The Long-Term Investment Strategy: Orchardists Observing and Reacting to Change

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Agricultural management systems are found at the intersection between human societies and environmental dynamics. Traditional apple orchards are fruit production systems that were developed in Eurasia and transferred to many other regions around the world including a wide range of temperate to subtropical climates. We interviewed 255 long-term (20+ years) apple orchard managers in nine European countries and seven other countries that were former colonies. Patterns and types of management observations were compiled to illustrate descriptive aspects of orchard manager’s thinking. Observations and adaptive responses by orchard managers seem to share similarities that go beyond cultural and large-scale environmental differences. Orchard management systems appear to be adaptive responses by traditional orchardists not only for local environments but also for success in unknown, newly encountered environments and therefore might be expected to cope with climate change and functionally adapt to ecosystem variation due to that change.

Keywords: climate change, apple orchard management, adaptation, Europe

Introduction

A management system (sensu Lertzman 2009) is the sum of actions, goals, and objectives that bring together cultural and environmental dynamics as coupled drivers of managed ecosystems. The adaptations within management systems often derive from long-term observations and experiences generally referred as “traditional ecological knowledge” (TEK) (Berkes et al. 2000). TEK can be defined as a knowledge system based on the accumulation of experiences, adaptive learning, and gradual understanding of environmental processes, variable over time and space (Cruikshank 2004; Macchi et al. 2008; McGregor 2004). Management systems are flexible enough that they may be developed in one environment and then transported to others as transported landscapes (Kirch 1984). Lertzman’s (2009) analysis of management systems serves as the logical framework for this paper. In particular, we assess his conclusions that management systems largely serve to regulate human behavior, rather than
manipulation of the environment, with generation of rules about the “right” way to interact with resources. Rules do not need to be explicit but can be inferred from patterns of decisions made when faced with specific conditions. Management systems probably meet their greatest challenges when conditions in either the social or environmental situation change, as is happening with climate change (Adger et al. 2012; Berkes and Jolly 2002) and more importantly, as this has happened in the past when members of cultural communities transported their agricultural systems to new locations, often with different climates than in their homelands. These translocations required a rapid adaptation process (Blanton 2003; Kupperman 1982).

Rindos (1984) consolidated a range of theoretical arguments on evolution of agriculture. One of the issues he discussed in his still-controversial analysis is the role of constantly changing climate in shaping agriculture and furthermore that any doctrine of homeostasis is an illusion. We may conclude from his lengthy arguments that all traditional agricultural systems have been constantly influenced by changing conditions, perhaps climatic, perhaps related to other aspects of the environment, but changing conditions nonetheless. By contrast, Richerson et al. (2001) argued that constantly changing climates of the Pleistocene inhibited development of agriculture while relative stability of the Holocene made agriculture an inevitable product of growing populations and developing environmental management activities. Either way, we would expect changing climates to impact agricultural systems. Ethnobiologists are currently exploring management systems at a time when climate is a driving variable. In this paper, we contend that agricultural management systems, as they developed in the past, included embedded mechanisms that are finely tuned for adaptive responses to changes in the environment, particularly those that are climate-driven, as they are encountered locally or through migration. We have observed a range of strategies being used by agriculturalists who identify differences between “traditional” and “modern” systems. Some self-proclaimed traditional agriculturalists have indicated that climates are becoming more variable and they are attempting to use “traditional” strategies to address changes. This work seeks to explore the actions being taken by a subset of agriculturalists working with longer-lived crops through orchards.

As a test model we have selected orchards (mostly apples) being grown by multigenerational orchardists (managers), interviewing orchardists in Europe (e.g., France, Italy, Spain, and the United Kingdom) and former European colonies (e.g., Argentina, Canada, Mexico, United States of America; see Table 1). Traditional orchards (sensu Lush et al. 2009) are fruit production and management systems typically consisting of several landscape elements. Some of these transportable elements include: plants (e.g., fruit and nut trees, ground cover, sheltering hedges or walls), animals (e.g., pollinators and predatory insects, birds, and grazing mammals), microorganisms (e.g., yeast/other fungi, protective and opportunistic bacteria), and cultural components (e.g., aesthetics, management objectives, stewardship/responsibility, and concepts of space and planning; see discussions in Reedy et al. 2009, 2013). These are integrated with less-transportable landscape elements (e.g., geology, soils, weather patterns, climate, slope, and aspect) to produce a locally socio-ecological system that
results in enduring food supply. Modern commercial orchards are reduced/simplified versions of traditional orchards with less consideration for the full suite of landscape elements (Reedy et al. 2009). Modern and traditional orchardists are the managers of, respectively, modern (often entirely commercial) and traditional (marginally commercial), orchards. Knowledge and practices of orchardists in both traditional and modern orchards are not static but are continuously evolving. We recognize this plasticity even in rather long-term established practices by applying the term “traditional” (when referring to knowledge) in the sense of Lepofsky (2009) and Berkes and Turner (2006), that is, by referring to non-static knowledge and practices built up over generations of in situ experimentation and observation in particular cultural and ecological settings. In contrast, modern orchards are typically developed and managed following prescriptive practices acquired from experts, usually elsewhere, and not particularly attentive to subtle variations in local conditions. Adaptation within such agricultural systems may happen in situ, or through processes of migration, colonization, or more generally cultural or knowledge transfers.

Apples (*Malus pumila* Mill.) evolved in Central Asia, probably in association with large mammals (Forsline et al. 2003; Harris et al. 2002) and were adopted and dispersed by humans as part of orchard systems in the late Pleistocene or early Holocene (Harris et al. 2002; Mallory and Adams 1997). Dispersal was largely through clonal propagation (Velasco et al. 2010). Central Asian apple clones were distributed throughout Europe thousands of years ago, where they were often grafted onto local native apples (e.g., *Malus sylvestris* Mill.) that were

### Table 1. Numbers of orchard managers interviewed in various countries (and states/regions). Interviews encompass six ecozones (Nearctic, Neotropic, Paleoarctic, Australasia, Afrotropic, and Indomalayan).

