil, 2012).

Since Paul couldn't afford one big orchard in the Bay area, he set up many small orchards across the landscape. These orchards may be having large effects on the landscape ecology of the bay area by providing landscape diversity and regional biodiversity. Having smaller orchards spread across the landscape also provided economic resilience for Paul. When fires ravaged the bay area in October 2017, Paul lost his house and two of his orchards, but the rest were saved.

Producing value-added products provides economic viability for small or lower productivity orchards, allowing for farmer's like Paul to make a living with an orchard management style that is lower in productivity but beneficial to the ecology of the landscape and sustainable for the agroecosystem itself.

The production of cider could allow for apples to compete with grapes economically in Sonoma. Currently the landscape is dominated by residential development and vineyards. Grapes sold for $150/ton in 1979 as the wine industry boomed. This was the same time that the Kollings bought their first orchard. Now apples are approximately $400 per ton and grapes can go for $2,000-$4,000 per ton. Cider makers are willing to pay more, around $800-$1000 per ton but they purchase a relatively small quantity. Paul thinks the cider industry can compete with the

wine industry, but it will take time. He also thinks the future of cider is reflected in the current marketplace, where the beverage industry has been trending toward niche, local, sustainable, mindful and healthful. He believes people are ultimately going to do what is best for them and the planet because in the end that is what will sustain them.

The spatial distribution of Paul's orchards creates an ecoregion of small agroforest patches distributed across a landscape dominated by vineyard production and urbanization. Island biogeography theory applied to enhancing the biodiversity of vineyards shows that patches of agriculture over a landscape which are closer together exhibit greater species richness than patches of agricultural habitat which are more isolated (Shinderman, 2015). Paul's orchards may serve as a critical habitat patches for pollinators that do not have food sources and habitat available in monoculture vineyards. The forest agriculture patches could also provide other valuable ecosystem services such as improving air quality, reducing the urban heat island effect, and improving carbon sequestration (Ontl and Schulte, 2012)

Paul's ecological sustainability did come at the price of financial viability and low productivity, so he continually acquired more land as the business grew. In the case of Sonoma County, wilderness spaces are minimal and land not cultivated for agriculture is likely to be developed for other purposes. Utilizing the agricultural space to maximize biodiversity is the current approach for areas under intense development pressure, as we see with the support provided to Case Study 5 by the Slow Foods Foundation and the support provided to Case Study 4 by the land trust and conservation district.

