The Uncertain Future of New Mexico Chile: Can a Heritage Crop Adapt to Water Scarcity?

Abstract: Chile is an essential component of New Mexico's cuisine and is an economically important heritage crop. Despite its popularity, commercial New Mexico chile producers struggle to remain competitive in globalized markets. Geographical indication labels and branding, both based on claims of New Mexico's unique terroir, are used to distinguish the product in the global marketplace and add value. Chile production, however, is increasingly also threatened by issues of water scarcity exacerbated by climate change. This article uses ethnographic data collected between 2014 and 2022 to examine strategies for securing a viable chile industry in a changing landscape of production. I discuss the benefits and drawbacks of fallowing, efficient irrigation systems, and the creation of new chile varieties to confront water scarcity and their potential effects on the quantity and quality of chile grown in the region. I show that both water scarcity and our adaptations to water scarcity, though necessary to confront water-scarce futures, could undermine claims of terroir that distinguish the product in the global marketplace.

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The end of summer in New Mexico ushers in the celebration of the state's iconic crop: chile. Burlap sacks and cardboard boxes filled with glossy, green pods appear at farmers' markets, roadside stands, festivals, and grocery stores. New Mexicans who have been eagerly awaiting the new crop line up to buy their yearly supply. Such chile sales events would be incomplete without the roasters. On sturdy stands, metal cylinders filled with chile pods are rotated by hand over a series of flames using a crank. It is a sensory experience. The visual spectacle of the chiles turning and falling in the metal basket until they have reached charred perfection. The feeling of the heat from the propane flames and the late-summer desert sun. The crackling sound as the flames cause the outermost layer of chile skin to blister and pop. And most of all, the smell. The aroma of roasting chile is rich, smoky, and delicious. It provokes a sense of joy and nostalgia for those waiting in line to buy their fill.

I also line up each fall to get my chile fix. After spending the better part of a decade in the state, I know exactly which variety I want, from which farm, and from which part of the harvest season. For fresh green chile, I buy Sandia, a variety sometimes sold simply "hot" amongst the options of mild, medium, hot, and extra hot. In recent years an improved Sandia Select variety was released, intended to maintain the flavor and heat of Sandia, but with a larger, meatier pod. My preference persists for the flavor of the original Sandia. I wait until later in the harvest season because I like a mix of pods that have started to turn red, adding a touch of sweetness to the heat. And I have come to trust the quality of a particular farm in the Mesilla Valley and know the exact unmarked parking lot where it can be bought and roasted on the weekends throughout the harvest season.

Many New Mexicans have definitive preferences of variety, farm, and time of harvest. The yearly ritual of buying roasted green chile in bulk is a family tradition. When brought home, family members gather to peel the chile, put it in plastic freezer bags, and store it to be used throughout the following year. Some is chopped for dishes like green chile stew and green chile enchiladas, and some kept whole to be stuffed for chile rellenos. Dried red chile pods, strung together as ristras, loose in bags, or sold pulverized into power form, are also bought and used throughout the year for red chile, posole, and carne adovada. Both red and green chile are integral components of New Mexican cuisine and culture, so much so that the official state question is "Red or Green?"

In addition to local consumption, New Mexico chile is sold around the country and around the world in fresh, dried, and canned forms. The 2020 New Mexico chile crop was valued at $51.9 million (USDA NASS 2020), and is an important component of many diversified crop farming operations in the state. Despite its economic and cultural value, chile acreage planted in New Mexico dropped significantly after the passage of the North American Free Trade Agreement (NAFTA) in 1994 (Nierenberg 2019). Correspondingly, across the border in Chihuahua, Mexico chile production for export

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to the United States increased dramatically after NAFTA (Villagran 2017). New Mexico chile farmers continue to struggle to compete with the low prices of chile produced in Mexico and in other places around the world.

