

Article

Terroir in Transition: Environmental Change in the Wisconsin Artisanal Cheese and New England Oyster Sectors

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Abstract: Even as the concept of terroir becomes more salient in diverse cultural and national contexts, climate-driven environmental change threatens to alter the ecologies that contribute to the distinctive terroir of place-based products. Yet few studies examine how producers of terroir products perceive and experience environmental change. Our comparative case study addresses this gap, as we examine ways that changing ecological conditions will influence the emergent terroir of Wisconsin artisanal cheese and New England oysters. Drawing on in-depth interviews and a survey, we describe the environmental and sociocultural elements that Wisconsin artisanal cheesemakers and New England oyster farmers identify as characteristic of the terroir and merroir (terroir's maritime adaptation) of their products. We then compare cheesemakers' and oyster farmers' perceptions and experiences of climate change. We find that both groups perceive climate-related threats to the terroir and merroir of their products, though each group experienced these threats differently. We argue that the ongoing constitution of terroir—which has always reflected a tension between nature and culture—will be further complicated by changing ecologies. We suggest that a generative understanding of terroir that emphasizes terroir's sociocultural dimensions may help artisanal cheesemakers and oyster farmers mitigate some climate-related threats to their products.

Keywords: terroir; merroir; place-based products; climate change; artisanal; cheese; oysters

1. Introduction

Terroir—the way soil, climate, topography, and cultural practices influence the distinctive tastes of agricultural products—has long been associated with its French viticultural origins. Yet various translations of terroir can be found around the world: From Mexican mezcal to Hungarian Tokai, Wisconsin artisanal cheese to Darjeeling tea, and Vermont maple syrup to Chiapan mangos, to name a few.

The character of terroir's translations varies according to cultural and national context. In many European nations, for example, terroir is embedded in food cultures and institutionalized in agricultural policies. Terroir is often legally codified through designations such as geographic indications (GIs), protected denominations of origin (PDIs, PDOs, DOs), Appellation d'Origine Contrôlée (AOCs), and Appellation d'Origine Protégée (AOP). Such designations contribute to European Union agri-environmental rural economic development initiatives, particularly under the Common Agricultural Policy's Second Pillar, serving in some cases as “a valuable tool to use in an attempt to foster local development processes and to increase agricultural economic sustainability” [1]. Similarly,

countries in the Global South have increasingly adopted legislative frameworks for protecting terroir products as a means of stimulating trade and spurring rural development [2]. In the US, although terroir translations are not widely embedded within national or state rural development policy initiatives, and with only rare exceptions are designated GIs (e.g., Vidalia onions, Florida oranges, Idaho potatoes), emergent efforts to “test-drive” and “reverse engineer terroir” [3] emphasize anchoring foods and drinks to particular places and practices [4,5], in an effort to develop new markets for quality foods. This can also reflect American attempts to “emplac[e] our food systems” [6] (p. 23) and transcend proximity-based measures of locality, such as “food miles” or face-to-face interactions with producers [7–11]. Due to their potential to foster rural development, preserve food practices, and conserve environmental resources, terroir products have been promoted as a promising counter to conventional agriculture [12–16].

However, even as various translations of terroir have become more salient in many contexts, climate-driven environmental change threatens to alter the ecologies and signature qualities associated with these diverse places, creating new challenges for producers. For example, studies suggest that North American maple syrup producers [17], Lake Superior wild rice cultivators [18], and Arabica coffee growers [19] face climate change effects that could impact the very viability of their products. Climate impacts may also influence the quality and distinctiveness of terroir products, such as wine varieties [20] and tea [21,22]. Conversely, in some cases climate-driven environmental change may even catalyze opportunities for some place-based products, such as those seen with the resurrection of ancestral wine varieties in Spain or the favoring of climate-hardy regional heirloom apple varieties in Appalachia [23].

Yet in spite of the increasing evidence of climate-driven environmental impacts on the quality, distinctiveness, and viability of terroir products, the existing scholarship is relatively silent on how place-based producers perceive and experience climate-driven environmental change, as well as how that change may impact their products and practices. We address this silence as we examine how changing environmental conditions may influence the emergent terroir of two place-based products: Wisconsin artisanal cheese and New England oysters. We begin by describing environmental and sociocultural elements identified by Wisconsin artisanal cheesemakers and New England oyster farmers as contributing to the terroir and merroir (terroir’s maritime adaptation) of their cheese and oysters. Second, we compare how cheesemakers and oyster farmers perceive and experience environmental change in their respective sectors.

Our findings indicate that cheesemakers and oyster farmers perceive climate-related threats to the distinctive terroir and merroir of their products. In our study, however, each group experienced these threats differently. New England oyster farmers, for example, expressed a widely-shared recognition of the effects of climate-driven environmental change on the quality and distinctive taste of their oysters. In contrast, in initial interviews, Wisconsin cheesemakers did not cite climate change as a significant threat to the terroir of their cheese. However, their perspectives shifted following a severe drought in 2012, when cheesemakers began expressing concerns about potential impacts of environmental change on their operations. Both Wisconsin cheesemakers and New England oyster farmers showed signs of some adaptive efforts to protect the terroir and merroir of their products, in response to climate impacts. We argue that the ongoing constitution of terroir—which has always reflected a complex and delicate tension between nature and culture—will be further complicated by changing and unpredictable ecological conditions, necessitating new institutional, consumer, and producer adaptations.

Terroir Discursives: Nature/Culture and Tradition/Modernity

Scholarly debates on terroir have focused largely on two related tensions: between nature and culture, and between tradition and modernity. The negotiation of these two tensions allows us to explore the relative importance of ecological conditions and sociocultural practices in the constitution of terroir, as well as its static versus dynamic nature, in the face of environmental change.

Many debates focus on the primacy of either ecological or sociocultural elements in the construction of terroir. Early articulations of terroir in France underscored the environmental origins of the distinctive qualities of French cuisine. As early as 1789, the French historian Pierre Jean-Baptiste Le Grand d'Aussy described how French cuisine was embedded in “what nature has seen fit to allow each of our provinces to produce” [12] (p. 11). Contemporary articulations of terroir that emphasize the primacy of ecological contributions suggest it emerges through unearthing specific environmental qualities in foods, rather than generating them in an alchemic dialogue with nature. As Barham [24] (p. 136) describes, this vision of terroir focuses on “interpreting what is there in nature to be known, rather than viewing nature as an obstacle to be overcome or controlled for production.” Importantly, a focus on the primacy of terroir’s environmental factors—climate, microclimate, soil, and “terre” (land)—tends to present terroir as statically linked to specific, relatively stable nature(s), fixed in place as well as time.

Despite the longstanding focus on the environmental origins of terroir, many scholars argue that sociocultural contributions, such as producer practices, are—and always have been—more central to terroir’s constitution. For example, Trubek [14] notes that in France, “it was ultimately France’s food culture, more than the natural environment, that created the *gout* (or taste) of terroir.” Elsewhere Trubek et al. [16] also note that “a complex local ‘social imaginary’” is at the heart of the idea of terroir, one that emphasizes its history and traditional practices. Barnea [25] (p. 624, 633), drawing upon Lukacs’ [26] history of wine, similarly describes the ways that the legal codification of terroir in France linked to Bordeaux region wines was primarily the result of a socially-constructed “mythology of unbroken tradition” designed to “suppress fraud and maintain wine reputation.” Moreover, as Demossier (2011) illustrates in her examination of the changing nature of French wine terroir, a “paradigm shift” is underway; contemporary framings of terroir have begun to place greater emphasis on the active role of culture and producers dialoguing with nature to create signature tastes [27].