Figure 21: Crop Health Status
Nana Mae's Organics

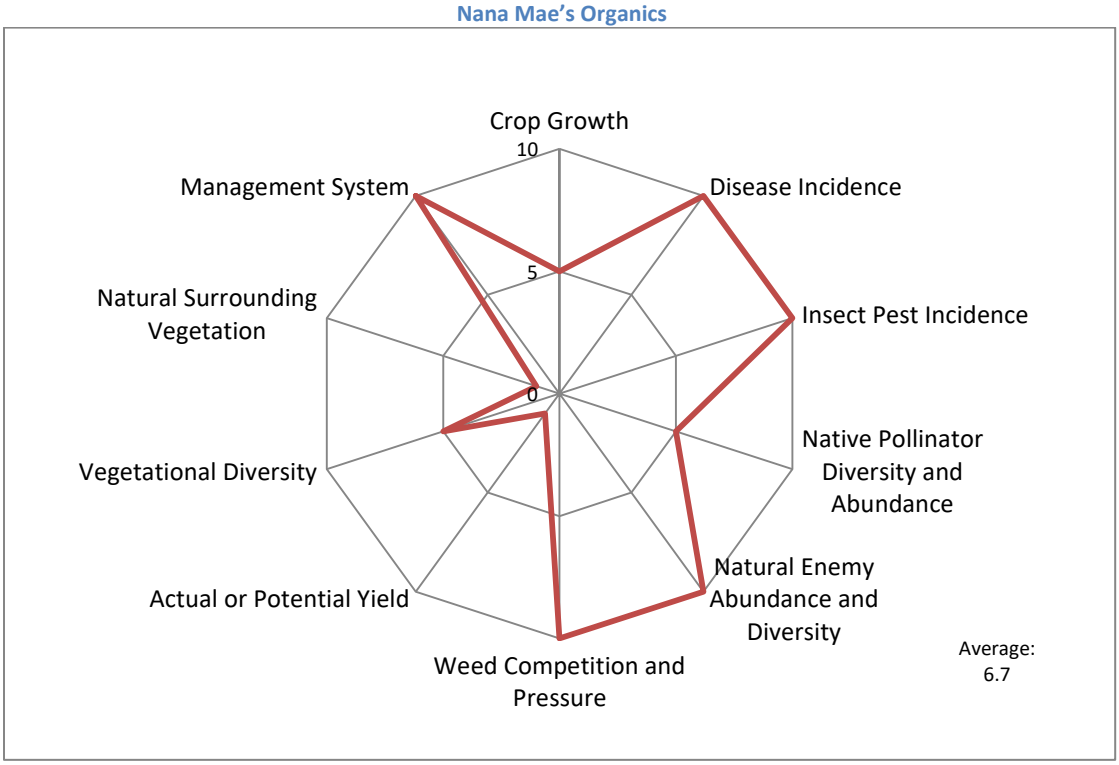


Figure 22: Soil Status
Nana Mae's Organics

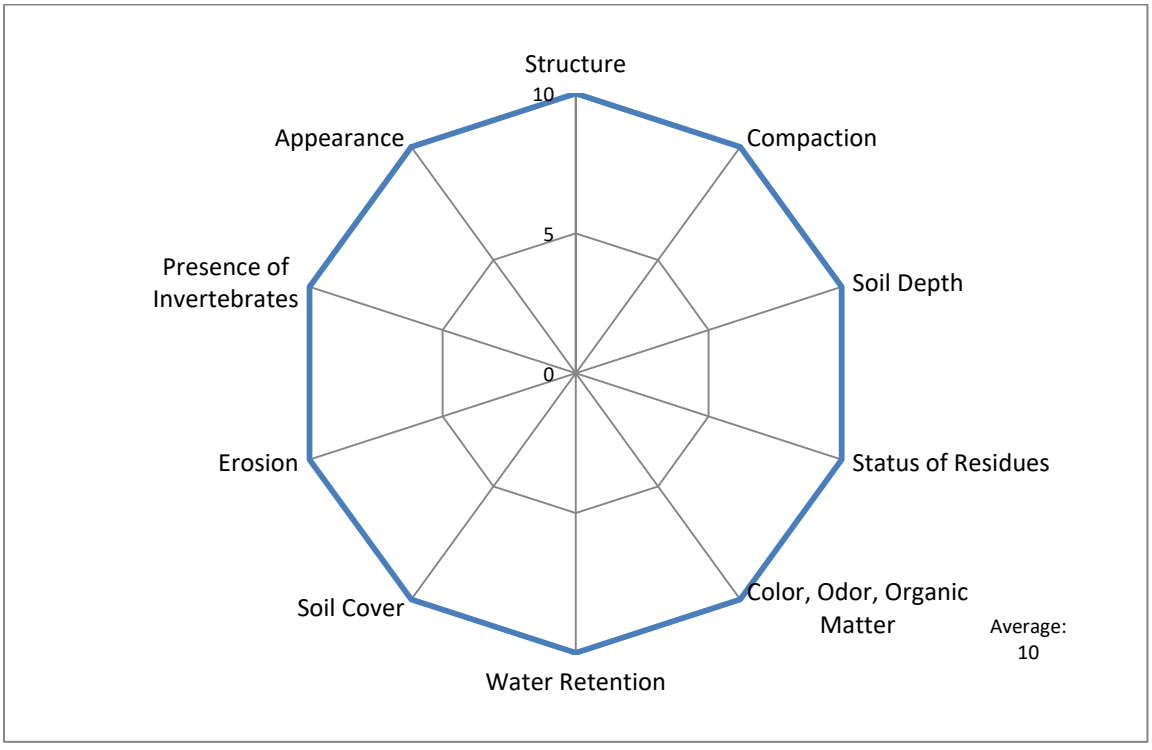


Figure 23: The two properties which border the survey site are emblematic of the impact of differentiating agricultural management styles on the landscape. One bordering property is a second orchard leased by Paul. At this property the owner preferred that the orchard be more actively managed. The other adjacent property is a small, intensively managed, young vineyard typical of northern California's wine country.

Figure 24: The blackberry bush provides multiple ecosystem services; a sellable product for the farmer, a niche habitat for quail, and improved soil water retention to aid dry farming.

Figure 25: Image of survey site used to determine crop health status and soil status with a close-up of soil.