To avoid the neoliberal "race to the bottom" practices of cutting production costs to compete with international producers, some have turned to food labeling (Guthman 2007) or other forms of "storytelling" that seek to return social and environmental histories of production to otherwise anonymous global commodities (Tsing 2014). Modeled after long-standing geographical indicators used to protect wine-growing regions from counterfeits, products such as liquor (Bowen 2015), tea (Besky 2014), cheese (Paxson 2012), and more now use some form of geographical indicators to distinguish their products in the global market and to protect their value. The state of New Mexico has a long history of promoting the distinctiveness of chile grown in the state. State-led promotion strategies have included large-scale advertising campaigns with chile ambassadors, forming regional chapters of the "International Connoisseurs of Green and Red Chile" club (Paterson 2001: 32–33), and passing the New Mexico Chile Advertising Act that makes it unlawful to advertise, describe, or label any product as New Mexico chile unless the chiles are grown in New Mexico. Most recently, the independent New Mexico Chile Association developed a New Mexico Certified Chile™ label to indicate the authenticity of New Mexico grown chile.

At the heart of claims of distinction and value based on geographical zones of production is the idea of terroir. The narrow definition of terroir refers to the flavor present in a food or beverage (particularly in wine) that is caused by unique physical attributes of the soil and climate in which the food was grown (Cross, Plantinga, and Stavins 2011). A broader definition includes, but goes beyond, the physical characteristics of place to encompass cultural processes like agrarian practices, history, and tradition (Trubek 2009). Use of the term terroir also indicates claims of authenticity and quality (Demossier 2011; Paxson 2012).

The New Mexico chile industry promotes the value of chile grown in the region by emphasizing the unique flavor coming from the special terroir of New Mexico grown chile. For example, the now defunct website https://www.getnmchile.com stated:

> Chile craves warm, dry weather and warm soil. We can deliver! In the southern part of the state where much of the chile is grown, the sun shines 350 days a year! In addition, New Mexico's climate, soils and agricultural practices produce the unique flavor and quality that makes our chile second to none. ("Get New Mexico Chile" 2018)

The particularities of New Mexico's sunny days, desert climate, elevation, and the mineral profile of the soils are often cited to explain why the state's chile is distinct.

For many localized heritage crops integral to regional food cultures, using the concept of terroir to build legal claims like Geographical Indication labels or to create place-based distinction through branding efforts is essential to maintaining the value of the crop in a globalized market place. Environmental shifts, however, undermine the ideal of terroir: that a particular set of geographically contained physical and cultural conditions will produce a consistent flavor profile and quality of a food or beverage over time. Scholars have identified multiple ways in which climate change will affect terroir, taste, and food production (Clark and Kerr 2017; Field 2008; Nabhan 2010; Vermeulen, Campbell, and Ingram 2012). This article focuses on the challenges presented by one environmental issue exacerbated by climate change: water scarcity.

Water scarcity is increasing throughout the US southwest, augmented by drought, climate change, and increased competition for the resource. In New Mexico, it is uncertain if there will be sufficient water for agriculture in the future. This local concern is linked to a broader question: what will become of heritage crops and food cultures as water scarcity creates shifts in the landscapes of production? The question is about quantity (can we maintain yields?) and also about quality (can we maintain flavor, heat, and terroir?). Questions of both quantity and quality are especially important for crops like New Mexico chile, with strong ties to heritage, identity, and regional culinary culture. At stake is the New Mexican food culture, generations of emplaced chile farming knowledge and tradition, and livelihoods that depend on chile processing, cultivating, and harvesting.

In this article, I argue that the threat posed by water scarcity to heritage foods and culinary cultures comes both from lack of water to irrigate crops, and from the strategies used to cope with lack of water. Changes to agricultural practices or changes to plant physiology to adapt to declining water availability can change the quality of the product in a way that undermines claims of terroir. I show how strategies to protect water resources and grow chile in water scarce conditions have unintended effects on the quantity and quality of New Mexico's chile. I suggest that there is no silver bullet when it comes to protecting heritage food products and culinary cultures from the threat of water scarcity. Protecting heritage crops like New Mexico chile will require adaptations that attend to both quantity and quality of the crop, along with imagination, dedication, and collaboration.