In addition to the scholarly dialogues concerning the environmental versus sociocultural contributions to terroir, another key debate navigates the tensions between tradition and modernity. This debate largely focuses on the static versus dynamic nature of terroir—whether, and to what degree, terroir is wedded to unchanging traditions or is a result of ongoing sociocultural adaptations. In articulations of terroir that emphasize tradition’s primacy, terroir is presented “as the carrier of memory, history, and culture, but also . . . a component of the larger ‘imagined community’” [16] (p. 140). In such conceptualizations, the nostalgia for a “lost past” serves an important social function, and terroir plays a role in shaping modern national identities by “provid[ing] a secure landmark at a time of change . . . [while] also hid[ing] ruptures, conflicts and tensions” [28] (p. 127).

Yet others argue that attempts to obscure ruptures, tensions, and change—by codifying tradition and institutionalizing terroir through labels and designations, such as GIs, PDOs, GIs, and AOCs—can also generate static notions of culture, potentially limiting producer innovation [29]. As Demossier explains, “public policy regarding heritage, food and foodstuffs is in many ways paradoxical by fixing ‘traditional’ ways of doing things while, at the same time, emphasizing modernization, reforms and adaptation to global market forces” [28] (p. 125) (see also [30]). Indeed, even as tradition is valorized, terroir products also embody a contradiction when those traditions find value in hypermodern global markets. Barham [24] argues this contradiction reflects “a conscious and active social construction of the present by various groups . . . who jostle for position in their efforts to recover and revalorize elements of the rural past, to be used in asserting a new vision of the rural future” [24] (p. 132). This construction of terroir can also engender what Potter and Tilzey [31] have termed the “consumption countryside,” in which terroir products reflect a “profitable production of nostalgia” [28]. Such a commodification of terroir to serve modern markets can reinforce neoliberal governance structures [32] and foster “museums of production” in tokenizing ways, altering the very nature of place-based products [29].

Both of these debates—environmental versus cultural constructions of terroir, and tradition versus modernity—reflect the dynamic and contested nature of terroir. In practice, in spite of discourses that argue otherwise, the distinctive terroir of place-based products has emerged through on-going adaptation—to specific ecologies, food cultures, producer practices, and markets [4,27,29,33].

As Trubek et al. [16] (p. 140) note, “terroir, as well as the appellations that protect it, resulted from a localized and collective conversation that, in many ways, is on-going. The social life of terroir has never been static.”

Importantly, however, while scholars argue that the social life of terroir has never been static, with a notable recent exception [34], the key debates surrounding terroir’s framing are typically premised on the assumption that the ecological context is relatively stable over time. For, although any oenophile is familiar with good or bad years for a wine vintage based on the year’s weather, the long-term ecological contexts that define the terroir for that wine have been presumed to be based on consistent ecological assemblages and conditions. Additionally, although there has been considerable conversation around terroir’s adaptive versus fixed nature with respect to changing markets, regulations, and sociocultural contexts, the social science literature has given less attention to terroir adaptations in the context of climate-driven environmental transitions.

In contrast, a range of ecological studies have investigated how regional climate change effects are altering the growing conditions and terroir for certain place-based products. For example, Cayan et al. [35], Nemani et al. [36], and Holland and Smit [37] have all examined how climate change will influence wine quality [19,38–40]. Nicholas et al., for example, find that environmental shifts have already altered “three key phenolic compounds in grape skins important to premium wine quality” [20] (p. 1556). They examine the transformation of the geographic components of terroir of California’s winegrowing regions and effects on varieties, such as Pinot Noir. Similarly, van Leeuwen et al. [41] find that unpredictable regional climates could affect wine quality by influencing the interannual variability of viticulture. Ecologists have also investigated the impacts of climate change on other terroir-based products, including coffee and tea. For instance, Davis et al. [42] suggest that higher temperatures can negatively impact the ripening of cultivated Arabica coffee fruits, as well as their yield: increasing average temperatures across the majority of coffee growing regions suggest a decline in Arabica quality and distinctiveness. Ahmed et al. [21,22] also show that phytonutrient and secondary metabolite concentrations in tea are susceptible to projected climate variability [43].

As ecologists have demonstrated, we can expect that climate-driven environmental change will increasingly affect the environmental conditions that influence the terroir of place-based products. It is therefore critical to examine producer perceptions and experiences of and adaptations to climate-driven environmental change. The way in which terroir of the future is constituted stands to influence social relations, rural livelihoods, regional power dynamics, and economic inequalities. Importantly, which elements of terroir will change or vanish, and which elements will remain stable? Moreover, who—and what factors—will constitute the terroir of the future, in the face of climate-driven environmental change?

2. Material and Methods

Our study of the effects of environmental change in the Wisconsin artisanal cheese and New England oyster sectors was one component of a broader research project that examined the role of heritage and terroir in fostering agri-food clusters and rural development [44]. Cases were selected based on preliminary research assessing their potential to foster agri-food clusters, their long-standing links to regional or cultural heritage, and the connections between place/territory and taste or quality of the products. In each case, we explored a range of challenges and opportunities experienced by cheesemakers and oyster farmers.

The Wisconsin artisanal cheese case study from which this analysis was drawn included 26 in-depth semi-structured interviews conducted between 2010 and 2013. Interviews were conducted with retailers, institutional leaders, experts, and 14 artisanal cheesemakers. Most cheesemakers were based in the Driftless Region in southwestern Wisconsin [45], home to approximately 70 percent of the state’s artisanal cheesemakers [46]. In interviews we queried cheesemakers and key informants in the sector about their perceptions of the particular factors that contributed to Wisconsin’s cheese terroir, as well as the challenges and opportunities they faced. In addition to in-depth interviews, we visited

cheesemaking plants, farms, retail outlets, and university research facilities, conducting informal interviews and engaging in direct observation. We triangulated our data collection by drawing on secondary data on the evolution of the cheese industry in Wisconsin (e.g., websites, blogs, historical documents) (see also [4,47]).

For the New England oyster aquaculture case, we conducted 58 in-depth semi-structured interviews between 2011 and 2012, in two phases. In the first phase, we interviewed sixteen key informants in the oyster sector: Government officials, farmers' association leaders, extension agents, aquaculture coordinators, and seafood distributors. In the second phase, we interviewed 42 New England oyster farmers (approximately ten percent of the sector at the time). The oyster grower sample was stratified by geographic sub-region and then randomized. Sub-regions included (1) the North Shore of Boston through New Hampshire and Maine, (2) the South Shore of Boston, Cape Cod and the Islands, (3) Rhode Island, and (4) Connecticut. Interviews focused on participants' perceptions of the particular factors that contributed to New England oyster heritage and *merroir*, as well as challenges and opportunities faced by these producers. In addition to in-depth interviews, we triangulated our data collection with participant observation through membership in the East Coast Shellfish Growers' Association (ECSGA). We also attended regional aquaculture conferences and oyster festivals, visited hatcheries, and spent time informally with New England oyster farmers.