<table>
<thead>
<tr>
<th>Countries (states, regions)</th>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina (La Pampa, Neuquen, Río Negro)</td>
<td>9</td>
</tr>
<tr>
<td>Australia (New South Wales)</td>
<td>1</td>
</tr>
<tr>
<td>Austria (Vorarlberg)</td>
<td>4</td>
</tr>
<tr>
<td>Belgium (Ardenne)</td>
<td>2</td>
</tr>
<tr>
<td>Canada (British Columbia, Quebec)</td>
<td>20</td>
</tr>
<tr>
<td>France (Brittany, Normandy, Pays d’Othe)</td>
<td>19</td>
</tr>
<tr>
<td>Germany (Baden-Württemberg, Hessen, Rhineland)</td>
<td>20</td>
</tr>
<tr>
<td>Ireland (Clare, Kildare, Tipperary)</td>
<td>5</td>
</tr>
<tr>
<td>Italy (Campania, Lazio)</td>
<td>16</td>
</tr>
<tr>
<td>Mexico (Puebla, Vera Cruz)</td>
<td>4</td>
</tr>
<tr>
<td>New Zealand (Nelson, Bay of Plenty)</td>
<td>3</td>
</tr>
<tr>
<td>South Africa (Western Cape)</td>
<td>4</td>
</tr>
<tr>
<td>Spain (Albacete, Asturias, Cuenca, Madrid)</td>
<td>12</td>
</tr>
<tr>
<td>Switzerland (St. Gallen)</td>
<td>2</td>
</tr>
<tr>
<td>United Kingdom (England (Cornwall, Devon, Dorset, Gloucestershire, Herefordshire, Oxfordshire, Somerset, Suffolk, Worcestershire), Northern Ireland (Armagh), Scotland (Ayrshire, East Lothian), Wales (Cardiff, Ceredigion, Denbighshire, Mid Glamorgan, Pembrokeshire, Powys, Swansea, Wrexham))</td>
<td>49</td>
</tr>
<tr>
<td>United States of America (California, Connecticut, Maine, Massachusetts, Minnesota, Missouri, New Hampshire, New Mexico, New York, North Carolina, Oregon, Pennsylvania, Texas, Vermont, Virginia, Washington, West Virginia)</td>
<td>85</td>
</tr>
<tr>
<td><strong>Total number of interviews</strong></td>
<td><strong>255</strong></td>
</tr>
</tbody>
</table>
better adapted to local environmental conditions. Apples were introduced in the Americas during the seventeenth century, where they became naturalized, and in Australia during early colonial times (Hedrick 1988; Mabberley et al. 2001). From practices of forest management developed by Native Americans to the terraced traditional orchards in the Mediterranean and modern monoculture orchards, the variety of agricultural practices and management strategies is considerable. Apples and orchard systems were transported to many parts of the world, probably as sources of potable water (Brown 1966). The products of orchards, in the form of cider (fermented apple juice), can be used as safe water sources purified of pathogens that may be found in other local water sources (Mac 2003). Orchards may be planted on top of sources of contaminated water, and the trees effectively serve as phytoremediating water pumps and biofilters that decontaminate water, presenting it in an edible package (McClatchey and Reedy 2010). Although these systems became established on every inhabited continent by the mid-1800s, during the subsequent period of widespread alcohol prohibition, and development of alternative deep well technologies (Glennon 2002; Outwater 1996), orchards fell out of use as sources of clean/preserved drinking water (cider) and became mostly sources of fresh fruit (Lender and Martin 1987; Watson 2013). By 2011 global commercial apple production was estimated to be over 75,000,000 metric tons per year (FAO 2011).

Research has already been conducted on observations and adaptive strategies to climate change by traditional apple orchardists in several countries (e.g., Pakistan [Ashraf and Routray 2013], Japan [Fujisawa and Kobayashi 2010], and India [Vedwan and Rhoades 2001; Vedwan 2006]). These papers, along with an expanding bibliography on climate change and its multiple effects on agriculturists around the world, created the background for developing our research hypothesis. While some of these papers report comments on adaptive strategies, these are not analyzed or discussed within a management system framework. Since 2004, we have conducted semi-structured interviews with small-scale orchard managers in multiple countries in Europe, North America, South America, and Oceania; as well as the country of South Africa (see Table 1). We assumed that orchardists (as socially driven actors) who have spent 20 or more years working in the same orchard were observing and addressing specific issues about changing weather, plant diseases, insect pollination and/or pests, and implement practices that interpret specific problems “on the ground” (Lertzman 2009). These actions will be built upon foundations of local environmental knowledge, updated with each active generation, adding to deeper experience with adaptation to new environments from ancient and recent migrations of orchardists or their ancestors. Our expectations were to learn generalizable lessons from the overall patterns of their observations that are often accumulated over a lifetime and have been tested over generations.

Methods

Ethnographic and botanical field methods employed in this project have been reviewed in Reedy et al. (2009) and McClatchey and Reedy (2010). Informed consent procedures and human subjects review were provided by the University
of Hawai‘i, Committee on Human Subjects. Apple orchardists were identified for interviews using a networking strategy with three levels. First, we conducted Internet searches for cider makers within each region (since we assumed they were located in typical apple production areas within each country). Individuals were contacted via email, telephone, and/or mailings to arrange face-to-face interviews (Figure 1). This phase led to a small number of interviews in each region. These individuals were asked if they could make introductions to other orchardists (other apple and cider producers) in the area (snowball sampling; see Bernard 1988), which led to most of the interviews. We used this procedure because small-scale orchardists and fresh apple producers rarely have a website; this allowed us to make field trips more effective (and reduce costs). Indeed, not all of the orchardists were growing apples for cider production, but if they were small-family scale producers, we still included them in our interviews. Finally, a third level was achieved by visiting farmers’ markets, pubs, and small shops where local cider was available and we could find cider makers through their commercial activities. Only a few orchardists were located in this way.

A wide range of questions was asked of each orchardist. These focused on recognized biodiversity (both intra-specific and inter-specific), its roles in orchards, changes observed over a lifetime managing orchards, and decisions made when the environment changed. Interviews were audio-recorded and then transcribed (see Figure 1). The complete set of questions is available in Reedy et al. (2009). Information pertinent to the objectives of this paper was digitized and organized in a database for sorting and categorization. Observations and

Figure 1. Interviewing an orchardist in Cuenca, Spain. Photo by Will McClatchey.
adaptive responses were sorted by impacts on predictability, environmental limitations, biodiversity, and opportunities used by the orchardists. We generalized these responses into two categories that are relevant to adaptive management of orchards in the face of unpredictable climate change impacts. The first of these is a diversification strategy, which consists of having multiple types of trees or rootstocks available to nurture and capitalize on in changing environmental conditions. The second is a selection strategy, which entails investment in a particular type of infrastructure, variety, or management approach to adaptively manage for the long term in the face of climate change impacts. Diversification and selection strategies are informed by TEK of local orchardists. The component of our research presented here is qualitative, and adaptive strategies were organized in general categories and described following Gómez-Baggethun et al. (2012) and Agrawal (2008).