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Studying Food and Water Futures

In New Mexico, people love talking about chile and do so with enthusiasm. Conversations about water scarcity, on the other hand, are more difficult. As a cultural anthropologist, I collected data about chile, water, and the future primarily through ethnographic research as part of two related research projects. My research on the future of the New Mexico chile industry occurred mostly between 2014 and 2019. While regional water futures formed part of this first research project, my focus on water began in earnest in 2019 when I was hired as a researcher by the New Mexico Water Resources Research Institute. My binational research on regional water use and management, funded by the Transboundary Aquifer Assessment Program, is ongoing. The field sites for both projects are southern New Mexico and northern Chihuahua, Mexico. In this article, however, I focus just on the Mesilla and Rincon (otherwise known as Hatch) Valleys of southern New Mexico south of the Elephant Butte Reservoir—an area known in New Mexico as the Lower Rio Grande (LRG).

An ethnographic approach involves three central research practices: participant observation, interviews, and analysis of relevant documents, archives, and scholarly literature (Elliott and Culhane 2016). Participant observation and the fieldnotes I wrote from those experiences were my primary source of data. Some examples of my fieldwork include on-farm activities like planting and harvesting chile, visiting processing plants, shadowing industry professionals, attending chile festivals and field days, assisting in research trials, meeting regularly with water scientists, attending water conferences, irrigation field days, and more.

I supplemented the ethnographic data with semi-structured interviews with twenty-nine individuals, including farmers, agricultural industry professionals, university extension personnel, researchers, water scientists, water managers, and modelers. I also collected relevant documents as data, including extension publications, public social media posts from pertinent organizations, fliers from events, and newspaper articles. I analyzed the data through a process of "qualitative analytic coding" (Emerson, Fretz, and Shaw 2011) using NVivo software. Using this method of analysis, I assigned every piece of text from transcribed interviews, fieldnotes, and documents one or multiple codes and/or subcodes, resulting in a strong sense of the patterns and salient themes in the data.

New Mexico's Growing Water Problems

Chile grows throughout the state of New Mexico, and many locations in the northern part of the state are known for their special landrace varieties (e.g., Alcalde, Chimayó, Isleta Pueblo, and San Felipe Pueblo chile). In those places, selective seed saving produced plants with distinct characteristics suited to the growing conditions and tastes of the local environment and community. Most of the commercial production and processing of New Mexico chile, however, occurs in the south of the state, concentrated in Doña Ana and Luna counties that share a border with Mexico.

The commercial chile-producing border counties are part of the Chihuahua Desert Ecoregion, terrain dotted with desert plants like creosote, ocotillo, and cactus. Despite the arid landscape, both the Mesilla and Rincon (Hatch) Valleys of the LRG have thriving agricultural economies due historically to the water provided by the Rio Grande. Local hikes in the surrounding hills and mountains during summer months give a bird's-eye view of these fertile river valleys—the winding river meandering through a patchwork of agricultural fields, scattered with population centers. The picturesque vision belies uncertainty about the future of water for agriculture in this important chile producing area. For much of the year, the Rio Grande doesn't flow through southern New Mexico at all, leaving a swath of sand as a place-marker until next flow season.

The Rio Grande's flow has been disrupted since the completion of the Rio Grande Project in 1916. To minimize regional flooding and to ensure irrigation water for agriculture, the Rio Grande Project included the construction of the Elephant Butte Reservoir, along with a series of smaller dams and diversions. The Elephant Butte Irrigation District (EBID) is charged with delivering water from the reservoir to farms during the irrigation season. Typically, water is released during the spring, flows through the summer months, and dries again in the fall. Yet as water accumulation in the reservoir diminishes, so does the window of time in which the river flows.

The river water for irrigation available to farmers changes year to year depending on the quantity of water retained in the Elephant Butte Reservoir and estimates of the annual snowpack and runoff that are expected to fill the river. In years with full water supply, lands assessed to receive EBID deliveries should receive 3.024 acre feet of water over the irrigation season (an acre foot equals about 326,000 gallons). Average actual delivery by EBID between 2009 and 2017, however, was only 14.1 acre inches, about 39 percent of the full allotment due to continuous years of drought (Fuchs, King, and Carroll 2019, 5874). As of March 2022, the estimated annual irrigation allotment that farmers would receive from the EBID was a mere four inches for the 2022 irrigation season (D'Ammassa 2022).