As we compared these two place-based product sectors, we noted that for both cheesemakers and oyster farmers, climate-driven environmental change emerged as a challenge to their operations. However, the cheesemakers in our study did not initially report that climate-driven environmental change was having a strong effect on their practices, cheese quality, or overall distinctiveness. During the period of this study, however, a significant challenge to cheesemaker operations came in the form of an extreme weather event: a severe drought in 2012. In order to more fully examine producer experiences of and responses to this drought, we surveyed the artisanal cheesemakers in the Driftless region in early 2013, drawing our survey sample from all artisanal cheesemakers we could locate in exhaustive online searches. Of the 45 producers that received a survey, we received 36 responses (an 80% response rate). In the survey, we asked cheese producers about changes in their production practices and the perceived quality of the milk and cheese before and after the drought, ways the drought had affected their operations, and if they felt that institutional supports could assist them during extreme weather events. We recognize that a single weather event, such as this drought, cannot be causally linked to shifts in long-term climate patterns. However, given that climate change in the region is expected to increase periodic extreme weather events—from summer droughts to spring floods [48,49]—the drought allowed us to consider a preview event with which to explore how cheesemakers perceive and experience the impacts of changing environmental conditions.

Unlike cheesemakers, the oyster farmers we interviewed did not mention specific weather events. Rather, they reported experiencing challenges related to environmental change that they perceived to be more gradual and persistent, and they reported observable effects over time, in the course of their careers (for most oyster farmers, this spanned five to thirty years). For example, oyster farmers frequently mentioned concern over the effects of warming ocean temperatures on their oyster quality and also cited significant concerns about ocean acidification and disease. They also worried that the distinctive sweet taste of their oysters that they associated with cold ocean temperatures was at risk.

All interviews for both cases were transcribed and coded for key themes, using NVivo qualitative analysis software. Our initial codes were purposely broad, and we paid particular attention to how oyster farmers and cheesemakers framed challenges to the quality of their products. We subsequently refined our coding to include climate factors and specificities related to environmental change. We analyzed the survey data by calculating aggregate results across all survey responses (for example, the percentage of producers reporting that the drought had affected their current operation). We analyzed responses to the open-ended survey questions by looking at key themes that emerged in the responses.

2.1. Wisconsin Artisanal Cheese Case

Cheese production in Wisconsin is part of a longstanding cultural heritage that began with European immigrants who settled in the state in the early 1800s. By the 1920s, close to three thousand cheese factories dotted the state, ref. [50] contributing to Wisconsin's moniker "America's Dairyland." Production of "American cheddar" dominated, though nearly a quarter of cheese production included so-called foreign cheeses: Limburger, Brick, and Emmenthaler Swiss [3]. The state's conventional cheese production declined between 1922 and 1980, but a resurgence of interest in specialty and artisanal cheeses in the mid-1990s helped spark Wisconsin's "cheese renaissance." In 1994, the Wisconsin Master Cheesemaker program was established to help foster that renaissance by providing high quality training to a group of emergent expert cheesemakers, some of whom had also visited European cheesemaking operations [51]. Today, specialty retailers and restaurateurs cater to a growing consumer base with a myriad of farmstead, artisanal, seasonal, mixed milk, and grass-based cheeses.

In 2016 Wisconsin's 144 cheese plants and farm-based producers led the nation in cheese production, producing approximately 27% of U.S. cheese and ranking fourth in the world for global cheese production [52]. Wisconsin also produces close to half of the nation's specialty cheeses, accounting for nearly a quarter of Wisconsin production and fueling the state's 5.5% growth in the sector with over 600 cheese varieties, including 65 cheeses original to Wisconsin [50]. In addition to specialty cheeses, Wisconsin produces dozens of artisanal offerings, many of which are handcrafted, aged carefully in cheese caves, use raw milk ingredients, are crafted by Master Cheesemakers, and garner a price premium over more standard offerings. Experienced aficionados describe the flavor profiles of Wisconsin's artisanal offerings with the nuance of wine sommeliers, contributing to the emergent terroir narrative of this place-based product.

In spite of the growth and success of the sector, as Wisconsin experiences climate-driven environmental change, ecological research suggests that the state's artisanal cheesemakers will face challenges related to the quality and volume of the milk produced. For example, most climate projections indicate that the numerous microclimates of the Driftless Area, home to the majority of Wisconsin's artisanal cheesemakers, will be altered through increased variability of precipitation and temperature [53], which will, in turn, influence the diverse array of forbs and grasses and the consistent quality of forage eaten by dairy livestock. Some studies have highlighted how increased regional temperatures and more frequent heat waves [54,55] are likely to increase dairy livestock stressors and impact milk production [56], potentially affecting milk quality and availability.

2.2. New England Oyster Case

New England oysters' regional distinctiveness builds upon a rich heritage of traditional fisheries that includes both wild-harvest and farmed oysters. Human oyster consumption in the region harkens back thousands of years, as evidenced by historic middens (piles of discarded shells) [57]. Through the early Colonial period, oysters were a main food source while agricultural lands were being developed [58], with shells often used as a source of lime [59]. As New England's oyster industry emerged, regulated coastal leasing systems were developed across the region in the 18th and 19th centuries [59,60]. Despite a dip in regional production during the Great Depression, which was followed by widespread oyster habitat destruction from the Great Hurricane of 1938, the industry today is experiencing a renaissance.

The revival of New England's oyster sector primarily emphasizes artisanal shellfish farming, in contrast to large-scale commercial oyster production. As of 2012, there were over 400 individual oyster farms in the region. Unlike their predecessors, who sometimes tended thousands of acres under one operation, the majority of today's artisanal oyster farms are small (<1–20 acres) and primarily rely on hatchery cultivated oyster seed and a novel, intensive approach to cultivation. Some farmers participate in shellfish aquaculture as a means of diversifying from wild harvest fisheries. Relatedly, interest has grown in oyster tastings. At these tastings, connoisseurs compare oysters from Cape Cod, Maine, and Rhode Island side by side while exploring wine and beer pairings with particular

oyster varieties, and pay a price premium for the distinctive quality of these oysters. For example, when compared with the US Gulf Coast oysters, New England oysters are widely appreciated by connoisseurs for their hard shells, sweet flavor, and clean taste. Taken together, these characteristics contribute to the emergent terroir of this quality product.

Oyster farmers contend with significant vulnerabilities that may affect the long-term viability of their operations and the emergent terroir of their oysters. The resilience of oyster aquaculture in New England is dependent upon ecosystems that are highly vulnerable to climate-driven change. For example, the Gulf of Maine where most New England oysters are grown is experiencing sea surface temperature increases faster than 99% of the global oceans [61]. Shellfish populations—both wild and those farmed in aquaculture systems—are also highly susceptible to ocean acidification, a side effect of increased atmospheric CO₂, because of the corrosiveness of acidification on calcifiers, particularly at the juvenile stage [62,63]. The estuaries and bays where oyster leases are commonly located are some of the most vulnerable hotspots for acidification [64]. The ocean absorbs approximately 30% of anthropogenic CO₂ [65–67], and studies examining climate impacts on New England fisheries emphasize ways that warming ocean temperatures, sea level rise, changing marine biogeochemistry, invasive species, novel disease, and parasite exposure will all directly affect fish and shellfish populations [68]. Furthermore, many of the New England oyster farmers interviewed in this project were familiar with the challenges that had recently been experienced by oyster farmers in the Pacific Northwest, specifically concerning mass-mortalities of juvenile oysters, of which climate change induced ocean acidification was the main culprit [69].