Results

Orchardists interviewed had worked with their orchards for periods as short as five years to as long as most of a lifetime (more than 50 years). For this analysis, we focused on qualitative comments provided by those orchardists who had worked in the same orchard for 20 years or more. Table 1 provides an overview of the number of interviews in each region. Additional results related to this work have been previously published (McClatchey and Reedy 2010; Reedy et al. 2009, 2011, 2013; Savo et al. 2013).

Context

Only one interview was conducted in each of 255 orchards although the number of people present for each interview varied. At least half of the orchardists were interviewed as individuals while walking through, standing, or sitting within the orchard under discussion. Other interviews involved up to five or six additional people including spouses, children, workers, partners, neighbors, and friends either within the orchard or in an adjacent house or barn. A consistent set of questions was applied and the number of researchers present varied. Most interviews with English-speaking orchardists involved one to three researchers. Interviews with non-English-speaking orchardists involved two to five researchers. Rather than using translators, local ethnobotanists led interviews using local languages. All interviews were recorded for transcription and analysis.

Orchard sizes were not measured; however, many orchardists reported the size in response to questions about the scale of their work. The smallest orchards were on less than one hectare and consisted of only 20–30 trees (20 trees was reported by some as a lower limit to their definition of “orchard,” while others reported it as a minimum number of trees to have a functional fruit production system. No one gave a clear explanation about why 20 trees was an important limit). Most orchards were small (~two to ten hectares) in relative comparison to modern commercial orchards in the same regions, but a few were as large as 300 hectares. Orchardists who were earning most of their living from their orchard work consistently had at least five hectares heavily planted with fruit
trees and other plants with little fallow space remaining. Orchardists were not asked their ages, but often gave this information; they were asked how long they had worked within orchards and we attempted to interview those with more experience when a choice was available. Orchards and orchardists varied in reported ages from 18–89 but most were 30–50 years old. One orchard in Brittany, France had been managed by the same family for over 1000 years, while most orchards had been planted by the current managing orchardist.

Orchards examined were all within regions also producing grapes, with many of these same regions known for their wine production. Apple orchards tended to be in slightly cooler areas and more upland than grapes, but our samples also included sites within a few hundred meters of the ocean at sea level (Brittany, France; Washington, United States) as well as sites located at over 3000 masl (Neuquen, Argentina). As fruit crops overlap in ideal situations, many orchards were mixed with many kinds of fruit trees, vines, and vegetables. Optimal soils vary widely depending on apple variety and root stock, but well-drained mid- to low-pH soils are more common than clay and basic soils. We did not sample soils but in many cases orchardists discussed soil as a characteristic of management. Although we began the work thinking that apple orchards are restricted to fertile, temperate climates, we learned that over thousands of years, varieties have been selected for a very wide range of conditions from quite arid and hot (e.g., Albacete, Spain; New Mexico, United States; and Puebla, Mexico) to wet and cold temperate (e.g., British Columbia and Quebec, Canada; and Scotland, UK).

Throughout the process we learned many anecdotal results that need to be examined in later efforts. For example, some orchards with numerous apple varieties receive little to no chill hours (time below 7°C) each year; yet common wisdom declares that even low-chill apples must have some cool temperatures. We wonder about the possibility that literature pertaining apple orchards (e.g., Juniper and Mabberley 2006) has a cool-temperate climate bias that is skewing the general understanding of the history of this crop and its management within orchards.

Climate

In every region where we conducted interviews, 100% or nearly 100% of individuals reported that over the last 20 years weather has become less predictable, with rain falling at unusual time intervals, or that temperature changes happened suddenly or inconsistently compared to past patterns. They generally reported that prior to the mid-1980s, spring temperature changes, flowering times, harvest times, and first autumn frosts were predictable to within a few days. Their past annual planning cycles included advance planning for issues such as labor, pollination services, and marketing, using calendar dates rather than environmental signals as reported in other studies (e.g., Kassam et al. 2011; Manandhar et al. 2011). Now planning for annual cycles must be done only a short time in advance and often in response to events that have just happened. While growers of annual crops might have the ability to cope with change from year to year, orchardists are growing and planting trees that might not fruit in their lifetime, making the possibility of sudden, unforeseen change a dire
prospect. Traditional ecological knowledge, based on a lifetime of daily observations of local climates and the ability to use those observations to predict and cope with future change, is the best strategy in the orchardist’s toolkit (see also von Glasenapp and Thornton 2011). Table 2 illustrates a list of impacts of climate change and observations/practices by orchardists.

Below we report some topics that were recurrent in orchardists’ comments, with particular focus on adaptive management in the context of climate change. However, it should be noted that some of these topics cannot be classified as adaptive responses but, more generally, as good practices (sensu FAO 2003) that could buffer potential problems due to future environmental (and social) changes. Although the particular circumstances of orchard management vary considerably, there are general patterns that hold for many orchardists. These general observations reflect common sentiments about the nature of management and long-term observations. We have not quantified these because although they appear to be patterned, orchard managers’ experiences and observations at the local level are substantially different from each other, reflecting the ample

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Table 2. Examples of climate change impacts and orchardists’ observations/practices.

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Observations/management constraints/practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictability</td>
<td>Weather patterns, particularly frosts and rainfall, are not predictable as they were more than 20 years ago. Unpredictable times when herbivorous insects emerge are resulting in greater lags before predatory insects can take action resulting in greater plant damage. Fruit trees with early flowering are more likely to be damaged from late frosts, so these varieties are becoming less desirable.</td>
</tr>
<tr>
<td>Environmental limitations</td>
<td>Reduced snowpack is changing which apple varieties can live in cold environments. Decreased rainfall is making some environments more difficult for growing fruit crops. The local environmental zone where orchards require the least investment is moving uphill or away from the equator (north or south). Apple sugar and flavor development are driven by many factors including environment (terroir). Trees selected for good fruit under one set of environmental conditions will not have exactly the same qualities as climate changes.</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Some traditional orchards have become havens for biodiversity (birds, insects, deer) as other parts of the landscape are either fragmented or developed for simplified, modern agriculture. Traditional orchards include multiple fruiting and other useful species. The particular mix at a site is the result of generations of experiments, microclimate management, and co-successes as collaborations among species have been realized. Shifts in any variable of climate would be expected to negate some of the optimization effort that has been developed. Conversely, the resilience of orchard systems is tested by climate change as a challenge to system integrity. Pressure to produce monocrop commercial fruit varieties using dwarf trees has a negative impact on biodiversity within the orchard, particularly intercropped vegetables and grazing animals that are incompatible with production and harvest methods and timing.</td>
</tr>
<tr>
<td>Opportunities</td>
<td>Diverse (many varieties) orchards are responding to climate changes with shifts from primary to secondary fruit varieties (this cannot happen in modern mono-crop orchards). Spread of diseases such as fire blight appears to be associated with changing rainfall patterns. Growing community recognition of orchards as cultural and biological reservoirs is enhancing their conservation value, tax benefits, and presumably, resilience to changing social climates. Extensive use of walls (including hedges) in traditional orchards produces a matrix of microclimates. Long-term complexity development within diverse microclimates should have generated an array of biological-cultural strategies suitable for unpredictable future climates.</td>
</tr>
</tbody>
</table>
spectrum of apple varieties, kind of pests, weeds, soil, terrain, and local climatic conditions (e.g., orchardists in mountainous areas of the Mediterranean are experiencing different specific problems than those of temperate plains on the West American coast). Nevertheless, we have been able to group them into general categories of observations that seem to be common either regionally or globally.