Conclusion of Results

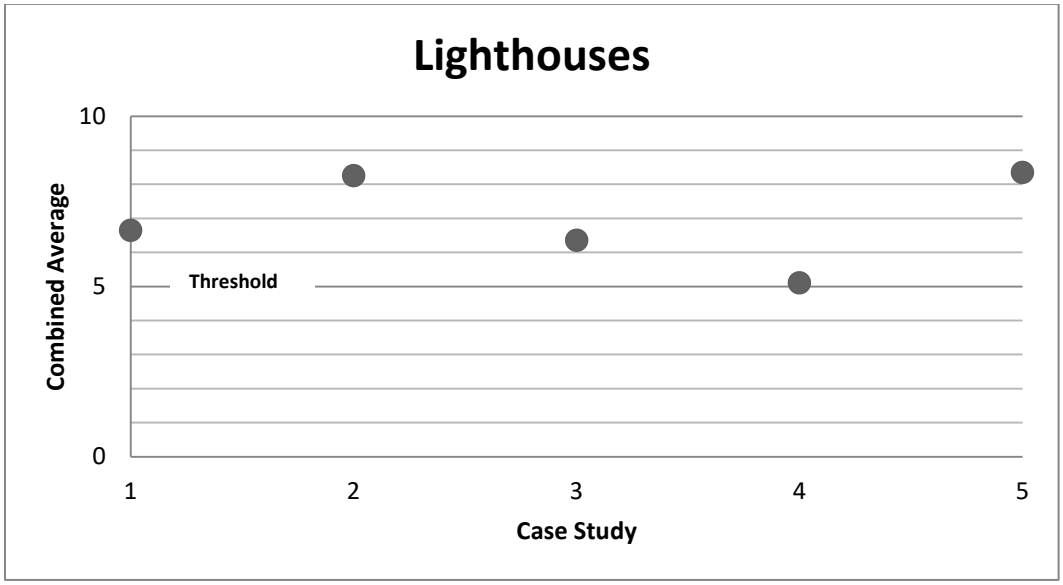


Figure 26: Combined averages of crop health status and soil status surveys relative to the sustainability threshold. Any case study with a combined average above the threshold of 5 is deemed a lighthouse orchard.

Combined sustainability averages:

Case Study 1: 6.65
Case Study 2: 8.25
Case Study 3: 6.35
Case Study 4: 5.1
Case Study 5: 8.35

Any orchard with a combined average above the threshold of 5 is deemed a 'lighthouse' orchard. The sustainability average of all case studies reached 5 or higher, indicating that the supply side of the cider industry is developing in a sustainable way.

Ultimately, a farmer is managing an ecology which allows for the growth of their desired crop. The amoeba structure used for this survey allows farmers to visualize and assess multiple interrelated metrics of their agroecosystem, allowing them to adjust their management techniques to address any imbalances. The concept of lighthouses is not to rank the individual case studies, but to better represent the combined averages of the crop health status amoeba and the soil status amoeba to provide a better picture of the overall ecological balance of these agroecosystems. The average of the combined survey results becomes a general gauge of the sustainability of the system, where anything greater than 5.0 is considered to be above the sustainability threshold. According the original framework used, 'The idea here is not for farmers to copy the techniques that lighthouse farmers use, but rather to emulate the processes, synergisms and interactions that emerge from the ecological infrastructure of the lighthouse farm, which are assumed to determine the successful performance of such systems in terms of soil quality and crop health. Simply copying the practices used by successful farmers does not work for diffusing principles

underlying the performance of lighthouse farms. Agroecological performance is linked to processes optimized by diversified systems and not to specific techniques. It may be that in a lighthouse farm the key is high soil biological activity or live soil cover, but this does not mean that the neighboring farmers have to use the same type of compost or cover as the lighthouse farmer; rather they should use techniques that are within their reach but which optimize the same key processes operating in the lighthouse farm' (Nichols et al., 2004).

Addressing potential falsities or weaknesses in the research

These surveys are designed to be usable by anyone to gauge the sustainability and ecological balance of an agroecosystem. Therefore the generality and lack of specificity could be considered a weakness. Furthermore, a single representative site was selected for the survey. Each survey is a snapshot of the orchard, and does not account for variance within the agroecosystem. Details on the rest of the orchard layout are available through maps, photos and interviews. A farmer also has the option to do several surveys at multiple sites throughout their property to better understand the variance. I removed the test for microbiological activity in the survey due to inconsistency of the tests and a lack of information available regarding the validity, replicability and scientific foundations of the test. Some bias may be introduced into the surveys because the metrics on 'presence of invertebrates' and 'disease incidence' were self-reported by the growers. I was unable to obtain an interview from any large-scale eastern Washington apple farms or from the juice companies, Hood River Juice Company and Fruit Smart, discussed in "Sustainability issues and ecological impacts of the large orchards in Eastern Washington". Data from this section is compiled through a combination of secondary sources and case study interviews.

Discussion

Comparing apples to grapes: Similarities and differences between the evolution of the wine industry and the cider industry

The wine industry is beginning to incorporate more sustainable management practices, but the cider industry is growing amidst a new societal awareness of the impact of agriculture on the environment as well as the slow food and craft beverage movements, and is in a better position to establish itself with long-term sustainability in mind. The overall level of development today compared to thirty years ago on the west coast also presents a different scenario for a new booming industry. The cider industry is likely to evolve with a different degree of ecological impact than the wine industry despite the rapid rise in popularity and overall similarities in geography between the wine and cider industries.

There is the possibility for cider cultivar trees to have a positive impact in certain landscapes. In California, small patches of orchard may be serving as a habitat refuge for pollinators, wildlife, plants, and other organisms in a landscape otherwise dominated by monoculture vineyards. Since grapes are wind pollinated, the landscape diversity of apple trees within an agricultural area dominated by grapes is likely to be critical habitat. An orchard environment is more similar to the native ecosystem of predominantly redwood forest and therefore more likely to be able to serve as an effective habitat corridor for native species. There is little education and/or awareness of agroforestry practices broadly across North America (Robbins, 2011). Nonetheless, agroforestry and conservation agriculture techniques are being used across these case studies. Furthermore, when operated in a sustainable way, with agroforestry principles, agroforestry can improve carbon sequestration and air quality (Ontl, and Shulte, 2012).