3. Results

3.1. Contours of Wisconsin Cheese Terroir and New England Oyster Merroir

Here, we first describe ways in which Wisconsin artisanal cheese producers and New England oyster farmers are identifying specific environmental and sociocultural and factors that they link to the emergent terroir or merroir of their cheese or oysters. Subsequently we detail our findings concerning producer perceptions and experiences of climate-driven environmental change and the potential impacts this change has on the emergent terroir of Wisconsin artisanal cheese and the merroir of New England oysters [70].

3.2. Wisconsin Artisanal Cheese Terroir

Wisconsin artisanal cheese producers described the terroir of their cheeses as a dynamic combination of environmental and sociocultural factors. As seen in Table 1, cheesemakers emphasized how the distinctive “taste of place” of Wisconsin’s artisanal cheese reflects the unique environmental conditions of the Driftless region, as well as the active involvement of knowledgeable cheesemakers.

Table 1. Environmental and sociocultural elements of terroir.

Environmental Elements	Sociocultural Practices
<ul style="list-style-type: none"> • Driftless soil minerals, limestone • Forbs and grasses, plant diversity • Natural cycles of milk production, calving, and lambing with smaller dairies • Seasonality, regional micro-climates 	<ul style="list-style-type: none"> • Experiential and multi-generational knowledge • Feel of the curd, “hands in the vat” specific production practices (use of raw milk, open vats, grass/feed regimens) • Farm-scale production factors (farm management) [71]

When identifying the environmental elements that contribute to the terroir of their cheese, many cheesemakers credited the minerals in the soil, particularly those minerals characteristic of the Driftless region. The name “Driftless” references the region’s geological history; during the Wisconsin Glacial

Episode, ice blanketed the entire state, with the exception of the Driftless region's upland plateau. As the glaciers retreated from the rest of the state, they eroded the landscape and stripped the soil of minerals, including limestone. The Driftless region, however, maintained its hilly topography and its dolomite limestone soils. One cheesemaker described a widely-shared belief about how the limestone soils influence their cheese, explaining:

We believe—and there is some science to back it up—that the minerals that are in the earth in this area, provide a distinct characteristic in the food that is produced, whether it be vegetables, the water, [or] the milk. Pigs and cows and other animals, sheep and goats are roaming animals—they get their minerals from the grass, which grows from here, and that is the main part of the flavor (see also [4]).

Due to its unique geological history and topography, the Driftless region is also characterized by a remarkable number of microclimates that host a myriad of plant species, some of which are found nowhere else in the state [72–74]. Many cheesemakers described their perception that the diverse array of forbs and grasses provided higher-quality forage for dairy livestock in the region, in turn shaping the unique terroir of the cheeses. As one cheesemaker described:

[T]he flavors that we get are different than the other parts of the country, got a lot of limestone, a lot of granite here . . . [This] county's got a tremendous amount of plant diversity, you know, this county's got something like . . . 20,000 species of plants. And that's more diversity than the whole state of Illinois (see also [4]).

This diverse forage was particularly important to the Wisconsin artisanal cheesemakers in our study, with many of them associating the distinctiveness of their cheese with milk sourced from grass-based dairies or their own pastured livestock. As one cheese producer explained:

I think you can put a piece of grass-based cheese and a piece of conventional cheese from anybody and I don't know if they would say one is better, but they would say the grass-based one is more complex.

Others focused on the interactions between climate, soil, and forage, which together foster the environmental conditions needed for crafting distinctive, high quality cheeses, as this cheesemaker described:

I would say it's our climate, the climate especially in the Springville/Dodgeville area, it really is, you know, the temperature is right, the pasture is right, it's that whole environment, I think the soil is so rich that it's perfect for the cheesemakers . . . the whole [Driftless] area, it's another incredible region.

While many cheesemakers described how environmental factors shaped the terroir of their cheese, all cheesemakers emphasized the critically important ways that specific cultural practices and producer knowledge contributed to the unique qualities of Wisconsin artisanal cheese. For example, cheesemakers credited first-hand, experiential knowledge for their distinct flavor profiles, emphasizing how they eschewed “short cuts.” Many cheesemakers placed a high level of importance on having a “feel” for the cheese by putting one's “hands in the vat”. One cheesemaker described this kind of experiential knowledge as second nature, explaining,

In Wisconsin, everything is open vats. So the milk is open, and everything is done by hand. They're cutting the curd with big knives . . . they're putting their fingers in the curd to see when to cut, and it's just like this thing that people take for granted, like—why would you want to push a button when you could have your hands in the milk?

Cheesemakers also emphasized the importance of specific cheesemaking practices, including using raw, grass-based, or mixed-milk cheeses, using traditional copper kettles, or aging cheeses on traditional wooden boards. Cheesemakers did not all emphasize the same practices, but their articulations of the importance of a range of practices reflected a shared commitment to quality and careful attention to detail.

In addition to experiential knowledge and specific production practices, artisanal cheesemakers identified the regional cheese heritage of Wisconsin as central to their understanding of Wisconsin cheese's terroir. This longstanding heritage contributes to a multi-generational knowledge that embeds these particular cheeses in a specific place. One cheesemaker described the uniqueness of this heritage:

We have so many third and fourth generation cheese-makers in this state; it's almost like you go into a cheese plant and . . . you start talking casually to the people working there . . . and so and so's great grandfather ran this cheese plant in 1922 . . . it doesn't happen anywhere else in the nation . . . nobody has that hundred-year history of cheesemaking.

Finally, some cheesemakers also pointed to how environmental and cultural factors interacted and created Wisconsin's cheese terroir. They emphasized how the taste of the cheese varied by place, arguing that not only the taste of the milk, but the cultures in the cheese, varied by farm and by cheese plant:

Well, I can take milk from my farms, make it into cheese, and it's gonna taste different than if those [milks from my] farms go to another plant. Yeah. Because not only is it the milk that is important, but it's the cultures you use, and it's also the environment in the plant that's also the terroir.

In sum, the cheesemakers articulated a range of environmental and sociocultural factors that contributed to the emergent terroir of their cheeses. However, although many cheesemakers conveyed to us the importance of environmental factors in contributing to the distinctiveness and quality of their cheese, climate-driven environmental change did not emerge as a significant factor influencing the quality or distinctiveness of their cheese in our initial interviews. Yet as we discuss in the next section, we noted that following the extreme drought in 2012, this theme emerged more strongly, informing our decision to conduct a topical survey to assess the impacts of the drought that we discuss in a subsequent section.

3.3. *New England Oyster Merroir*

As shown in Table 2, New England oyster farmers in our study identified many environmental and sociocultural factors that contribute to the distinctiveness of their oysters. These unique attributes led one oyster grower to explain, "Barnstable harbor is the Napa Valley of oyster growing—I think you can go a step farther and call it a Bordeaux."

The environmental aspects of New England's oyster merroir are embedded in a unique North Atlantic biogeography that includes both a cold-temperate Boreal coastal habitat (from Cape Cod northward to the Strait of Belle Isle, Canada) and a temperate Virginian/Mid-Atlantic coastal habitat (from Cape Cod southward to Cape Hatteras, North Carolina) [75]. The same glaciers that missed the Driftless region carved numerous bays in New England. Greater coastal type variation lies within these biogeographic regions than in any other region of the Atlantic coast [75].