Our observations are loosely sorted along two scales: 1) the orchard environment; and 2) individual trees within orchards. The more inclusive scale of orchard environments addresses observations and decisions impacting orchards within the landscape and manipulation of various elements of an orchard as an artificial ecosystem. The finer scale of individual trees within orchards addresses observations and decisions made about long-term management of individual fruit trees. As a general observation in our broader research, we regularly saw orchardists of both commercial and traditional orchards working at the orchard environment scale, but have never seen orchardists of modern commercial orchards treating trees as individuals worthy of focused attention. For example, modern orchardists select pruning styles and apply them more or less universally across an orchard, whereas traditional orchardists often prune each tree for maximization of its individual strengths and based on observations about its individual health and microclimate. Classification by scale was not provided by orchardists; rather, this division represents our own organizational structure based on the behaviors we observed. At these two management scales, four sorts of general climate change impacts are observed by orchardists. We discuss their immediate responses to these impacts.

Orchard Environments

One general and important aspect of orchard management in the face of climate change or other types of environmental change is the structure of the orchard itself. A variety of features and arrangements are used that merge holistically to provide resilience to these agricultural systems. There is much to be gained from comprehending the ways in which orchardists organize and use their physiographic spaces (or environments) given that these represent expressions of TEK that have been successful for generations for the purposes of manipulating microclimatic variables (e.g., temperature), providing defenses for crops, or enhancing productivity of the orchard. All of these are relevant for discussion of orchardist TEK in the context of adaptive responses to potentially dramatic climate change impacts in the future (von Glasenapp and Thornton 2011).

Walls

Stone walls, wood fences, and living plant hedges all served as barriers both around and within orchards. Sudden changes in prevailing winds, thought to be long-term, have recently caused reshaping the layout of these walls in some locales (e.g., Cornwall, UK). Some walls surrounded individual trees or entire orchards. Stated purposes for these walls vary but generally include the following: partitioning animals (in or out); reducing or directing wind flow under trees; propping up important vines (e.g., grapes); creating homes for
desirable insects, birds, or small mammals (Maudsley et al. 2000); modifying specific local temperatures (e.g., absorbing and radiating heat, or blocking light/creating cooler pockets); and, in some cases, providing additional ingredients for cider. Some orchardists take fruit from hedge species and blend it with apple juice to provide desirable flavors, and some claim that desirable fermentation yeasts (used in cider making) live on the fruit of their hedges. This multipurpose strategy increases diversification within the orchard and assures that specific conditions are stored and maintained within the orchard system. Because walls are critical to management of microclimates, they are probably the most important elements as initial adaptations to climate change.

Shifting Orchards

Each orchard environment consists of a matrix of microclimate adaptations that are managed within a larger diverse landscape. Some are responses of the orchardist to local conditions, and others are conditions produced by the orchardist. Presumably, orchardists have always had to make at least minor adjustments over time as environmental conditions change. However, in recent decades, this process has probably become increasingly important, and orchardists have not always been able to modify microclimates in situ but have sometimes resorted to moving the orchard to a new location within the same landscape. This strategy is adopted when it is possible to use the space (owning plots at different altitudes) and is common in different cultures (e.g., McDowell and Hess 2012; Savo et al. 2013; Tesso et al. 2012).

Orchardists in Campania, Italy reported that as climate has changed, resulting in less predictable rainfall and higher temperatures at lower altitudes, one of their responses has been to move orchards uphill into land not previously planted as orchards. Relocation may be an adjustment to local shifts in the relationship between phenology, soils, and elevation. Some orchardists in southwest England have begun planting orchards on north-facing slopes as a way to limit sunlight in the increasingly hot summers. Similarly, orchardists in Ayrshire, Herefordshire and Devon, United Kingdom; Normandy, France; and Neuquen and Rio Negro, Argentina stated that selection of apple varieties as contemporary replacement trees in a particular orchard location should be made from regions closer to the equator or lower in altitude, since these were felt to respond better to changing weather patterns. These practices address environmental changes using both diversity in either the physical landscape or the biological system. The first one is a mobility strategy; the second one can be categorized as a selection strategy (sensu Gómez-Baggethun et al. 2012).

Traditional orchardists are under regular pressure from modern orchardists, governments, and other institutions to “modernize” their activities. Their responses to these pressures are important to consider. For example, traditional orchardists in La Mancha, Spain discussed that there was a point in time between 20 and 30 years ago when technical experts from the Spanish government came to their villages and instructed them in new ways to manage apples, including use of chemicals, removal of hedges, planting dwarf trees, and adoption of new commercial varieties (all of these being hallmarks of most modern orchards). Orchardists recognized that time period as corresponding with the beginning of
their current troubles with pests, diseases, increased water needs, and economic
difficulties of growing fruit for commercial sale. This was the period when almost
everyone chose to shift from traditional management practices and to adopt some
of the modern practices, and some elected to completely abandon traditional
management strategies. The new modern practices, consisting of using
combinations of chemical fertilizers, pesticides, and shallow-rooted dwarf
cultivars, are thought to have reduced the resilience in orchard ecosystems,
making them highly dependent on intensive maintenance and susceptible to new
pests. This was further impacted by the removal of hedges, which harbor
beneficial insects and microorganisms (Maudsley et al. 2000). Traditional
orchardists and other locals strongly believe and expressed their opinions that
this damaged the system at a time when changes in climate were allowing new
pests to move in and existing pests to proliferate in an absence of predators
dependent on hedge systems. According to the orchardists, prior to this time
there was much greater diversity of production systems (cultivars, species, and
management details) as orchardists were not competing with each other to
produce the same crop variety for national/international commodity markets,
but collaborating for production of subsistence and small-scale local commercial
crops, including apples.