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FIGURE 1: *View of Mesilla Valley and Rio Grande from surrounding hills.*
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Chile growers, along with other LRG farmers, hope for a return to the days of full annual allotments. Water scarcity problems, however, seem to be only increasing. Scholars warn that the US southwest could be entering a "megadrought" period, exacerbated by climate change (Williams et al. 2020), and New Mexico is reported to have some of the most extreme water stress in the world (McFall-Johnsen 2019). "Drastic changes" are predicted for the Rio Grande river flow due to climate change impacts on snowpack that provides 75 percent of the flow (Davis 2022).

In the absence of robust river flows, farmers are permitted to compensate for the lack of full allotments by pumping groundwater for irrigation. Groundwater pumping adds additional expense to production costs because of the electricity and equipment needed, but there is no additional charge for the water itself. Using groundwater in years of river water shortage allows regional farming to continue in times of drought, a practice called "conjunctive use" of surface and groundwater resources, but in the LRG prolonged drought and lack of aquifer recharge cast doubt about the long-term prospects of this strategy (Fuchs, Carroll, and King 2018). Additionally, an ongoing lawsuit brought by Texas against New Mexico claims that excessive groundwater pumping south of Elephant Butte is affecting water deliveries determined by the Rio Grande Compact. Loss or settlement of that lawsuit could also impose curtailments of groundwater pumping for agriculture in this region.

Adapting to Water Scarcity

Whether by drought, climate change, or legal battles over water rights, water scarcity threatens the future of New Mexico chile production. In response to actual and predicted water scarcity in southern New Mexico, several strategies have emerged to maintain regional agricultural production of chile and other crops. These strategies include fallowing, efficient irrigation technology, and drought-tolerant plant development.

FALLOWING

Fallowing, or leaving an agricultural field uncultivated for a period of time, is an ancient agricultural practice. Leaving

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FIGURE 2: *Beer bottles in the dry Rio Grande riverbed.*
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a field to rest for a period is used to improve soil quality, but it can also be used to conserve water. Local farmer Greg Fischer explained how he fallows fields to compensate for seasonal water shortages, stating, "These last two years we have kind of got out of alfalfa because of the lake [Elephant Butte Reservoir] being so low, it [alfalfa] uses a lot of water. . . . So, we have been leaving out some of our farms and tilling them and getting them ready to raise onions the following year, or chile for our rotation, you know, we just leave it out." Fischer is able to work temporary fallowing into his crop rotation strategy when he knows his river water allotment will be low.

In the LRG, multiple paid fallowing strategies have been proposed for the region, and a pilot program by the Interstate Stream Commission is underway. Fallowing proposals for this region are short-term, "rotational fallowing" strategies rather than "buy-and-dry" strategies that are intended to take land out of production permanently. They use state funds to compensate farmers for leaving portions of their property uncultivated and unirrigated, reducing the demand for both surface and groundwater resources.

Water managers and policymakers are interested in fallowing to conserve water and meet delivery mandates to downstream users, but questions remain about the feasibility and sustainability of such programs (Wyland 2021). Some large farmers expressed doubt that the state would want to pay for fallowing programs over the long term and feared that the state would eventually tax farmers to support fallowing programs. Other farmers were hesitant because of the cost of fallowing to the land. Fallowed fields fill with weeds, dumping mass quantities of weed seeds into the local environment. Alternatively, if the fields are tilled to kill weeds, winds erode the top soil, creating dust and air quality problems. Local vegetable-processing facilities and the farmers that supply them worry that fallowing programs may damage local agricultural economies.

Chile farmers growing their produce on contract with local processors are among those concerned about the repercussions of fallowing programs. Chile must be grown in rotation with other crops to prevent the buildup of soil pathogens that cause diseases in the crop. After a chile field is harvested, most chile farmers wait four to seven years to plant that field in chile again. The intensification of pecan farming in the area, however, is taking land that could previously be used in crop rotations entirely out of that system, decreasing the acreage available for chile rotations. Once planted into pecan trees, a field cannot be fallowed lest the trees die and the enormous investment in planting a pecan grove be lost. Paid fallowing programs will thus need to count on the participation of growers known locally as "row croppers" who rotate crops like chile, onion, cotton, and forage crops to take their land out of production. Many chile processing facilities in the LRG that contract with local chile farmers also contract chile from Mexico, importing New Mexican pod-type chile. Some contract chile farmers fear that if the quantity of chile grown in New Mexico further declines, the processors themselves will move across the border into Mexico and no long offer markets for locally grown chile.