Vertical Integration vs. Ordering Wholesale Juice

My recent interview with the makers of Talbott Cider in Palisade, Colorado painted a similar picture to the status of the industry uncovered by Greg Peck and his colleagues at Cornell. Talbott Farms had been operating since 1901 and was passed down through the generations. Two generations back, one of their primary crops was apples. Unfortunately, they were soon out-competed by industrialization, making it cheaper to ship in apples from Washington than to grow them in Colorado to sell to Coloradans. So they shifted their production to the upcoming cash crop, peaches. To this day, Coloradans flock to Palisade annually to get the famous Palisade peaches. But the Talbotts chose to keep some of the well-established apple trees, and switch from selling the apples whole to pressing the apples and selling sweet (unfermented) cider. There is a market for sweet cider, as the drink is enjoyed throughout the US during the fall and winter holidays.

The youngest inheritor of the Talbott farm chose to start up a hard cider production using their high quality industrial scale press and to catch the wave of growth in the hard cider sector. They started less than two years ago and are upscaling production at a significant pace. They are interested in vertical integration with their own orchard if it can be financially sensible. Currently the cost of shipping in apples is far more economic than starting an orchard (Talbott and Leader, 3/25/2017).

Sustainability issues and ecological impacts of large orchards in Eastern Washington, and their role supplying to cider makers

Eastern Washington is America's primary region for apple production. Washington produces about 58% of the apples grown in the United States, and 68% of those are grown for fresh consumption (Apples in Washington State, n.d.).

Washington apples are grown in a moderate, marine influenced, desert climate, where the scant rainfall occurs in the winter months ("Apples in Washington State" n.d.). Eastern Washington lies in the rain shadow of the Cascade Range, and receives a relatively low amount of rain compared to the coastal area. The dry, sunny growing season gives growers the advantage of low disease pressure, but requires them to irrigate regularly during the summer. The average orchard requires about 3.5 acre feet of water per season, most of which must be applied during mid-Summer, when mountain snow-melt maintains plentiful stream flows ("Apples in Washington State" n.d.). The total of all crop irrigation in the Pacific Northwest states constitutes less than five percent of the available Columbia River watershed water supply ("Apples in Washington State" n.d.), so water shortage is not an issue as we see in California. The soils of the apple growing region are more arid than the coastal rainforest soils further west (Brady and Weil, 2012).

Large scale orchards frequently undergo orchard renovation. During orchard renovation trees are pulled out after their peak productivity, or low value varieties are swapped for higher value varieties. Orchards are replaced about every 18-25 years, as cultivars or varieties become less popular, or trees are excessively damaged by severe winters ("Orchard Management", n.d.). This inconsistent environment decreases the potential to establish strong root systems, and decreases biodiversity. Strong root systems improve soil aggregation, decrease erosion and improve soil biodiversity (Ontl and Shulte, 2012). Changing orchards to new varieties may lead to poor economic returns due to specific replanting disease unless the soil is carefully fumigated prior to replanting. This replanting problem is especially serious in the older production regions where family farms predominate ("Orchard Management", n.d).

In order to sell fruit as organically produced, growers must pay Washington State Department of Agriculture inspection fees and maintain their orchard under approved organic production methods for at least three years. The transition period is a financial hardship, as fruit must be sold under the conventional label though cost of production is often significantly increased by following organic production methods. This is the major impediment to growers who might wish to try organic production ("Apples in Washington State", n.d.). As seen in the case studies, the financial and logistic burdens of organic certification can be too great for large or small scale orchards.

Currently there aren't very many large-scale orchards supplying the hard cider industry, but one notable company is Fruit Smart. Another major regional supplier is The Hood River Juice Company. Fruitsmart is interested in cider and has even sponsored CiderCon, the annual conference for the cider industry. Both groups contract apple growers then juice the fruit at their facilities. They sell their products at an affordable price, making it an appealing sourcing option for an entrepreneur, and the most sensible option for urban cider companies. I went to several urban cideries and found that many buy their juice from these companies and few have direct relationships with apple growers (Seattle Cider Company, Portland Cider Company, Reverand Nat's). I also had it confirmed through emails that a number of other large companies order their

fruit wholesale. The Santa Cruz Cider Company in case study 4 also chose to order wholesale juice for some of their product line.

Other growers are emphasizing the quality of fruit and are more interested in creating a high quality artisanal product, primarily the smaller companies. An example of this in the research was the relationship between Upper Valley Farm and Rack and Cloth. Others are finding a happy medium, such as The Santa Cruz Cider Company, which has created two lines of cider, an entry level version using purchased juice that is more affordable and a higher quality line from local apples. One notable large company that does grow their own fruit is Two Towns Ciderhouse in Corvallis, Oregon, who declined to be interviewed.