As the oyster farmers in our study articulated their perception of the factors that contribute to a distinctive New England oyster merroir, they identified the region's cold ocean temperatures as particularly important. As one grower described, "the colder water tends to make firmer, sweeter oysters." Oyster farmers characterized New England's cold, clean waters as key to quality, as this grower described:

New England has always been known for seafood, and you know, clean and fresh. Those are a couple of things that never really are in question, whereas say the Gulf [of Mexico] has issues with their oysters, their water quality.

Table 2. Environmental and Sociocultural Elements of Merroir.

Environmental	Sociocultural Practices
<ul style="list-style-type: none"> • Temperature • Salinity • Sediment • Average depth of lease • Tidal flow and/or magnitude • Algae, seaweed • Sub-tidal or inter-tidal location • Freshwater runoff/stream nearby • Species selected * (<i>Crassostrea virginica</i>; <i>Ostrea edulis</i>) 	<ul style="list-style-type: none"> • Bottom culture, growing in gear • Means of harvest (i.e., dredge, by hand from gear, SCUBA) • Frequency of tumbling • Selectivity when culling • Wild spat or hatchery-reared seed (choice of diploid or triploid oyster) • Pitting • Defouling of gear and shells • Species selected * (<i>Crassostrea virginica</i>; <i>Ostrea edulis</i>)

* The species selected is a cultural choice that is embedded in regulations, as well as the biophysical context of the native oyster of the region being *Crassostrea virginica*, also known as the Eastern Oyster. Some farmers also raise *Ostrea edulis*, also known as the “Belon” or “European flat” oyster, which is technically an AOC product from the Belon River in Brittany. As species selection combines environmental and sociocultural elements, it fits within both columns.

In addition to cold water, oyster farmers cited salinity as another important characteristic that has a strong influence on the merroir of New England oysters. Higher salinity produces a brinier oyster, while lower salinity leads to a milder brine flavor. As one grower explained:

New England just doesn’t have the rivers like the Mississippi or the enclosed areas like the Chesapeake that are really diluting that salt quality, so, most New England oysters tend to be pretty close to an oceanic salinity level, most people tend to like that in their oysters.

Many oyster farmers reinforced this characteristic, describing cold water and salinity as essential to New England’s oyster merroir. As one grower explained:

In terms of oyster quality, that sets ours apart, is that they are a high salinity oyster. There are other areas that have high salinity, too. But, ours is a cold area with high salinity and that combination gives you a very salty, but sweet, oyster.

Oyster farmers regularly noted that consumers could tell the difference in taste in their oysters over, for example, an oyster from the mid-Atlantic or Gulf Coast region. One oyster farmer described the distinctive quality and flavor this way:

I think the key thing probably is the waters tend to be colder earlier on in the season. So the oysters for more of the year are loaded up with glycogen, which is what they use for an energy storage molecule and makes them sweet. So, I think the flavor and the taste are related to that and I do think that differentiates them from other oysters in the mid-Atlantic or Southeast.

In addition to cold temperatures, salinity, and glycogen levels, some oyster farmers emphasized the importance of additional environmental factors, such as sediment or bedrock under their farm or the types of algae their oysters were consuming. One grower said:

One thing for sure is: an oyster is what it lives in. Whatever area they are in and whatever food they get in that area, determines their flavor along with the salinity and whatever else Mother Nature does.

In addition to environmental factors, most oyster farmers also identified key sociocultural practices that contributed to the merroir of their oysters. For example, many New England oyster farmers highlighted the importance of the labor-intensive practice of growing oysters in “gear,” which entails a large amount of direct handling and protection to create a high-quality product intended primarily for the lucrative half-shell—as opposed to the shucked—market. Most New England oyster farmers use some unique form of gear in their production. Similar to the way Wisconsin artisanal cheesemakers associate having their “hands in the vat” and eschewing “short cuts” to produce high quality cheese, oyster farmers associate the care involved in growing in gear as directly related to oyster quality. One oyster grower stated:

You know, our oysters, they’re hand harvested, hand combed. [We] really pay a lot of close attention to delivering a super clean product. So it’s just . . . [the way] they are handled. We’re doing a big number, but they’re still treated really, really, nicely. No mechanical process cleaning or harvesting at all.

The hands-on character of most New England oyster farmers extends into the daily cultivation practices. Oyster farmers often described their unique approach to raising oysters in gear, whether it was a particular routine for cleaning oyster shells or equipment, closely choosing the density of oysters in a bag, arranging the gear on the lease, selecting different types of gear for different areas of a lease, or culling in a particular way or with very close attention to size and shape.

Cultural practices of merroir are also evident in the process of pitting oysters that involves taking them out of the water in the winter and storing them in the ground in high-humidity cellars, similar to a root cellar. This practice is labor-intensive, and oyster farmers have been pitting oysters for at least 150 years [58] (p. 2), see also [76]. With near 100% humidity in the pit, the oysters can survive for several months out of the water with limited mortality. New England oyster farmers practice pitting to protect the oysters from destructive winter ice flows in the harbor. As one grower from Rhode Island described:

The guys on the Cape bury them in a pit and you get better survival than us [in the winter]. I mean, these are invertebrates that are masters of shutting down and staying dormant.

In sum, New England’s oyster farmers described an assortment of important environmental and sociocultural factors that contributed to their distinctive oyster merroir. When discussing operational challenges, they also expressed significant concerns about how climate-driven environmental change would affect the quality and distinctiveness of their oysters. We examine these results in the next sections.

3.4. *Terroir and Merroir Transitions*

In this section, we describe the perceptions and experiences Wisconsin artisanal cheesemakers and New England oyster farmers describe with respect to climate-driven environmental change. We examine ways that such change presents challenges to these farmers and consider how climate-driven environmental change will influence producer practices, their articulations of terroir and merroir, and the distinctiveness of the products themselves.

3.5. *Wisconsin Artisanal Cheese: Climate-Driven Terroir Transitions*

As mentioned previously, in our initial interviews conducted in 2010 and 2011, Wisconsin artisanal cheesemakers did not report environmental change as a significant factor affecting their cheese quality and distinctiveness. However, during follow-up interviews conducted in 2012, the year of a severe drought in Wisconsin, artisanal cheesemakers expressed concern about the impacts of the drought, as well as future environmental change, on their operations. Some speculated that an increase in drought events might lead to long-term problems for Wisconsin cheesemakers. They wondered if Wisconsin’s comparative advantage selling quality cheese might wane due to potentially higher feed costs, if droughts were to become more common. One cheesemaker stated:

Well, I think climate plays some role [in Wisconsin's comparative advantage] ... you know, I have friends of mine that make cheese in Vermont pay \$250/ton for hay ... You know, that ties back to the infrastructure, but it's also climate, and I think some of the Western dairies are struggling with higher fuel costs. They truck everything in and out, greater distances. So, that might be more of an economic advantage that [we have], and quality difference, it's real.

Our subsequent survey, conducted to assess the impacts of the 2012 drought on cheesemaker operations, also indicated that this extreme weather event impacted producer practices and generated significant concern about environmental change. Cheesemakers reported impacts that included increased costs and reduced quality for forage, reduced availability of grass-based milk, a need to significantly increase prices for cheese sold in 2013 following the drought, and shifts in the calving or lambing cycles that affected their operations. Some also described being concerned about the impacts of the drought on the quality of their cheese. Cheesemakers reported responding to the challenges the drought presented by purchasing imported forage, adjusting their cheesemaking schedules, and emphasizing to consumers how seasonal variations in taste were to be expected, framing unevenness as part of the desirable lack of homogeneity that artisanal cheese affords.