EFFICIENT IRRIGATION TECHNOLOGY

The first chile I saw growing in New Mexico was in the northern part of the state. It was grown using a technique called furrow irrigation. Using the furrow irrigation method, the rows of chiles are slightly elevated above the aisles between the rows. Between waterings, these aisles serve as walkways and paths for tractor tires to pass through without disrupting the crop. When irrigating, the walkways are

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FIGURE 3: *Watering onions with furrow irrigation technique.*
PHOTOGRAPH BY HOLLY BRAUSE © 2022

flooded with water, released from one end of the field and traveling down to the other. The water seeps into the root zone of the raised bed from both sides, providing needed irrigation to the crop.

During a visit to Andrea Vasquez's small farm in the Mesilla Valley in 2018, I watched as she released irrigation water into her field. The earth was parched and cracked, baking under the July sun. The irrigation water slowly filled the furrows between rows of chile, squash, melons, and corn. Andrea, her father, and I hoed weeds in the field, keeping an eye on the progress of the water. Occasionally, Andrea would drop her hoe, grab a shovel, and hustle to rebuild a breach in an earthen barrier she had built to channel the water to the intended section of the field. Andrea's father monitored her work out of the corner of his eye as he cut weeds. She is now the one putting into practice the knowledge of the five generations of her family that farmed that land with furrow irrigation before her.

Furrow irrigation is the traditional technique used to water chile and many other kinds of crops in New Mexico; however, more efficient irrigation technology is gaining popularity in the state. In 2010, New Mexico State University Extension vegetable specialist Stephanie Walker estimated that about 70 percent of the state's chile crop was being grown on drip (Blake 2010). That percentage has likely increased over the last decade.

Like most farmers I spoke with in the LRG region, large and small, Andrea is quite open to improving her farming techniques. The year after I first visited her farm, Andrea decided to install a subsurface drip irrigation system. Subsurface drip irrigation is a technique in which "drip tape"—a flattened tube with emitter holes spaced at even intervals along its length—is buried eight to ten inches deep along the length of a cultivated row. Water is pumped into the tapes and seeps out at each emitter, soaking the root zone of the plants. This technology has the potential to conserve water because less water is lost to evaporation and less seeps into the ground beyond the root zone of the plants than with furrow irrigation. By keeping water at the root zone, more of the irrigation water is used by the plant. The field application efficiency of drip irrigation is estimated to be around 90 percent, compared to 60 to 80 percent for sprinkler irrigation, and 50 to 60 percent for flood irrigation (Skaggs 2001).

Beyond saving water, chile farmers also tout the increase in yields resulting from the use of drip irrigation. Farmers estimate that they produce up to twice as much chile on fields irrigated with drip systems. In addition to water savings and increased yields, farmers also laud the ease of adding fertilizers and other agrochemical inputs directly into the drip lines to be delivered at the roots of the plants. This allows for less waste of agricultural inputs, and fewer tractor trips through the fields, decreasing soil compaction and fuel costs. Drip also lessens the impact of some chile diseases that spread especially quickly when standing water remains in fields.

Despite the benefits of drip irrigation, there are also drawbacks. Cost estimates to install a drip irrigation system are between $1,000 to $3,000 per acre (Amosson et al. 2011; Bevaqua and Phillips 2001; Skaggs 2000). The cost of a drip system often requires farmers to borrow the capital necessary for the infrastructure investments. LRG farmer David Ruiz explained that he would like to switch to drip irrigation because he knows it is more efficient, but he doesn't have the capital to invest in it and is hesitant to accumulate a large debt to finance it. Current government programs will subsidize the purchase of more efficient irrigation technology, but Ruiz stated that he didn't think he would qualify since he rented farmland instead of owning it.

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Drip irrigation can also be difficult to use. When I asked Andrea how her experiment with drip irrigation went, she replied, "I hated it. I will never use it again." Andrea described her many struggles with underground leaks in the hoses or clogs in the emitters she was unable to locate until her crops were already damaged, the battle to repair damaged line, and her concern about the plastic waste of old tapes. She vowed to go back to furrow irrigation for good. Andrea's farm, however, is not the main source of her household income. Farmers whose livelihoods depend on their agricultural production are more likely to work through their problems with drip and stay with it because of the benefits in yield, ease of inputs, and water savings.