If cider makers continue to import juice to their location, the concept of *terrior* in cider is unlikely to develop (James, 2017). Likewise, it may decrease the potential for agrotourism to develop within the cider industry, as we see occurring at Tod Creek Cider. The overhead of starting an orchard is too much for many people just starting out making cider, but a recent survey by the cider research group at Cornell showed a high degree of interest by cider makers into expanding into the apple growing side of cider making (Peck, 2015).

Urban cideries introduce cider to a large number of people. Many urban cider makers questioned during this research order juice for their cider for economic and logistical reasons. An alternative for urban cider makers ordering juice is to connect with small scale local apple growers. The creation of networks can help to pair small-scale producers with cideries, such as the networking occurring within Case Study 3. There may be some barriers keeping small-scale farmers and urban cider makers from connecting. It may also be a challenge for one or a number of small apple growers to meet the demand for consistency and quantity of fruit required by large scale production. Organizing through a cooperative could improve the quantity and consistency of supply and simplify the logistics for business partners.

Prospective Analysis

The sustainability average of all case studies reached 5 or higher indicating the cider industry supply is developing in a sustainable way. Nonetheless, the cider industry could benefit from, and currently lacks, an association similar to LIVE. LIVE provides internationally recognized third party certifications for sustainable viticulture in the Pacific Northwest and LIVE educates, supports and promotes sustainability and best practices in wine making and viticulture. (LIVE, 2018). There is little awareness of agroforestry techniques, but lots of potential to incorporate these techniques (Robbins, 2011). Universities and market research groups are moving forward in earnest to research cider, but the industry is still a ways behind the wine industry. This blank canvas provides both challenges and opportunity to define cider making in the United States and Canada. The landscape and market appeal of cider will continue to evolve as we research more about cider apple characteristics, the supply of cider trees expand, and cider makers develop a new American tradition of cider making.

Although this value added product may allow for the survival of the small orchard, there may be a tipping point where the ecological footprint of cider production outweighs the benefit of maintaining small orchards. Based on my interview questions that does not seem to be the case, but the subject deserves further analysis

One question that will have enormous impact on the development and ecological impacts of cider orchards is whether hard cider makers will vertically integrate small-scale orchards or choose to order juice from a wholesaler. The industry is at a tipping point. Currently cider is a

value-added opportunity that can sustain a small scale operation, but as other quality cider companies scale up, small orchards may be hard pressed to compete.

Small orchards have the potential to restore land and landscapes in urban or degraded areas, if that land can be obtained. Seattle is an excellent example of the potential for urban forests to improve air quality, biodiversity, soil quality. Forest parks also provide space for recreation and improve the aesthetics of the area and quality of life for residents. Some parks in Seattle have small orchards within them where the public can learn about fruit production and if they are food insecure, get fresh fruit. Groups such as Branch Out Cider in Denver are working with hobby orchardists across the metro area and urban cider makers to collect apples grown in backyards and turn them into cider. It is cheaper this way and simplifies their production. This may not be logistically viable for all for-profit businesses but is an interesting project working to decrease food waste and promote fruit tree production in an urban area (Branch Out Cider, 2016).

Small orchards have large potential to make a positive or net neutral agricultural impact, particularly in cultivated landscapes such as in case study 5. More research would be needed to determine how the incorporation of small orchards across a landscape can create habitat and food sources for native pollinators. An ecoregional approach to pollinator enhancement could provide sufficient habitat for pollinators and reduce the necessity to rent bees.

Orchards on degraded soil such as in Case Study 1 can be reparative to the soil and broader ecology. At Tod Creek, tree roots aggregated soil which had been previously compacted by the presence of dairy cows. The impact of sustainably managed orchards on soils is an important consideration for landscape planning efforts and soil remediation.

Regarding the current tug-of-war between blackberry production and other crops in Santa Cruz, an awareness of alley cropping techniques could meet the demand for both, allowing the farmer to benefit from the high market price of blackberries without giving up on their trees. Blackberries as the understory improved soil water retention and created a niche habitat for quail and other small animals in Case Study 5.

As a value added product earning a higher price per pound than culinary apples, cider apples allow for operations to exist on a smaller scale, making it a more sustainable system with less impacts on the surrounding ecology and the larger landscape ecology. The overall impact and sustainability of the orchard depends on sustainable design and management, but based on the above case studies, the development of the cider industry at this point is so far sustainable.

There is the possibility for cider cultivar trees to have a positive impact in certain landscapes. In California, small patches of orchard may be serving as a habitat refuge for pollinators, wildlife, plants, and other organisms in a landscape otherwise dominated by monoculture vineyards. Since grapes are wind pollinated, the landscape diversity of apple trees within an agricultural area dominated by grapes is likely to be critical habitat for pollinators. An orchard environment is more similar to the undisturbed ecosystem of predominantly redwood forest and therefore more likely to be able to serve as an effective habitat corridor for native species.