As seen in Figure 1, our survey indicated that a high percentage of cheesemakers were concerned about the impacts of drought on their operations, with many expressing concerns about potential droughts or other significant future weather-related events: 89% of cheesemakers who responded expressed some level of concern about the drought on their operations, with over 42% reporting that they were either "extremely" or "very" concerned. In keeping with this level of concern, as seen in Figure 2, 42% of respondents indicated that they either have made or anticipate making changes to their operation as a result of this drought, with over 89% reporting that the 2012 drought had affected their current operation.

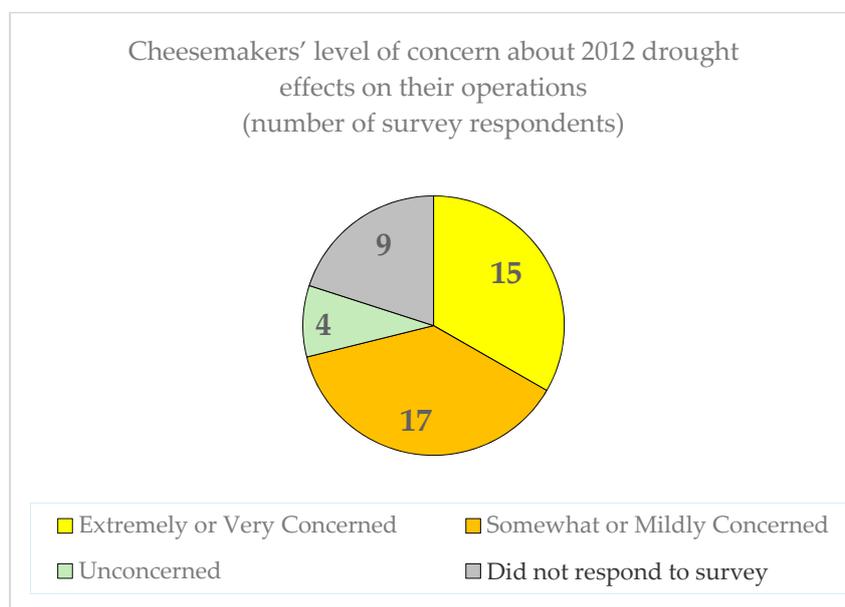


Figure 1. Cheesemakers' level of concern about the 2012 drought.

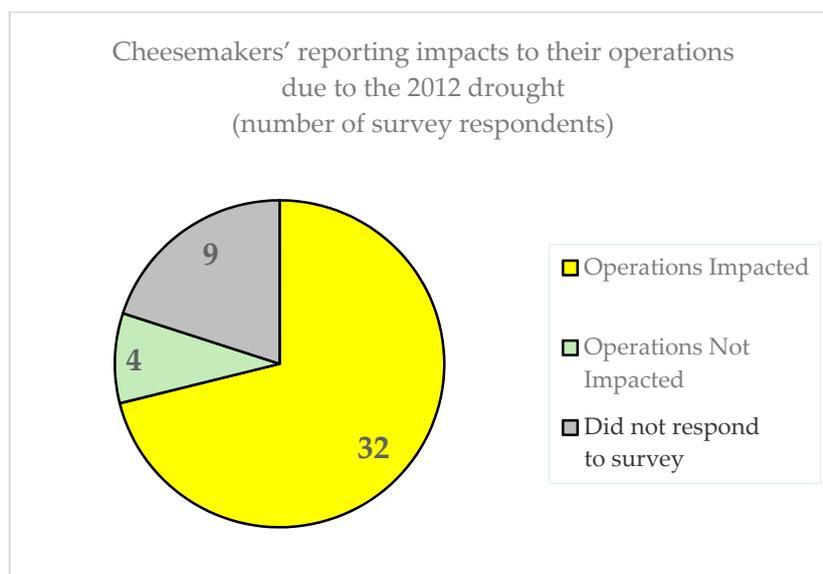


Figure 2. Number of cheesemaking operations impacted by the 2012 drought.

Survey results also indicated that approximately two-thirds of cheesemakers believed that this singular drought event might compel them to economize in other aspects of production, affecting what the cheesemaker above described as the “quality difference.” For example, as a result of the 2012 drought, for example, several cheesemakers reported in an open-ended query that dairy livestock were spending less time grazing in the pasture, or were given different feed, such as hay or silage.

Many reported feed shortages, with a few indicating that hay that was available was poorer quality “ditch” hay. This finding aligns with the Upper Midwest Haymarket report for 2012 that reported higher state prices for hay, as well as a “lack of quality-tested hay auctions in Wisconsin” due to the drought emergency [77].

Some cheesemakers indicated that they were forced to risk making cheese from milk from cows that were fed silage rather than grass. This reflects a vulnerability in a foundational aspect of Wisconsin artisanal cheese terroir—that of eschewing “short cuts” in quality production.

Several cheesemakers responded to open-ended survey queries about drought impacts by citing negative effects on animal health, such as dairy livestock that ceased production a month early, as well as more animal deaths overall. Several cited effects on their land and to their animals that will continue for several years. Given the impact of a one-year drought on their operations, it seems clear that increased climate variability, evidenced in more frequent heat waves and varying precipitations patterns (including increased precipitation some years and drought during other years), means cheesemakers will be expected to adapt rapidly to changing environmental contexts.

In spite of the challenges artisanal cheesemakers faced, there were also signs of adaptive responses that cheesemakers were employing to protect the quality of their products. For example, several cheesemakers with on-site pastured operations indicated in the open-ended survey question that they planned to add expensive new irrigation systems to buffer their farms from the effects of future droughts. Others were testing new high-protein feeding regimes. Many of those without pastured operations on site were also seeking additional sources of milk to ensure a consistent supply of high-quality milk in the face of potential shortages.

Concern over shifts in quality, driven by the drought and warmer temperatures, also led some cheesemakers to emphasize to their customers various ways that their cheeses that tasted differently from season to season and year to year:

It’s just ‘cause it’s been so hot, ‘cause it had not been like that earlier in the season. I just had to laugh. So this cheese doesn’t even taste the same. ‘Cause it would if we had a constant

climate, more constant, and it changes over here. One of the things we did early on at the market was tell people that it wasn't gonna taste the same, they shouldn't expect it to, we didn't want it to.

This adaptive framing of the cheese terroir—explaining that the variability of the cheese taste due to the heat from the drought was a natural and even desirable outcome—demonstrates just how central cheesemakers view themselves in shaping the narrative around terroir. As Paxson [3] has similarly argued, cheesemakers who are “reverse engineering” terroir are adapting their articulations of terroir to changing conditions.

While most cheesemakers did not initially report climate-driven environmental change as a significant challenge to their operations, the 2012 drought affected nearly all of their operations in some way. Importantly, too, several of the key environmental and sociocultural factors that cheesemakers associated with the terroir of their cheese—including the natural cycles of milk production, plant diversity, and specific production practices such as the availability of raw milk—were affected by the single drought event. Many cheesemakers responded in two ways. First, they shifted their management practices to protect the quality of their products—adding irrigation, for example, or seeking out additional milk suppliers. Second, some cheesemakers began shifting the way they articulated the terroir of their cheese, in some cases emphasizing the positive aspects of variations in taste.