Switching to drip irrigation requires different farming practices, and the learning curve can be steep. Stories circulate of massive crop die-off due to mistakes with drip irrigation. One farmer explained that he has seen many farmers try it, make mistakes, get frustrated, and abandon the method. "It takes about five to seven years to really learn to farm with drip," he said. Managing salinity is one of the major adjustments to working with drip systems. While furrow and flood irrigation systems tend to leach salts down into the soil away from the plants, drip systems can push salts to the surface of the soil where it can be damaging to the plants, impeding sprouts from breaking the surface of the soil and/or diminishing yields. This is particularly true when using groundwater sources that contain higher concentrations of salts than river water.

Beyond the difficulties of using drip irrigation, questions remain about whether or not more efficient irrigation technologies really save water. In the LRG region, groundwater and surface water (Rio Grande water) are connected, meaning that the level of one affects the level of the other. Some scholars argue that irrigation water from flood and furrow methods that seeps beyond the root zone of the plants actually helps recharge the aquifer and that efficient methods that keep water in the root zone of the plants and increase yields actually remove more water from the system at a watershed level (Ward and Pulido-Velazquez 2008). Beyond this local region, studies from around the United States suggest that subsidies for more efficient irrigation equipment that were intended to save water can actually speed depletion of aquifers (Nixon 2013). This suggests that efficient equipment and technology alone are insufficient to protect water resources in the long run.

Farmers in the LRG growing commercial quantities of New Mexico's heritage crop are not deeply tied to using traditional furrow irrigation, nor is that method legally or symbolically tied to notions of the terroir of New Mexico chile. Instead, chile farmers who switched to drip irrigation speak proudly of their adoption of efficient irrigation technology and the many ways it benefits their farming strategies. Some drip users claim that the increased yields from using drip irrigation are the only way they are still making a profit from chile in the face of depressed commodity prices.

DROUGHT-TOLERANT PLANT DEVELOPMENT

Fallowing and efficient irrigation techniques emphasize meeting the challenges of water scarcity by conserving water resources. Another approach to agricultural water scarcity is to change the needs of the plants. Chile researchers are trying to develop genetic strains of chiles that are productive even in water-stressed growing conditions. Some researchers focus on developing especially high-yielding varieties that can grow more chiles while requiring less irrigated acreage. Others develop varieties that are more salt-tolerant as reliance on groundwater with higher salinity content increases. One researcher described to me the need to breed chile varieties to cope with "climate chaos," including drought, hotter and colder temperature variations, and increased storms.

Chile varieties are developed by plant breeders at private seed companies, at some chile processors, by chile growers, and at public plant breeding programs at universities. New Mexico State University (NMSU) has a long history of developing new varieties of New Mexico pod-type chiles that meet the needs of the chile industry, including popular varieties like NuMex Big Jim and NuMex Joe E. Parker. Past and current research at NMSU has produced varieties with more uniform pods, increased yields, disease resistance, larger fruit, and specific levels of heat. Now, chile researchers are adding programs to develop varieties that are resistant to drought and climate change.

NMSU chile scientists use traditional methods of plant breeding and selection of outstanding plants from which to save seed. The process of selective breeding and cross-pollination is time consuming, as genetic lines are observed and selected over the course of years to decades. It is challenging work. Chile (*Capsicum*) are genetically complex and have three times more DNA than other plants of the nightshade family such as tomato and eggplant (Van Deynze 2020). Isolating particular characteristics using traditional methods is difficult, but genetically engineered (GE) research and gene-editing technologies on chiles are not on the table. The New Mexico Chile Association's 2008 request for state public funds for research into GE chile was met with intense public outcry from New Mexicans who did not want to see a plant so tied to their heritage and culture subject to

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FIGURE 4: *New Mexico green chile nearly ready for harvest.*
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such controversial interventions. The pushback was especially strong by those raising landrace varieties in the north of the state, their arguments rooted in ideas of food and seed sovereignty. Commercial growers in the south of the state are more ambivalent about the possibility of GE varieties, with some growers quite interested. The backlash, however, effectively halted discussions of GE chile research at NMSU. So, scientists continue to breed chile to meet predicted water-scarce futures using traditional methods.