Agroforestry can improve carbon sequestration and air quality (Ontl and Schulte, 2012). Introducing trees into other systems provides a canopy that gives shade and niche habitat as well as stabilizes soil. While an orchard expanding into undisturbed natural ecosystems is detrimental, effectively utilizing agroforestry practices in orchards in agriculturally developed zones can have a positive influence on the ecosystem. In case study 1, tree roots aggregated soil and reduced erosion. In case study 4 the orchard was being re-structured to incorporate a wetland which

harbored native plants and the endangered red-legged frog. In case study 3 an internal wetland promoted biodiversity of wetland flora and habitat, and filtered and distributed water evenly across the agroecosystem. In Case Study 5 dry farming techniques conserved water and eliminated the risk of salinization. Case Study 5 also improved soil conservation and carbon sequestration across the landscape. Case Study 4 incorporated a riparian buffer that improved biodiversity and filtered agricultural water runoff. Case Studies 3, 4 and 5 serve as diverse habitat corridors across a largely monocultural landscape.

There seems to be an awareness of sustainability in agriculture not present during the period when the US entered the wine industry. The overall level of development on the west coast also presents a different scenario for a new booming industry than it did in the 1970s. The cider industry is likely to evolve with a different degree of ecological impact than the wine industry despite the rapid rise in popularity and overall similarities in geography between the wine and cider industries.

Many farms are operating in ways that are primarily organic despite not being certified as such because of the cost and burden of the process, which means the ecological impact is probably much less than one would think just by looking at organically certified cider apples as an indicator of sustainability.

There are also lower nitrogen inputs for cider orchards because nitrogen-deficient trees make better cider. In terms of impacting surrounding water bodies, the primary concern relates to phosphorus inputs, not nitrogen, which has been proven to be the limiting nutrient for eutrophication (Schindler et al., 2008).

Codling moth appears to be the primary pest challenge for all orchards. Birds are the primary natural predator to codling moth ("Natural Enemies of Codling Moth and Leafrollers of Pome and Stone Fruits" n.d.). Apple orchards which can support birds as ecosystem residents can reduce codling moth. Case Study 5 harbored woodpeckers, a key predator to codling moth, and displayed a high degree of disease resistance within the system. Harboring natural predators is an effective alternative to agrochemical application (Gleissman, 2006).

As it continues to develop, the availability of cider cultivar trees in U.S. and Canadian nurseries will impact the development of the cider industry. Trellising is the current trend in orchard management. Trellised trees are a high density production system that has been researched and praised for its ability to produce lots of fruit rapidly, reduce job-site injury by removing the need for a ladder, as well as for the ease and affordability at which trees can be replaced in the case of reduced productivity. The ecological impact of trellised and dwarf trees is another area for further study. In California where the landscape is already dominated by trellised vines, this may take away the potential for trees to provide shade, habitat, and large, soil-stabilizing root systems not found in most vineyards.

Suggestions for Further Study

More comprehensive research is needed to determine whether agroforestry and the conservation of apple trees within landscapes decrease habitat fragmentation for native pollinators. This is just one example of the potential for further research on the application of ecoregional approaches to sustainability, landscape diversity, and habitat conservation.

Because the craft cider industry is so new in North America, there is a plethora of cider specific research questions, such as how the supply and availability of cider variety trees are

promoting or inhibiting the expansion of the industry. There is also potential to do research on forms of cooperative networking among industry professionals. More research could also clarify why the organic certification process has become too burdensome for farmers to undertake, and how this change impacts agricultural and consumer economics, the environment, and human health. As the cider business develops, suppliers will want to know more about the degree of consumer demand for sustainable sourcing in the cider industry.

Other research topics uncovered during the course of this research include whether overwintering or allowing for periods of decreased productivity impacts the life cycle and longevity of apple trees, how orchard renovation impacts soil erosion and biodiversity, and the ecological impacts of trellised trees or lower nitrogen inputs.

As the farmer looks to increase biodiversity in the system, it would be good for them to know how to get the most benefit to the system without wasting financial resources and time. Information such as what plants for a specific geographic region best support the habitat for natural predators to common apple tree diseases and pests like codling moth would be very useful. Furthermore, there is little awareness, or use of, pasture grazing or cider pigs. In my research I encountered only one cidery, called Virtue Cider, using cider pigs (Virtue Cider, n.d.). Incorporating animals into agroforestry systems is called an agropastoral system. Further research could determine what factors could be inhibiting this development and how it might influence the function of the agroecosystem.

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Appendix

Appendix #1

History of Cider in America

Cider has migrated its way around the world with its drinkers. The roots of cider in England are unclear but pre-date the invasion by Romans in 55 BC. The Romans also drank cider and were surprised to find it in England upon their arrival (Orton, 1995).

Cider was first brought to America on the Mayflower in 1620. Early colonists got right to work establishing apples trees in the new country. Nine days after the Puritans landed, a man by the name of William Blackstone planted the first apple trees in the New England colonies. The first recorded shipment of honeybees to America, important for the pollination of apples, was recorded in Virginia in 1622 (Orton, 1995).

