Envisioning the Farms of the Future: In Pursuit of Sustainable Agriculture in the Rio Grande valley

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ENVISIONING THE FARMS OF THE FUTURE: 
IN PURSUIT OF SUSTAINABLE AGRICULTURE IN THE 
RIO GRANDE VALLEY 

by 

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BA - EDUCATION W/SOCIOLOGY/ANTHROPOLOGY 

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DEDICATION

This work is dedicated to mi Adelita, and to all the other children who will grow up with her in a world of changing climate and an uncertain future. Espero que con los pequeños pasos que hacemos aquí podamos hacer lo posible de cambiar el trayectoria de la humanidad y crear un mundo sano y un mundo lleno de alegría y paz. Perhaps with the small act of sembrando semillas and learning from the world around us, we can learn what is necessary to produce food for all children who come after her and all of the plants and animals that grow around them.
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ABSTRACT

This thesis attempts to define the parameters that characterize sustainable agriculture on the level of an individual farm in the context of the central Rio Grande valley. Using historical sources about New Mexican agriculture, contemporary scientific literature and interviews with practicing farmers in the region, it develops a vision for the shape that farms must take in order to sustain agriculture in the region indefinitely. In doing so, particular attention is paid to how farms can be successful in the present moment and prepare for a future defined by resource scarcity and climate change.

It begins with a brief history of agriculture in the Rio Grande valley, including an evaluation of the sustainability of traditional agriculture in New Mexico and the issues posed by modern changes in agricultural methods. This is followed by a brief review of literature on sustainable agriculture that articulates some current ideas about sustainability and refutes some misconceptions about the form of sustainable agriculture. The bulk of the study is devoted to an analysis of 15 discrete components that constitute current farming practices in the Rio Grande valley. For each component, current practices in the valley are discussed and the sustainability of these practices over the long and short-term is analyzed. Finally, ideal sustainable outcomes are proposed for each category along with suggestions of practices that will successfully reach these outcomes. The concluding section of paper reflects on the sustainability of current farms in the Rio Grande valley as a whole and articulates a vision for what a sustainable farm in region should look like.
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I. Introduction: A Problem and an Opportunity

The 20th and 21st centuries have been, without a doubt, very unique moments in the history of the human race. For the first time, humans have come to occupy almost every piece of suitable land on earth, and their population has grown astronomically along with their technological prowess and their standard of living. As a result, these years have brought with them previously unimagined wonders in almost every facet of human life. At the same time, however, the human race is also facing new unforeseen challenges, as the current trajectory of population growth, over-consumption of resources and climate change threaten to destroy the very resource base that human societies use to sustain themselves. As a result, societies worldwide are beginning to evaluate the way that they live and their relationship to the natural environment in order to provide for a future that is just as rich as the present. The most popular word used to describe this line of study is sustainability, meaning the ability of a society to sustain its current way of living indefinitely into the future. Understanding the sustainability of current societal practices is critical to understanding the future trajectory of a society, and it is particularly critical in this moment in human history. The societies that adopt sustainable practices now may be able to sustain or continue to increase both their wealth and their population for years to come. Those that do not, however, risk severe declines in their standard of living and their quality of life in the years to come. This study aims to contribute to one facet of sustainability research by defining sustainable agriculture in the context of New Mexico's central Rio Grande valley.

Objectives

The intent of this study is to define the parameters that characterize a sustainable farm in the socioeconomic and environmental context of New Mexico's central Rio Grande valley, a contiguous strip of agricultural land in central New Mexico that stretches from Cochiti pueblo in the north through the city of Albuquerque and south to the city of Socorro (see Map A). This is a particularly relevant line of inquiry because of a great many on-going concerns about the sustainability of agriculture in New Mexico and the United States. In response to these concerns, a number of different agricultural
models have branded themselves as sustainable solutions to growing food, presenting themselves as the responsible future of agriculture. The most widespread of these movements is organic agriculture, now a multi-billion dollar industry. Despite the benefits of organic agriculture, however, there are many good reasons to believe that organic does not truly represent sustainability in agriculture. (e.g. Pollan, 2006) At the same time, however, organic agricultural enterprises market themselves as sustainable and clearly profit from their association with such a word. In central New Mexico, where large "agri-business" farms have never thrived, a similar debate is taking place involving "local" agriculture. In the Rio Grande valley, there is a small, but thriving collection of small-scale farms growing specialized produce for the local market. Often branding themselves as "beyond organic", these farms portray themselves as a sustainable option to the distant industrial agriculture, organic and conventional, that supplies almost all of the valley's food. These farms are also profiting from their association with "sustainable
agriculture”, due to the assumption the public makes that smaller farms that sell locally are more sustainable than large wholesale operations in distant states. Still, critics raise a number of concerns regarding the sustainability of local agriculture, pointing out that small-scale and local is by no means automatically sustainable. (Matlick, S., interview, Feb 25, 2014)