Effects on Quality, Flavor, Terroir

Fallowing, efficient irrigation technology, and chile varietal development are all attempts to adapt the chile industry to water-scarce conditions to ensure that chile production — the quantity of chile — remains robust into the future. Yet some of these adaptations might have deleterious effects on the quality of New Mexico chile and undermine claims to terroir. The use of terroir indicates unique and predictable flavor profiles based on the physical attributes of the geographically designated area, as well as the cultural practices used to produce those flavors. Both physical and cultural attributes are subject to change as producers, scientists, and industry professionals try to adapt the crop to increasingly water-scarce conditions.

Efficient irrigation technologies, while important to maintain yields, have the potential to affect the terroir associated with New Mexico chile. As mentioned above, one problem associated with drip irrigation in the LRG is the accumulation of salts in the soil that can damage plants. Mineral content of the soil is a key component of terroir, so the buildup of salts changes the mineral profile of the soil — potentially affecting flavor in addition to yields. During my research, however, no one I spoke to expressed concern for flavor changes associated with changing minerals in the soil. But I did hear people express concern over changes in flavor due to heat levels in chile that are affected by drip irrigation.

The heat levels of different varieties of chiles comes partly from the genetics of a particular strain, and partly from agricultural practices. Chile farmers and experts alike state that chile needs to be stressed to develop heat. Advice circulates to avoid "babying" chile lest it be too mild. Traditional furrow irrigation saturates the soil and then leaves the soil to dry out until the plants begin to take on a "stressed" appearance — a droop or sag easily detected by a trained observer. When the plants are showing sufficient stress, another round of water is applied. Conversely, drip irrigation systems frequently apply irrigation water right at the root zone of the plants. This practice increases yields but does not force plants into periods of stress in which the heat is developed in the chiles. I heard several stories of complaints from New Mexicans who went to their usual farm and bought their preferred variety of chile, and were disappointed to find that it did not have the level of heat they were accustomed to because the farmer had switched to drip irrigation.

Plant breeding and the development of new varietals of chile also affect flavor. When making selections or cross-pollinating in order to produce chiles that can, for example, withstand drought conditions rather than selecting for flavor, the taste of chile may suffer. Some chile breeders are more concerned with maintaining flavor than others. When I volunteered to help NMSU scientists and students harvest their chile trials and select chiles to save seed from for further development, taste was an important part of the venture. For New Mexico pod-type chile trials that were being developed for ease of machine harvest, we looked for plants with heavy yields, chiles with uniform size and shape, and strongly

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rooted plants that held their fruit high up off of the ground. When we found a plant with the desirable characteristics, we tasted them for "New Mexico flavor." Plants bearing chiles that were determined to lack sufficient flavor were passed over in the seed-saving process.

In my work with NMSU chile scientists, I found they have a sense of responsibility toward protecting the distinctive New Mexico chile flavor. For example, in response to reports that some New Mexican varieties did not taste the same as they did years ago, NMSU chile scientists embarked on a study that determined that commercially grown varieties like NM Big Jim and NM 6–4 were lacking flavor compounds compared to the same varieties grown from vault-saved seeds (Bosland and Coon 2013). The NMSU breeding program re-released both varieties — NM Heritage 6–4 and NM Heritage Big Jim — in order to rehabilitate these heirloom varieties. Many commercial breeders, however, do not share the same commitment to maintaining the New Mexico heritage flavors. Creating varieties with commercial promise, like those with exemplary yields, takes precedence over flavor.

Within the commercial chile community (growers, processors, and scientists), there is some disagreement on the level of importance of maintaining traditional flavor. Seventy-nine percent of the 2020 chile crop was sold to processors, while 21 percent was sold as fresh market (USDA NASS 2020). Some question whether, beyond the distinctive culinary traditions and flavor preferences of New Mexico, subtle differences in flavor really matter. Once chile is processed, canned, and found on supermarket shelves in the Midwest, for example, does terroir continue to be salient? Some scientists, processors, and producers in New Mexico are unconvinced, or else ambivalent. Others emphatically argue that flavor matters and envision efforts to build up recognition of the distinctive terroir of New Mexico–grown chile as the key to maintaining a viable chile industry in the face of global competition.