Colonial America was in many ways shaped by apple and cider production. The fermented beverage was preferred over the often unclean water (Watts, 2017). Apple trees struggled to grow in the southern colonies but took extremely well in New England, which is a major apple producing region in the United States to this day (Orton, 1995). Applejack (an apple spirit) and apple cider vinegar, made by further fermenting cider, were also colonial products (Orton, 1995). Apples and cider were so commonplace they were even considered an acceptable form of barter currency (Orton, 1995).

Rapidly changing agricultural economics and the temperance movement, which led to the passage of the Volstead Act and the 18th Amendment, coincided to bring about the decline of the popularity of cider in America (Watts, 2017). This period in American history, called prohibition, made the production and sale of alcohol illegal. Throughout the 1920s international alcoholic beverages were smuggled through ports such as Boston (Orton, 1995). It was much more lucrative to ship in wine, beer and whiskey from abroad than it was to maintain the rural American cider making tradition. As a result, most cider operations switched to what is called ‘sweet cider’, the unfermented apple juice. This is why Americans today distinguish between ‘hard’ (fermented) and ‘sweet’ (unfermented) ciders. After the repeal of prohibition, beer, wine and spirits re-established themselves as industries but cider did not (Orton, 1995).

In 1976 a Californian wine won the Judgement of Paris competition, bringing Californian wines to the national stage. Around this same time, the microbrew industry began, elevating the level of American beer brewing. These resurgences are spreading to the cider industry, which is finally regaining strength in U.S. culture and forging a spot in the economy after nearly a century of dormancy. The craft cider industry has established a stronghold across much of Canada, the Northwest, New England, and the Great Lakes regions.

Cider around the World

Americans brought the tradition of cider making with them on the Mayflower from England. Today England is the number one country for both the consumption and production of cider (Merwin, Valois, and Padella-Zakour, 2008). There are a variety of small and large scale producers throughout the country. Normandy and Brittany in France, as well as Asturias in Spain

also have strong cider making legacies. The drink has spread around the world and changed in various ways with globalization (Merwin, Valois, and Padella-Zakour, 2008).

Appendix #2

A Rapid, Farmer-Friendly Agroecological Method to Estimate Soil Quality and Crop Health in Apple Orchards

Structure	1 5 10	Loose powdery soil without visible aggregates Few aggregates that break with little pressure Well formed aggregates, difficult to break
Compaction	1 5 10	Compacted soil, cannot be broken with a penetrating wire Thin compacted layer, some restrictions to penetrating wire No compaction, wire can penetrate all the way into the soil
Soil depth	1 5 10	Exposed subsoil Thin superficial soil (10-20 cm) Superficial soil (>10 cm)
Status of residues	1 5 10	Slowly decomposing organic residues Presence of last year's decomposing residues Residues in various stages of decomposition, more residues well decomposed
Color, odor, and organic matter	1 5 10	Pale chemical odor, no presence of humus Light brown, odorless and some presence of humus Dark brown, fresh odor, and abundant hummus
Water retention (moisture level after irrigation or rain)	1 5 10	Dry soil, does not hold water Limited moisture level available for short time Reasonable moisture level for a reasonable period of time
Soil cover	1 5 10	Bare soil Less than 50% soil covered by residues or live cover More than 50% soils covered by residues or live cover
Erosion	1 5 10	Severe erosion, presence of small gullies Evident, but low erosion signs No visible signs of erosion
Presence of invertebrates	1 5 10	No signs of invertebrate presence or activity A earthworms and arthropods present Abundant presence of invertebrate organisms
Microbiological activity	1 5 10	Very little effervescence after application of hydrogen peroxide Light to medium effervescence Abundant effervescence

Appearance	1 5 10	Chlorotic, discolored foliage with deficiency signs Light green foliage with some discoloring Dark green foliage, no signs of deficiency

Crop growth	1 5 10	Stunted, uneven growth, evidence irregular fruit bearing patterns Some irregular growth and erratic fruit bearing patterns Strong even tree structure and predictable fruit bearing pattern
Disease incidence	1 5 10	Susceptible, more than 50% of plants with damaged leaves and/or fruits Between 25-45% of trees with damage Resistant, with <20% of trees with light damage
Insect pest incidence	1 5 10	Extensive damage caused by codling moth, apple maggot or other pest Limited, controlled damage caused by insect pests Very limited if any damage caused by insect pests
Native pollinator abundance and diversity	1 5 10	No native or wild bees present, renting bees necessary Limited native or wild bees present, renting bees necessary Healthy population of native or wild bees, renting bees unnecessary
Weed competition and pressure	1 5 10	Ground cover and trees stressed, overwhelmed by weeds Medium presence of weeds, some level of competition Vigorous and healthy ground cover overcomes weeds
Natural enemy abundance and diversity	1 5 10	No presence of predators/parasitic wasps detected in 50 random leaf samples At least one individual, of one two beneficial species At least two individuals of one or two beneficial species
Actual or potential yield	1 5 10	Low in relation to local average Medium, acceptable Good or high
Vegetational diversity	1 5 10	Monoculture Primarily apples trees with ground cover and/or some other crops or animals Mixed orchard with ground cover and a variety of other crops and/or animals
Natural surrounding vegetation	1 5 10	Surrounded by other crops, no natural vegetation Adjacent to natural vegetation on at least one side Surrounded by natural vegetation on at least two side
Management system	1 5 10	Conventional In transition to organic with IPM or input substitution Organic, diversified with low external biological inputs