In response to these debates, this study aims to address the many definitions and uses of the words sustainable agriculture by defining specific parameters that encompass sustainable agriculture in New Mexico’s central Rio Grande valley. Rather than attempting to link sustainable agriculture to a kind of farm or a specific production process, this study attempts to describe the specific outcomes that indicate sustainable agriculture. These outcomes, when properly defined, will then allow for all agricultural operations to be evaluated for their sustainability, regardless of how those operations advertise themselves. In order to define these outcomes, this study draws on the knowledge of local farmers as well as historical accounts of the area and the literature on sustainable agriculture. It investigates in detail the agricultural practices being used on currently operating farms, evaluates the sustainability of these practices, and suggests what outcomes sustainable agriculture would be able to produce with respect to each parameter. While the specific practices and situations examined are very specific to the ecological, social and economic context of the central Rio Grande valley, the basic principles of sustainability that are discussed are ones that can be applied in any situation. The hope is that this study can serve as a guide to help planners and agriculturalists in the region envision the kind of farms that will reliably grow food and strengthen communities in the centuries to come, even as climate change and population growth stress the existing environmental and socioeconomic systems. With a cohesive vision of what the sustainable agriculture looks like, these individuals can then craft policies that promote the development of farms and of a food system that best reflects that principles of sustainable agriculture discussed here.
Defining Sustainability

The general concept of sustainable agriculture is not a difficult one to understand. Sustainability comes from the word "to sustain", which implies a maintenance of the current situation. In this sense, sustainable agriculture is a form of agriculture that can be perpetuated indefinitely in a given environment without any great reorganization. In order to be able to identify sustainable agriculture, however, it is important to define the elements of agriculture that must be sustained. In addition, sustainability must always come with a caveat, which is that the environment is always changing. Therefore, sustainable agriculture must be robust enough to survive indefinitely in its current environment, and it also must be resilient enough to perpetuate itself under changing conditions in the future. This issue of change and resiliency has never been more relevant, as environmental conditions are likely to change dramatically over the coming years. On the one hand, both the global economy and the development of technology are continually growing and becoming more powerful, meaning that farmers may have access to more resources, more powerful technology and more refined science in the future than they do today. At the same time, as climate change progresses, it promises to bring with it more intense and more unpredictable weather, and it will soon change even the basic weather patterns and climactic constraints that farmers have long taken as a given. Finally, as worldwide population growth continues to occur on an environmentally stressed planet, many resources will become less available in the future, and the demand for food will likely become much greater as production drops worldwide due to climate change.

As issues of sustainability have become increasingly relevant in recent years, so have studies looking at the elements of any human institution that must be sustained. One of the most influential frameworks to come out of this literature is one commonly known as the Triple Bottom Line (TBL). This framework argues that for any human endeavor to be sustained over the long term, particularly in business or industry, there are three major factors within this process that need to be sustained simultaneously: the environment, the economy and the society. (Slaper and Hall, 2011) This study relies on the TBL in order to define the elements of a successful agricultural enterprise that must be present to ensure its long term survival. Its environment is defined as the physical
environment of the farm itself as well as any natural systems that the farm relies on to provide it with important resources. The economy is defined as the means by which the farmers are able to support themselves economically from the farm and to a lesser extent from the local economy. The society of a farm is defined as the people who are involved in the farm, primarily the people who work on the farm, but also the consumers who benefit from the farm. Precisely because of the uncertainty of the future, none of these three factors is measured numerically, as the exact numbers that represent the maintenance of these three systems are likely to be very different in the future, both short and long-term. Instead, a definition for each element is posited here qualitatively regarding what sustainability of each of these three legs would look like.

With regards to the environment, a sustainable farm will have practices in place that are maintaining or improving the health of their soil and they will not use more natural resources during a given time period than are naturally produced over that same time period. In the case of non-renewable natural resources such as metals or oil-based products, this farm will use these in very small quantities and what they use will be made to last for a long time. Some non-renewable resources such as stone may also be locally abundant to an extent that they can be used in large quantities indefinitely. With regards to the economy, a sustainable farm will generate enough economic goods for the farmer, whether income or farm products, such that the farmer will always consider it worth his or her while to farm again the following year. In addition, farming will be economically worthwhile enough to provide all the food demanded by the market at an affordable price. Finally, with regards to the society, the farm will produce products that are reliably consumed by its clients and it will always have access to sufficient labor to perform the necessary tasks. Over the long run, the farm will also have a sufficient supply of potential farmers willing to manage the land once the current farmers no longer farm.

Ideally, a sustainable farm will be a place of social cohesion, not of social division. In this study, therefore, sustainable agriculture is conceived as one that sustains the land it uses, the people who work on it and the human communities that depend on that land for their subsistence. In order to sustain these three elements successfully, a sustainable farm must be prepared not only for the present, but for the changes that loom
in the future, and it must be able to flexibly adapt to changing and unpredictable circumstances.