In the ongoing debates over whether terroir represents a set of static, unchanging qualities, or is adaptive in response to changing markets and ecologies, Wisconsin's artisanal cheesemakers appear poised to adapt their practices and articulations of terroir, in the face of climate-driven environmental change. As the terroir of these producers is emergent, this suggests that a narrative of desirable variability—as also seen with seasonal variation—could eventually be incorporated into articulations of terroir.

3.6. *New England Oysters: Environmental Change and Merroir Transitions*

In contrast with Wisconsin artisanal cheesemakers, New England oyster farmers cited long-term patterns of climate-driven environmental change as a significant challenge to their operations. Key themes that emerged from interviews with farmers about environmental challenges included widespread reports of warmer winters and ocean temperatures, concern about novel pests and diseases attributed to climate change, and worries over how climate-driven changes would impact oyster taste. Oyster farmers also expressed an interest in new efforts to breed more climate-resilient oysters.

Most oyster farmers observed a widespread pattern of warmer winters and ocean temperatures. Even those who did not profess a “belief” in human-caused climate-driven change nevertheless described in detail how environmental changes were affecting their operations. One oyster grower expressed a typical perspective when he explained:

Well, you know the warm temperatures, you know there's this global warming coming on, and you can debate what's causing that, or who's responsible, but the fact is, it's happening, and the slightly warmer temperatures I think will change the product.

Many other oyster farmers expressed concerns about how such change would affect future production and described how, traditionally, warmer winters were viewed as anomalies—reprieves from costly winters with potential gear damage. Many described their view that warmer winters were becoming a new norm. One oyster grower described an oft-cited concern about increases in the number of invasive pests and diseases, which she attributed to warmer winters:

I mean, ice, we used to get ice. I've been in the business for 20 years, ok ... We haven't had real ice in 8 years, 7 or 8 years ... But we need ice ... Our diseases I think are more prevalent than they used to be. They are cyclical. You'll always have peaks and drops. But the invasive predators, green crabs, southern drills, whelks, are much worse than they

used to be because they're not getting knocked down [by harsh winters]. And tunicates. And you know, especially tunicates are more prevalent now in the East because it's not getting knocked down . . . the only people who can really tell you that are the old timers.

Many oyster farmers also associated warming ocean temperatures with new pests and diseases that, as the grower above described, are now found more frequently on their oyster leases. While discussing his lease environment and the increase in pests that he had noticed over the past twenty years, a Rhode Island oyster grower explained a concern typical of many New England oyster farmers:

Heat brings disease. So that will be my number one climate change concern, with the warmer summers and the milder winters . . . being knowledgeable about the environment, you need a hard winter to kill of some of the stuff you don't want around, from pests to inert diseases that you don't see, you know like *Vibrio* [bacteria], things like that, to knock things back.

Another grower in the region echoed this widely held perspective, describing:

The impact really is . . . this *Vibrio* bacteria, which you might have heard about really spikes with the increased temperature, so the hotter it gets the sooner it gets [hot], it all stays hot with this *Vibrio*.

Increased coastal acidification, linked to coastal oceanic CO₂ absorption, such as that observed with the West Coast oyster hatcheries, was also on the mind of farmers and others in the industry. For example, one oyster grower, who also has hatchery experience, described acidification as a top concern:

Things that keep me up at night right now . . . one is ocean acidification . . . I'm not a marine biologist, but it could mean the end of oyster growing overnight. It could just be done. Once you start melting zooplankton into water, it's a whole web of life thing on a microscopic level, and then it's over. It's friggin' over . . . I'd have to sprinkle something in the water to reduce the pH every day. Like you would a swimming pool . . . Mother Nature can't keep up with how acidic the oceans become.

The majority of farmers expressed their perception that shifts in local climate affected the distinctive taste of their oysters. As one grower explained, "the amount of difference [in taste] in even a small change in climate is pretty remarkable," indicating how local climate was incredibly important to oyster taste and varied on a small spatial scale.

Other farmers, when discussing differences between New England and Southern oysters, frequently mentioned New England's "cold water" as key to the flavor of oysters, and thought that in the South "the warm temperatures kind of change the texture and the taste." Farmers who made the connection between climate change and taste and quality expressed concern, with one linking it to the difficulties faced by the North Atlantic cod fishery:

Well oysters are moving north or cod is moving north . . . when these things shift we're not just growing grapes in a different place or growing oysters in a different place, we're potentially losing flavor.

Another grower described a widely held perception that changes to the warmth of ocean temperatures could alter the emergent merroir of the oysters, even if the species itself survives:

Climate change would definitely impact the way we grow oysters, yea, the whole way that the oyster grows, and the taste and all that for the product, it's so dependent on the water quality and the temperature and all that . . . But as the temperatures warm . . . these animals—they're pretty hardy, I'm not sure about killing them [but] I know that down in the Panhandle it's a lot warmer, but there's a definite taste difference.

Some farmers mentioned, too, how warming temperatures will affect their production practices. For example, one oyster grower described how changes in climate will likely influence the previously discussed practice of “pitting”:

The winter was so warm up there we couldn't maintain a cool enough temperature in the pit. So, I don't know if that's going to be an annual thing or just a freak thing this winter, but I was really concerned about it . . . Usually they stay in the pit until March, and the pit usually stays around 40 degrees. This year we couldn't get the pit lower than 47 degrees, which is borderline. 50 degrees is the breaking point. At 50 they'll start looking for warmer water. In the pit they're dry and if they open up they'll lose their water; they're dead. It was so warm we decided they had to go back into the water. We'll have to consider that the next few years.

In the face of climate-driven environmental change, one potential adaptive management approach mentioned frequently by farmers was the development of resilient brood stock by hatcheries to increase availability of disease resistant seed. As one grower described:

I don't know if it's in their mind that they're adapting to climate change, but they're definitely trying to develop disease-resistant shellfish, which are also local shellfish so that they're basically acclimated to the conditions here, or accustomed to the condition here.

But another grower suggested that even with resilient seed, there is still a balance to be struck between husbandry and the improved genetics:

The scientific community has really helped out, that we do have some disease resistant strains of oyster now . . . [they] do better with Dermo, and MSX [disease], but that's only if I do things correctly on my end . . . if I get it right I get [the oysters] up the sides and out the door before they croak. I can test my oysters and I can see traces of Dermo or MSX [disease] but they don't die. So it's really, I think that still husbandry is, you know certainly disease-resistant stock is important, but the husbandry is equally, at least equally as important.

Overall, the oyster farmers in our study had a keen awareness of how climate-driven environmental change would impact the merroir of their oysters, as well as their future management options. While such genetic adaptations may help the sector remain viable in the face of environmental changes, shifts in management practices will undoubtedly influence the emergent merroir of New England oysters.

As New England experiences climate-driven environmental change, the environmental contributors to oyster merroir will likely shift, affecting the quality and distinctiveness of these regional oysters and potentially affecting the very viability of this product. Specifically, warmer ocean temperatures and shifting acidity and precipitation patterns as a result of climate change are likely to alter the oyster merroir by impacting oyster sweetness and related quality measures. Moreover, increased acidification puts the viability of sector at risk, as has been seen in the West Coast oyster sector [69,78].