Conservation and Sense of Place

Although there is not a consistent type or level of reverence for lands, some
orchardists particularly emphasized the deep conservation roles of the
management practices they perform, even discussing that they are working
with or for the environment. A few orchardists went so far as to say they were
growing environments, not orchards. In the Rhineland and Hessen, Germany
orchardists work within their *Streuobstwiesen*; these are loosely structured
community orchards with mixed fruits. Many of these orchards serve as primary
wildlife habitat, pollinator and predator insect reservoirs, and sanctuaries for rare
fruit varieties and traditional non-commercial practices. As such, some have been
set aside as working biodiversity conservation preserves (such as the Rhön
Biosphere Reserve). Similar conservation within working orchards has been
promoted in national programs in England and Wales; orchardists we
interviewed in some regions (Breconshire, Cornwall, Devon, Herefordshire,
Powys, and Somerset) received tax breaks or government subsidies for various
strategies such as maintaining hedges, conserving pollinators, planting standard
rootstocks, and keeping ancient sheep varieties. None of the orchardists we
interviewed indicated that it is profitable to manage for these diverse elements,
but most stated clearly that they do so because they love the landscape. The
maintenance of these diversified systems also serves as a storage strategy to
maintain varieties that could be eventually used to deal with different
environmental conditions in the future (Padulosi et al. 2011; Sthapit et al. 2010).

Intercropping

In addition to perennial woody plants that are grown within an orchard
system, many orchardists—particularly in the Mediterranean region—grow
herbaceous annual food, medicinal, and ornamental plants (Figure 2) in and
around orchard trees. Microclimates from full shade to full sun provide an array of opportunities for different crop needs and also diversify the production of the orchard. This is a diversification strategy addressing practical economic and ecological opportunities, but also provides a buffer for adaptation to climate change impacts (e.g., when the risk is spread in the production of crops with different needs, such as water or sunlight, it is more likely that at least one crop could give produce with variable or changing climate).

Several orchardists in Hessen, Germany also discussed growing other species in the same genera as their main crop plants. Their intention was to attract existing orchard pests into a known location with genetically weak ornamental flowering plants that bloomed a few weeks prior to the crop plants. This trap-crop method was said to give the orchardists time to plan a solution to the pest problem before they have time to attack the main crops (see Figure 2). A few generations ago this method was not needed, as most problems were associated with known and predictable pests. Nevertheless, with the changes in climate, combined with an alteration of natural balance by increased chemical treatments and changes in cultivars, the trap-crop method has been catching on.

**Pollinators**

Orchardists in Hessen and Rhineland, Germany were particularly adamant that mixes of native plants support pollinators. They discussed locally developed apple varieties as being native and compatible with local climes and modern commercial varieties as being non-native and largely non-compatible. Plants supporting pollinators served as alternative pollen sources, hiding places and

Figure 2. Ornamental plants serving as an insect trap in a traditional orchard in Campania, Italy. Photo by Will McClatchey.
homes, and less distinctly as bridging habitat between “forests” and “managed fruit forests.” Similar perspectives were held in other locations in Germany, France, Spain and the United States. This represents a long-term diversification strategy.

Animals and Fertilization

Unfounded health concerns in some countries have brought about legislation regulating domestic animal access to orchards. In some areas, animals are banned completely, while in others they are not permitted during fruit harvests and the months preceding it. However, traditional orchardists have long maintained a variety of large animals (e.g., sheep, cattle, horses, and goats) as part of orchard management systems. Sheep are particularly common elements that convert grasses into fertilizer and browse on a diversity of plants, maintaining open airflow under the orchard canopy. So common are sheep that several orchardists self-identified as sheep farmers who grow orchards on their pastures. Small animals (e.g., chickens, ducks, geese, and rabbits) are also often part of these environments. Small animals are identified as regulators of insects, as providers of fertilizer, and as useful control of small plant growth. Timing of animal activities varies but we most commonly encountered grazers being allowed within orchards following harvests and then being removed in the spring as summer vegetable crops were planted within the orchard.

Traditional fertilization includes managing animals within the orchard and/or spreading animal manure and other types of fertilizers in the orchard that were produced elsewhere. Other fertilization materials include compost, seaweed, wood chips, and leaves. Orchardists might also use synthetic chemical fertilizers (more commonly among modern orchardists), but the practice is loosely similar to that used in the past (i.e., to increase nutrients in the soil). Additionally, mushrooms that grow within orchards and can be harvested relate to the health of the trees and the type of fertilizer that has been applied. Therefore, orchardists seeking to harvest certain kinds of mushrooms can plan for them by spreading specific fertilizers or by having certain kinds of animals in the orchards. This is a diversification strategy because livestock or mushrooms represent an alternative source of income (or food) but also a storage strategy, since nutrients from plants can be more efficiently returned to the soil. Mulching and fertilization are aimed at preserving the quality of soil by reducing the loss of organic matter and humidity, which could buffer soil erosion due to more frequent heavy rainfall events, but also drought and winds. These strategies are maintained as localized TEK, but there are some general approaches shared by orchardists from diverse world areas.

Trees within Orchards

Management at the coarse scale of the orchard itself offers adaptive management strategies that are beneficial in the face of climate change impacts. Management also occurs at finer resolution at the scale of trees within orchards, which incorporates decisions about variety selection, taste, rootstock, pruning, and other variables. The following presents orchardists activities at the scale of individual trees.
**Apple Variety Selection**

Orchardists have a tendency to stick with varieties that have proven to be successful in the past. However, it is quite common for them to participate in two actions that create alternatives. First, there is a widespread tradition of growing “pips” (seeds) that result in seedling trees that have new genetic combinations and therefore may possibly be reproduced as new varieties. These are most often grown for rootstock, and it is widely assumed that most of these will not become viable alternatives, but again and again, orchardists pointed out unusual varieties within their orchards that had resulted from this process in the past. Children living on farms with orchards are often encouraged to grow pips and to tend these trees. As the child and tree age together, a form of social linking between generations and between people and the environment is developed. A second way that diversity alternatives are promoted is through watching for mutations on tree branches followed by vegetative propagation of these “sports” (genetic mutations growing as distinct parts of an individual) as grafts. Stories of sports abound in the oral history of apple varieties and a sport from a particularly popular lineage is something an orchardist proudly shows off.