Please note any unusual circumstances that may have influenced the results of your survey:

Appendix #3

Ecology Based Designs and Sustainable Management of North American Cider Orchards
Interview Questions

Orchard: General

_Do you operate your own orchard?
If so, for how long?

_Did you plant your own orchard?
If not, please describe its legacy.

_How did you learn about orchard management?

_Have your management practices changed over time, if so how and why?

_Please briefly describe your current annual process of production.

Orchard: Ecological

_Do you classify your orchard as conventional, organic, or biodynamic?

_Do you use a mixed orchard system?
If so, please describe.

_Do you have any other crops in your orchard?

_Do you employ any agroforestry techniques?

_Do you use cover crops?

_Do you fertilize?

_Do you have any animals in your orchard (such as cider pigs)?

_Please describe your methods of pest management.

_What are the common pests and diseases in your orchard?

_Would you describe disease incidence in your orchard as low, average, or high?

_Would you describe pest infestations in your orchard as low, average, or high?

__Do you have any specific management practices to prevent or address disease or pest problems? If so, how effective have those tactics been, and have you noticed any additional impacts on the orchard or surrounding ecosystem?

_Do you rent bees?

__Renting aside, what have you observed about the bee population of your orchard? For example what type of bees do you have and what is their relative quantity? Could your orchard be successfully pollinated without renting bees?

_Please describe your irrigation practices and your water source.

_Is this orchard located near any bodies of water?

_Do your irrigation practices consider soil salinization?

_How would you describe your soil?

_Have you done anything to address the quality of your soil?

_Do you leave any biomass on the orchard floor?

_Do you have many birds in your orchard? Do you have many birds in the surrounding ecosystem?

_Do you find other wildlife in your orchard? If so, what kinds and how frequently?

_What are some of the primary challenges in your orchard (ie pests, bears, low productivity, water shortages, etc)?

_Have you noticed any direct positive impacts on your system based on specific management practices?

_Have you noticed any changes in the surrounding ecosystem?

Orchard: Expansion

_How many and what are the primary apple cultivars you use in your system?

_Does orchard management for cider apple cultivars differ from orchard management for culinary apples and if so, how?

_Are there economic advantages or disadvantages to growing cider apples over culinary apples?

_Have you expanded your orchard to accommodate for additional cider specific cultivars?
If so….
__How have you expanded? Have you planted trees (from what stage of growth), have you used grafting, or a combination of those techniques?
__Did you have an expansion plan for your orchard? (For example, an outline may have identified the best locations to put new trees or that accounted for additional inputs such as water usage).

__How did you calculate the economic benefit of expanding? Did you have an idea of how many trees would result in economic growth for your cider business?

_Do you have plans for further expansion? If so please describe them?

_Is the cider market currently favorable for expansion?

_Is the supply of cider apples a fairly limited niche or is there a significant amount of competition?

_Where did you purchase your trees? Is it challenging to find cultivars desirable for cider making?

_Are you currently lacking any cultivars you would like to have in your production?

_Is your business, and the demand for cider growing? Would you describe the growth of your business as a rapid or steady?

_Are there any economic challenges or benefits to working with cider cultivars and producing cider over simply selling culinary apples?

_If you supply your apples from another company, why did you choose to do so? Are there any specific advantages or disadvantages to supplying your apples from a third party? Do you have plans to vertically integrate your business?

_If you are vertically integrated, why did you choose to do so? Are there any specific advantages or disadvantages to supplying your apples from a third party?

_Do you use all of your apples for cider? If not, where do the rest go?

Cider:
General

_When did you begin making cider?

_Why did you begin making cider?

_How has cider production impacted the economic value of your orchard?

Cider: Environmental

_Is cider making a water intensive process?

_Is cider making an energy intensive process?
__Do you get your energy partially or entirely from a renewable source?

_Does cider making generate much waste? Where does that waste go?

_ How and where do you ship your product?

_Do you have plans to expand the shipment of your product?

_What do you use for bottling and where does it come from?

_Where do you source additional inputs such as yeast and sulfite from?

_Are they any additional agricultural inputs in your cider (such as for flavored ciders) and where are they sourced from?

_Are there any specific governmental environmental regulations imposed on cider makers?

_Do you do employ any specific practices to reduce your environmental impact?