4. Discussion

As they articulate an emergent terroir and merroir, the Wisconsin artisanal cheesemakers and New England oyster farmers in our study identified specific environmental and sociocultural characteristics that they perceive contribute to the quality and distinctiveness of their cheese and oysters. Cheesemakers identified environmental factors such as minerals in the Driftless region soil that influence the taste of a diverse array of forbs and grasses and pointed to high quality milk associated with natural milk production cycles, seasonality, and regional microclimates. Sociocultural factors, such as direct “hands in the vat” experience, multigenerational knowledge, and traditional production practices that include

making cheese in open vats and using raw milk, were perceived to be critical elements that contributed to Wisconsin artisanal cheese terroir. New England oyster farmers identified environmental factors such as water temperature, salinity, tidal flow and location, algae and seaweed, and lease depth as contributing to the distinctiveness and quality of their oysters. They also pointed to sociocultural factors such as frequent tumbling, growing in “gear,” overwintering oysters by pitting them, frequent defouling of gear and shells, and the oyster species they selected as important contributors to the merroir of their oysters.

The study of the effects of climate change in agriculture and fisheries is challenging because of the difficulty of establishing clear, causal links between climate change and specific impacts to production. Nevertheless, we found that Wisconsin artisanal cheesemakers and New England oyster producers increasingly perceive climate-driven environmental change as a threat to the quality and the distinctive terroir/merroir of their products. Currently this change is not drastic in the Wisconsin artisanal cheese sector. However, events such as the severe 2012 drought can offer a preview into potential future instability for cheesemakers. Such preview events can offer a window into both the impacts of and adaptations to climate-driven environmental change. Unlike the Wisconsin artisanal cheese sector, New England oyster producers perceive environmental change to be a more pressing threat. Oysters—as a raw, harvested product—are more elementally-linked to relatively stable oceanic environmental conditions. Thus, the emergent merroir of New England oysters currently appears more significantly threatened by climate-driven environmental change.

Specific elements that were potentially threatened by climate-driven environmental change for Wisconsin artisanal cheese terroir were the availability and quality of feed that, in turn, impacted the quality and taste of their milk. Cheesemakers also expressed some concern about longer-term impacts to the seasonal variation that might impact milk quality. While cheesemakers largely expressed confidence in their ability to weather the drought, more frequent climate-related events (such as floods or droughts) would likely strain their operations, impacting their cheese quality and terroir.

Specific potential impacts to oyster merroir included change in water temperature and salinity, the waning ability to pit oysters over the winter to avoid disease, and the increased presence of disease and ocean acidification linked to warmer ocean temperatures. Throughout the period of our study, New England oyster farmers consistently expressed the strongest level of concern about climate-driven environmental change to their oysters. This is unsurprising, given that oyster producers perceived and experienced ways that climate-driven environmental change was already impacting critical elements of their oyster production.

As they envisioned adapting their practices to protect their operations and terroir/merroir, both Wisconsin cheesemakers and New England oyster producers tended to emphasize individualized shifts in practices, rather than collective responses to climate-driven environmental change. As Wisconsin artisanal cheesemakers adapted to the 2012 drought, they emphasized technical innovations or investing in infrastructure to buffer themselves from the effects of environmental shifts. Some cheesemakers who grazed dairy livestock anticipated adapting their operations to changing climates by drilling new wells to irrigate forage or seeking new suppliers for high quality feed. Others adapted by drawing upon narratives highlighting the value of varying, seasonal tastes in their cheese.

Similarly, oyster producers emphasized technological adaptations, such as fostering new breeding stock or buffering acidity at crucial times of juvenile oyster development. Unlike cheesemakers, oyster producers did not respond by reframing their articulations of merroir to emphasize variability; instead, most expressed concerns that warmer temperatures would affect oyster sweetness and quality.

The fact that producers are not articulating collective strategies to adapt to climate-driven environmental change may reflect the individualized character of emergent American articulations of terroir/merroir. In contrast with the institutional supports provided to terroir products seen, for example, in the European Union, emergent US articulations of terroir/merroir rely primarily on local branding and are characterized by more market competition. Absent strong institutional supports

to buffer producers not only from ecological change, but also from the blunt force of the open market, US place-based producers may see few routes toward sector-wide adaptation. As Bowen [12] has shown in the case of Mexican tequila, an emphasis on individual adaptation to market change has the potential to lead to concentration and inequality among producers, which offers a cautionary tale for both sectors.

5. Conclusions

Fundamentally, the constitution of terroir has always been about adaptation—to environmental, sociocultural, and economic contexts. However, climate-driven environmental change raises questions regarding the adaptability of terroir. As Trubek et al. [16] (p. 144) ask, “When considering the future of terroir, what will stay, what elements will be transformed, and what will disappear?” If we recognize that neither the ecological conditions nor the social life of terroir is static, how might this influence the institutional, producer, and consumer responses to the challenges that climate-driven-change presents to place-based producers?

We argue that emphasizing a generative, process-based understanding of terroir offers the most viable route for producer adaptation to climate-driven environmental change. While an understanding of terroir or *merroir* that allows for innovation in the face of change may not rescue oysters from ecological limits or cheese from shifts in flavor profiles due to sub-par feed, adaptive articulations of terroir that emphasize terroir’s sociocultural dimensions may help artisanal cheesemakers and oyster farmers to more nimbly shift their practices when facing climate-driven environmental change challenges. In their ecological study of how Burgundy wines are affected by climate change, for example, White et al. [40] similarly suggest that the “terroir of the future must embrace change, yet preserve the cultural connection (invented or not) between winemakers, the land and consumers” [40] (p. 84). This is one arena in which US producers of terroir products may hold some advantages over more formally codified products such as geographic indications. For although US place-based producers may not enjoy the institutional support mechanisms of rural development initiatives seen in other national contexts, emergent terroir translations may more easily encompass an adaptive, generative understanding of terroir.

To support a more adaptive approach in national and cultural contexts where terroir is more formally codified, we suggest that the institutional and market mechanisms in place to support terroir products—such as legal designations—must also adapt. For example, ecological changes have significant implications for producers of terroir products, as they attempt to adapt their practices to new conditions and face, in some contexts, legal threats to protected designations. As Raz Barnea argues with respect to the potential legal implications of climate change impacts on French viticulture, “the legal rigidity of the AOP [Appellation d’Origine Protégée] designation becomes its own downfall. If growing patterns shift drastically, some of the appellations will be obsolete unless they can flexibly adapt to these new spatial patterns” [25] (p. 619). Jones and Webb [79] similarly argue that producers unencumbered by rigid origin-labeling regulations may be freer to innovate and better adapt to changing climate than their more regulated place-based counterparts.

Our findings also suggest that, in the face of environmental transitions, an emphasis on the human and cultural dimensions of terroir and *merroir* might help artisanal cheesemakers and oyster farmers mitigate, to some degree, some of the climate-related threats to their products. This suggests that the role of knowledgeable producers in articulating a dynamic terroir and *merroir* could become elevated in the face of rapidly changing environmental contexts.

As understandings of place-based products and the potential transitions of terroir/*merroir* unfold in the context of climate-driven environmental change, we suggest that more research is warranted to foster better understanding of place-based producer experiences of and responses to that change. Such understanding is critically important for future discussions of the resilience of terroir and *merroir*. Moments of substantial change—in markets, local communities, and ecologies—propel us to consider the adaptability and resilience of terroir. How, if at all, will producers act to protect terroir, and how

will the concept of terroir change in response to shifting environmental conditions? In the face of rapid transitions, an emphasis on the human and cultural dimensions of terroir may enhance emancipatory possibilities for place-based producers by marshaling terroir in resistance to the homogenizing impacts of the conventional, industrialized agro-food system, as well as a rapidly-changing climate.

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