Global market pressure, rather than environmental factors, drives the selection of specific varieties in modern commercial orchards. In contrast, traditional orchards are generally stocked with trees that are best adapted to the local environmental conditions following generations of environmental selection. This is one of the main differences between modern and traditional orchards and is likely one of the critical strategies for resilience in the face of climate change.

Traditional orchardists discussed the results of selecting apple varieties based on market pressures rather than environmental suitability. For example, an orchardist in New Mexico, United States showed how apples selected for his unusual riparian orchard environment differed strongly in taste with trees planted even a few meters farther from the ideal environment where desirable tastes are generated. Similar observations were made in other locations and given as the reason for off-taste in varieties, such as Red Delicious, that were not so delicious when grown in orchards outside of the environment in which they were selected. These varieties are tolerant of their environments rather than adapted to them (at least in terms of human tastes).

A more drastic example of this idea of tolerant rather than adapted goes far beyond taste and quickly becomes one of survival, as we saw in Quebec, Canada. Orchardists there emphasized impacts of cold weather and changes in snowpack levels, noting that in the past (more than 20 years ago) snow was usually so deep that it covered most or all of the tree stems and remained this way during periods of extreme cold. Although temperatures could fall far below freezing, the parts of the tree covered in snow would be insulated and not get much colder than freezing. Now with less snowfall and tree stems exposed to severe cold, there is higher incidence of freezing within trees resulting in bark cracks and eventually death of the trees. While some apple varieties can tolerate these sorts of changes, most cannot, so extreme cold periods without snow are the limiting and selecting factors for apple variety production in Quebec. We note that orchardists primarily within Europe discussed *biological* mechanisms for dealing with cold
temperatures, while orchardists in Argentina, New Zealand, South Africa, and the United States more often discussed mechanical mechanisms for dealing with cold temperatures. An extreme was an orchardist in New Zealand who was proud to have hired a helicopter to hover over his orchard blowing out cold air and heating the trees with its exhaust. As with most individuals we interviewed, this novel practice included a mix of new and old ideas; use of a helicopter was something the orchardist’s ancestors surely could never have considered.

Variatel diversity in a single orchard contributes to resilience through risk aversion for both the orchardist and the marketplace. Some varieties set flowers early and others do so late. Generally, the earlier the flowers set, the earlier the fruit will ripen. Early fruit often fetches better prices in markets and in subsistence settings may be essential for food before other crops mature. However, early crops carry greater risks from late frosts, early herbivorous insects (emerging before their predators can control them), and fruit damage from early spring rain or hailstorms. Late-blooming varieties may be at risk from early fall frosts and late fruit may be less valuable in markets that are saturated and after other fall crops have filled immediate food needs.

Diverse varieties may have been selected not only to diversify risk, but also to spread out labor needs. By having a few trees producing fruit over each week spread out over the entire growing season, local labor for short durations is likely to be sufficient for harvests. However, commercial monocrop production requires a large labor pool that may not be available locally, especially if multiple orchardists are competing for the same laborers.

To summarize, choice of apple variety can be described as both a selection strategy and a diversification strategy. This aspect of management is based on long-term knowledge of local environmental conditions, which are paired with the selection of phenological, taste, and fitness characteristics of specific varieties of apples. Local knowledge of these specific details is linked with tree survival (partly due to environmental fitness and partly due to human selection/choices) and these causalities are potentially interdependent with climate change.

Rootstocks

Rootstock is a variety or species that is selected for its adaptations to specific environments, diseases, or pests. These are grafted onto the bottom of cuttings (clones) of desirable fruiting varieties. With apples, rootstocks are commonly different varieties than those grafted on for fruit. In many cases, an additional result of grafting is a reduction in fluid and energy movement up through the tree that causes dwarfing/stunting of tree growth. Many reasons were provided for selection of particular rootstocks including disease resistance, modification of tree size (larger or smaller), availability of water, and modification of fruit taste. Orchardists in Cuenca, Spain emphasized the importance of using rootstock that is from a locally adapted native species, particularly Malus sylvestris. Other locally-adapted species include various “crab apples” (a non-scientific term referring to any species of the genus Malus with a wide range of physical-chemical characteristics), quinces, and pears that are native species in many parts of the northern hemisphere. Using rootstock to reduce the size of a tree was a controversial issue among traditional orchardists (see dwarf trees below). Apple
trees can live for up to 150 years or more, depending on rootstock and conditions. Choice of rootstock is a long-term selection strategy that results in conservation of species-level diversity through incorporation of local native species within the managed orchard complex. Although some local species are used, most locally available wild species that could be used as rootstock material are not selected for inclusion within the managed area and therefore are selected against.

**Dwarf Trees**

Using selected rootstocks and inter-stocks (stem sections of other varieties or species able to bridge otherwise incompatible root-stem grafts, or serving to modify tree size) can result in trees of reduced size compared to a standard tree. Arguments for reducing tree size include much more rapid fruit production, ease of harvesting, and ability to change varieties more often in response to changing markets. Orchardists frequently, but not consistently, argued against the use of dwarf trees for a number of reasons: 1) they are not as strong because of smaller branches resulting in breakage under fruit weight; 2) they are less resistant to drought because of corresponding reduction of root mass penetration; 3) they are more susceptible to diseases and pests; and 4) they are productive for fewer years. Some orchardists planting a new orchard have adopted a strategy making use of semi-dwarf and dwarf trees planted as an intercrop between standard-sized trees. A dwarf tree can be in production in three to five years and die in under 20. A standard tree can take up to 20 years to come into production (although five to ten years is common). The objective of planting dwarf trees is to have some fruit production in the short term with the smaller trees while planning for long-term fruit production with standard trees. This is a diversification strategy wherein orchardists hedge their bets by synergistically addressing both economic and environmental issues. This sort of intercropping constitutes a diversification strategy that may also contribute in spreading the risk of crop failure with different climatic conditions as it has been reported in similar studies (e.g., Gómez-Baggethun et al. 2012; Tengo and Belfrage 2004).

Dwarf trees are considerably less compatible with grazing animals as their new growth, flowers, and fruit are all closer to the ground. Standard trees have a much thicker trunk and taller canopy leaf, flower and fruit well above the animals’ heads, and can support the weight of a sheep leaning against them trying to get at low-hanging leaves. In Asturias, Spain and France’s Brittany and Normandy regions, cows are, or were in the recent past, common in orchards with standard trees. Such trees were repeatedly said to withstand cows brushing against them, whereas orchards that have switched to dwarf trees have had to remove livestock.