Conclusion

Water scarcity is reshaping landscapes of production all around the world. Agricultural endeavors of all kinds will have to adjust. For those producing heritage crops that depend on value based in terroir, there are extra complexities to consider. Some are already working in this vein: the NMSU researchers who are dedicated to maintaining traditional New Mexico chile flavor even as they develop new varieties, farmers who are adjusting the timing of their drip irrigation strategies to ensure chiles get the stress needed to produce expected levels of heat, and a new project by the New Mexico Water Resources Research Institute to study the potential effects of fallowing proposals on the local agricultural economy. There are multiple, overlapping, and imperfect efforts to secure viable futures for agriculturalists and for heritage crops.

In New Mexico, the stakes of such efforts are high. Chile, as a species, is highly adaptable. Original to the Western hemisphere, chile is now grown around the globe and has become an integral part of many culinary traditions. If problems with water scarcity and climate change push the production of New Mexico pod-type chiles to other regions of the world, its cultivation could continue though some qualities may suffer. Beyond flavor, at stake is the local, New Mexico food culture built up around the cultivation, preparation, sale, and consumption of chile. Generations of emplaced farming knowledge and tradition are at risk, along with the processors, field laborers, and crop experts. For a state that proclaims to be the "chile capital of the world," cultural identity is at stake as well.

When it comes to agriculture and water-scarce futures, there are no easy fixes — especially for products in which quality, taste, and terroir matter in addition to quantity. As seen in efforts to maintain chile production, adaptations to water scarcity can also have undesirable effects on the quantity and quality of a crop. Fallowing strategies can be used to protect long-term water resources but could have a negative effect on the quantity of chile grown, threatening the critical mass needed to maintain a viable chile industry in southern New Mexico. Drip irrigation is more efficient, growing more chile with less water use, but the technology may not save water at a watershed level and can affect the quality and flavor of chile. The development of new chile varieties may help meet the needs of changing water and climate contexts but may also sacrifice quality, especially if flavor is not prioritized. The point is not to dismiss strategies like fallowing, efficient irrigation, or drought-tolerant plant development as having negative effects on chile — all will likely be essential components to regional agricultural resiliency in times of water scarcity. Instead, I wish to highlight that there are distinct challenges for foods with strongly associated terroir and place-based food cultures.

Invoking terroir has been an important tool in protecting the value of heritage foods and the livelihoods of their producers in an era of neoliberal globalization of food and agricultural commodities. Yet we are entering an era of unprecedented environmental changes. Both the environmental changes and the necessary shifts in productive strategies to adapt crops to meet such challenges that may

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undermine expectations of terroir. At this point, there are no clear success stories of heritage food or beverage products that have managed to overcome the multiple threats of climate change—the shifts are ongoing, compounding, unpredictable. But I do find hope in the dedication and ingenuity of people committed to seeing products such as New Mexico chile survive into the future. Protecting the future heritage crops like New Mexico chile against the threat of environmental changes like water scarcity will require an ongoing investment of imagination, dedication, vision, and collaboration.

Ultimately, I question not just if heritage crops can maintain their expected terroir but also if the very concept of terroir can survive in the face of unprecedented environmental change. Like the heritage crops it is invoked to protect, can terroir as a concept also adapt to the context of global climate change? Perhaps it can maintain the strong sense of tradition, locality, and authenticity described by scholars (Demossier 2011; Paxson 2012; Trubek 2009)—its storytelling component that distinguishes a product in the global market—while accommodating a more flexible range in actual flavor that will likely accompany climate variability and changes in agrarian practices. Flexibility in acceptable flavors is easier to imagine for a product like New Mexico chile with a more recent and tenuous relationship to terroir than it is for luxury goods like wine with long traditions of connoisseurship and value based on terroir. It is, however, worth considering in a climate context in which variability in weather will demand changes in agricultural practices, inevitably resulting in challenges to the consistency of flavor implied in the term terroir.

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