**Pruning**

Fruit trees steadily develop more branches over time as natural responses to uneven light distribution within a tree crown. Orchardists have different ways to manage the density of branches. Pruning is done not only to remove dead branches but also to allow airflow, change tree height, reduce fruit crowding, and to allow light and heat to reach the stem. Most traditional orchardists stated that they managed each tree for specific microclimate objectives. The result is that
each tree is very much a unique contributor to the local environment. This differs from the modern orchards we have examined in our work, where all trees in an orchard are pruned more or less in the same way in an attempt to create a single system in which trees are expected to function as a single unit, and microclimate differences are either ignored or attempts are made to mitigate them. Pruning of individual trees among traditional orchardists allows tailoring of the tree and orchard in the face of climate change impacts.

**Taste**

While the reasons each orchardist has for growing their orchard are diverse, the whole of the effort, and perhaps the aspect most susceptible to changes in climate, relies mostly on the quality and taste of the fruit. The reaction of each variety to different microclimates, fertilizers, pesticides, changes in rainfall periodicity, levels of exposure to heat and sunlight, duration from fruit set to fruit drop, etc. all play important roles in the resulting taste. As orchardists move varieties near or far based on market demand or proclamations of varietal performance, the fruit is frequently noted as tasting different in a new locale, under a different barrage of stresses. Most orchardists interviewed mentioned some aspect of this phenomenon, but none were more adamant about this topic than the orchardists in France (Brittany, Normandy, and Pays d’Othe).

There are four commonly accepted taste categories of apples—sweet, sharp, bitter-sharp, and bitter-sweet (Watson 2013). Cross-regionally, cider makers tend to seek taste balance by mixing apples of different flavor profiles. As a result, different regional taste profiles for food and beverages (Figure 3) were observed in the process of this study. Each includes distinctive development of locally available materials, including the diversity of fruiting plants selected for inclusion within the orchard system. For example, in California, United States one orchardist was growing citrus and apples together (otherwise not common and only observed in one location in Asturias, Spain and another in Brittany, France, and a handful in Campania, Italy). He then fermented the juice of the two fruits together (or added citrus juice to fermented apple juice) producing several unique products. More widespread patterns of similar activities include mixing maple syrup with cider (Quebec, Canada), co-fermenting apples and blueberries (Maine, United States), mixing hops with cider (Washington and Oregon, United States), co-fermenting apples and pears (German-speaking regions), and widespread mixing of apple juice with honey (another common orchard product) to produce *cyser*. Undoubtedly the most unique product we encountered was produced by a family in Campania, Italy. They grew an apple variety, locally called *melanurca*, and during the process of juicing would save the seeds. Once a large volume of cleaned seeds was generated, they were soaked in alcohol, releasing a heavily cyanogenic juice and producing a strong aromatic alcoholic beverage. Human taste preferences are competing elements within the overall process of orchardist varietal selection. Orchardists often stated that their selection of tastes was a reflection of working with the soil and other environmental features. However, we have not yet identified a pattern of relationships between taste and environmental responses. Our tentative conclusion is that taste is driven by cultural factors that are not part of
adaptations for local climates despite this being part of the orchardists’ perspectives, but we would not be surprised to learn that there is an environmental basis for taste selection such as selection of chemicals (e.g., tannins and other polyphenols) that are resistant to tree diseases or insects.

Almost all of the orchardists interviewed grow more than five varieties of apples as well as other species within their orchards. For some reason, possibly ancient, many orchardists in France, Spain, Germany, Austria, England, United States, and Canada, claimed that an orchard should produce at least 20 varieties of apples or that at least 20 should be mixed together to produce good cider. This claim was even stated by some orchardists who only grew a few (less than five) varieties within their own orchard. Globally there are few regulations on cider production in terms of content. However, traditional practices codified into two appellations in France for production of Calvados and pommeau in Normandy and Brittany do require a minimum of 20 apple varieties (from more than 200 approved varieties) and some Calvados producers claim to use more than 100 varieties. Presumably, the higher levels of varietal diversity contribute to greater diversity of chemistry, and thus, taste complexity.

Apple varieties are typically harvested in order of ripening but a few types are allowed to reside on the tree for extended periods. The extreme of this variation was observed in Canada (British Columbia and Quebec) and the United States (Vermont), where “ice cider” is traditionally produced by allowing apples to freeze on the tree followed by sublimation of water resulting in more concentrated sugars for a higher-proof alcohol beverage. While commercial companies cannot afford to follow this traditional practice, some orchardists
modify their growing system to increase airflow around the fruit trees and otherwise promote the desired effects needed for production of ice cider. While this pool of strategies does not address any environmental constraints, they represent diversified responses to social/cultural issues. Furthermore, cultural and regional combinations of tastes are built upon specific biodiversity features in response to local environmental conditions. With increasing climate change, we would expect these cultural taste selections to change either through loss of diversity, or through ongoing selection of different plant contributions. Effectively, in terms of adaptive management, these practices related to taste produce epiphenomenal diversification.

Discussion

Orchardists reported a wide range of observations and responses to climate change that we have organized based on scale. These scales were never explicitly stated by the orchardists, but emerge quite consistently across regions and interviews. We could easily have organized their responses in other ways (e.g., based on region, estimated cultural longevity in an environment, environmental impacts), but the orchardists themselves moved fluidly between subjects and presented more of an integrated set of action responses that do not support any other pattern of organization that we could discern. Global similarity of orchardists’ responses to patterns of climate change implied the presence of unstated rules about the right way to interact with or manage resources (Lertzman 2009). Further, since these patterns are consistent across sites where there was cultural transfer (e.g., colonial communities and their founding cultures) we can assume that there has either been a common logic passed down during migrations as part of the cultural tool kit for adapting to new environments, or that there has been convergent evolution of similar responses to similar problems.

Microclimates generated and managed by agriculturalists producing wine grapes have been studied (Nicholas and Durham 2012) and are insightful for understanding similar actions taken by orchardists. Nicholas and Durham (2012) found that winegrowers respond to environmental changes as reactive individuals, not through collective action unless there is a severe and imminent threat from unfamiliar pests or diseases. The most important pattern of responses involved selection of vines better adapted to new conditions. Similarly, orchardists interviewed appear to respond as individuals to their distinctive local microclimates—using walls, pruning or planting arrangements, and other mechanisms to manage airflow, temperature, and humidity. However, patterns of their responses illustrate either common cultural problem-solving/planning, or convergence on similar logical choices within a limited range of options.

Unlike grain production, orchards (and vineyards) emphasize vegeculture rather than sexual reproduction. Differences in resilience of vines and grains have been explored revealing different strategies for addressing climate change (Olesen et al. 2011). Advantages of vegeculture include conservation and propagation of specific desired and selected traits. Disadvantages include clonal susceptibility to diseases and reduced resilience or biological options resulting from lower genetic diversity. The traditional orchardists interviewed overcome
weaknesses of vegeculture by maintaining an array of clones, rootstocks, and species.

Most of the traditional orchardists we interviewed were pragmatic, considering diverse information and selecting elements that seem to support their worldviews and needs. Traditional knowledge is dynamic, integrating new elements (e.g., plants and ideas) as they arrive, which are then tested and deemed worth retaining or not. Evidence of past integrations show up in many ways. An example was seen in Spain where a foreign fruit tree was introduced about a century ago in the Segura range under its scientific name, *Diospyros kaki* Thunb. (Japanese persimmon). Although the Japanese name, *kaki*, is used in many parts of the world for this tree and its fruit, the orchardists in Spain are sometimes now applying the name *diospyros* that was associated with the plant when it arrived. A great number of other elements of consideration and adoption are doubtless nested within the orchard systems we examined, most not as easily disentangled as this bit of history.

The strategies adopted by orchardists are generally long-term. This may be because apples are perennial crops and need several years before they can be productive, but there could also be local cultural biases driving decisions. Since the majority of informants were traditional orchardists it is likely that we are not giving a complete spectrum of perspectives but are focused on more conservative participants within each local cultural community. Management strategies are conservative in the sense that orchardists tend to change factors within their orchard system either by spreading risk (e.g., multiple varieties and intercropping) and/or storing biodiversity and resources. All the mentioned strategies are supported by a foundation of TEK containing information necessary for finding solutions in the context of a changing environment.

Effective traditional management systems blend the strengths of cultures (multi-generational experiments and observations, learned knowledge, and contextualized interpretations) with environmental/biodiversity resilience through natural selection. Traditional orchardists we interviewed have demonstrated a range of observations about, and responses to, climate change. While we have emphasized the importance of changing predictability of local environments, the large-scale issues of orchard management appear to be strongly predictable (i.e., planting apples trees will produce apples; constructing walled enclosures with fruit trees and other elements can function as microclimates that attract a range of additional biota). While specific details managed by orchardists vary with geographic ranges (e.g., tree and pest phenology and precipitation patterns), the overall pattern is of some level of predictability in most environments, but with built-in diversity that provides resilience to the production system faced with unforeseen events (e.g., unusual weather events and the emergence of diseases).

Every environment has certain limitations as well as a range of opportunities. Part of the management system employed by the orchardists is to test the boundaries of both opportunities and limits. In fact, discovery of these boundaries is actually how management systems are structured. Variables such as availability of biological diversity are likely the most important elements of resilient systems, not because they allow an orchardist to restore particular functions, but because they provide a constantly shifting mosaic of opportunities.
Physical environmental variables (e.g., geological substrate, soil type, and rainfall) are difficult to modify, and therefore the focus of adaptation is to biological processes.

Management systems (Lertzman 2009) employed by the traditional orchardists we interviewed emphasized locally adapted and native biodiversity, microclimate development, and goals that are not limited to production of a single crop, but rather plan for contingencies such as variation in weather. This built-in resilience offers opportunities for traditional orchardists to persist in their lifestyles when modern commercial orchards in the same area may be struggling to survive the changing climate. Orchardists are highly active participants within systems that have coevolved as managed agroecosystems, where trees are planted but the natural surrounding elements are more or less free to flow, or sometimes selectively free to circulate/integrate within and around the orchard. Traditional orchards are also landscapes that represent biota and ecological knowledge that have been transported from place to place, followed by development of newer local adaptations wed to ongoing traditions.

From our observations, it appears that orchardists in different regions are convergent on similar actions, implying that there are limited options available despite cultural and regional variation, or that the actions are logical conclusions to similar problems. Orchardists facing climate change utilize logical sets of organisms, tools, and knowledge that they have inherited and apply these in ways that have been selected for. We do not know how orchardists first developed their sets of rules, but assume that processes of observation and experimentation have led to predictive responses both from humans and various elements of the environment. Cultural practices (or principles) then emerge as successes of earlier generations and not as limitations on what is possible. Traditional ecological knowledge is therefore dynamic, not static. This seemingly subtle difference is important, as it opens a window on how traditional orchard managers might be successful in the current climate change regime. They have not learned a system that is optimized solely for fruit production; rather, they have learned ways of thinking about systems that encourage the recognition of patterns and action based on probabilities.

Rindos (1984) and Richerson et al. (2001) both argued from different positions for impacts of climatic variability in agricultural development. Our study provides ethnographic evidence that managers of traditional orchards have management systems (sensu Lertzman 2009) that have been adaptable within changing climate regimes. The simple fact that traditional orchard management systems (primarily focused on apples) developed in Central Asia with a certain set of conditions, migrated westward into a wide range of climates from warm Mediterranean to cold Scandinavia, and then through colonial activities that expanded globally into many other locations, is an indication that the systems are resilient to climatic variability. Imagine, for example, an English orchardist arriving as a colonist in the Southern Cape of Africa. Very few environmental aspects were similar to those from home, yet new orchards were developed, new varieties selected, and new local ecological knowledge was developed as part of an ongoing, successful and resilient processes of human adaptation to climate variability and climate-driven environmental changes.
Conclusion

Orchardists in various locations around the world are recognizing and responding to climate change and climate variability as well as adapting their transported orchard landscapes to new environments/climate conditions. We surmise that we are seeing a normal management system response rather than an anomaly. However, climate change is having multiple effects—social, ecological, and economic—and we wonder if orchardists as well as humans in general will be capable of adapting as they did during the past with migrations that involved almost instantaneous and radical changes in climate.

Humans and our management systems are inseparable. We do not see evidence supporting the idea that the management systems primarily serve to limit human activities, but rather that the management systems are adaptive measures of human interactions within ecological niches that we may call agriculture. We live in a time of unprecedented climate change when diverse and resilient solutions are needed to maintain our food production systems. Trans-disciplinary collaboration between local management systems, agroecologists, and other environmental researchers is the best way forward.

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