**Methodology**

In order to best evaluate what constitutes sustainable agriculture in the Rio Grande valley, this study pulls from four different kinds of data: historical information about agriculture in the Rio Grande valley, current information about sustainable agricultural practices being developed worldwide, information about practices used on existing farms in the Rio Grande valley, and current information about the conditions farmers in the Rio Grande valley can expect to face in the future. The historical information about agriculture in the Rio Grande valley relies primarily on secondary sources and scholarly accounts of traditional Hispanic and indigenous agriculture before the widespread adoption of industrial techniques. This history is very important to any account of sustainability because it demonstrates both the potential for sustainable agriculture in New Mexico's high desert climate and it also demonstrates some of the limits on sustainability. It is also important because worldwide, traditional agriculturalists maintain intimate relationships with their land and possess a wealth of knowledge about how to confront common agricultural challenges in simple ways using local materials and practices. In New Mexico, where traditional agriculture are, with some exceptions, no longer used, the traditions of the past may provide some insight into how modern agriculture can become better adapted to the microclimate and ecosystems of the Rio Grande valley. Although the historical investigation seeks to uncover specific agricultural practices used in the past and to evaluate how sustainable those practices were, it is in many cases limited by the nature of historically documented information, which often times did not record the specific ways in which traditional agriculturalists performed their work.

The current information regarding sustainable practices being developed worldwide relies primarily on academic publications. Some information is also drawn from interviews with local farmers and agricultural experts when the information was demonstrated to have originally come from a specific source or from repeated direct experience. Because most of the literature regarding sustainable agriculture has been developed in regions and climates that are generally more favorable to agriculture than
the Rio Grande valley, special consideration is given to the transferability of the
techniques or practices studied to New Mexico’s high desert climate. Wherever possible,
this study draws from literature regarding practices undertaken in other semi-arid or arid
regions of the world with comparable climate regimes to the one examined here. In
general, however, many sustainable agricultural techniques discussed, especially those
developed or applied in other parts of North America, have proven to be transferable to
the Rio Grande valley.

The information regarding current farming practices in the Rio Grande valley was
gathered during 15 interviews with 16 current farmers, one agricultural expert, and one
compost maker. The interviews were approximately 90 minutes to two hours in length
and covered a range of topics drawn from the environmental, economic and social aspects
of farming. In these interviews, farmers were asked both to explain their current
practices and the challenges they face and also to opine about farming practices that
would be the most sustainable in the context of the Rio Grande valley. The farmers
included in the sample were selected because they are actively involved in the local
agricultural economy of the Rio Grande valley and have experience attempting to grow
organically or chemical-free. As such, they are the farmers who are practicing on the
cutting edge of sustainability and who most often think about sustainability in their
practice. Aside from these guidelines, however, the farmers interviewed were largely
self-selected via convenience sampling, as they were the ones who chose to participate
after being contacted via e-mail or phone. As much as possible, every effort was made to
include a diverse range of voices, agricultural models and perspectives. (See Table 1)

The farms sampled included 8 mixed vegetable farms, 3 mixed use farms and two
animal dairies. Except for one 10-acre farm and one five-acre farm, the mixed vegetable
farms are all 1 – 3 acres in size, and only the 10-acre farm has more than 3 acres in cash
crop production. The goat dairy interviewed has 30 acres and the cow-dairy interviewed
has 120 acres, with 33 in dairy-related production. The mixed use farms are 2.5, 3 and
0.5 acres in size, and each has small areas of less than a ¼ acre devoted to vegetables
with the remaining land serving as pasture or, in one case, wildlife habitat. Eight of the
farms are located in semi-urban or suburban neighborhoods of Albuquerque or nearby
unincorporated areas of Bernalillo County. Five more farms are located within a one-
hour drive of Albuquerque and serve the Albuquerque markets as well. Three of these are located within the confines of the Rio Grande valley while two are located on the east side of the Manzano mountains that rise to the southeast of the city. (See Map B) Four of the farms are certified organic, while the other nine are not, but all of the farms profess to be chemical free and to maintain practices that they consider to go above and beyond the standards of organic certification.

<table>
<thead>
<tr>
<th>Farm Type</th>
<th>Mixed Vegetables</th>
<th>Mixed Use</th>
<th>Dairy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Farms</td>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

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<th>Farm Size</th>
<th>&gt; 10 Acres</th>
<th>5 – 10 acres</th>
<th>&lt; 3 acres</th>
</tr>
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<tbody>
<tr>
<td>Number of Farms</td>
<td>2</td>
<td>2</td>
<td>9</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Farm Credentials</th>
<th>Certified Organic</th>
<th>Not Certified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Farms</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

The interview participants represent a wide range of ages and farming experience. (See table 2) Eight of the research participants are under 40 years old, two are between 40 and 50 and seven are over 50 years old. Of these, two have been farming for over 30 years, one has 15 years of experience, seven have been farming for 7 – 10 years, and six have less than five years of experience farming. Thirteen of the participants are male and five are female, while fifteen are white and three are Hispanic or Latino. Seven of the farmers interviewed own their properties outright, one is the part owner, and one owns some land, rents some land and works part-time for another farmer. Three of the interviewees rent their properties and work as farm manager while one more is working for a farm manager who rents the land. Nine of the farmers interviewed are supporting themselves exclusively based on income from their farms while seven of the farmers interviewed rely on second jobs for a significant portion of their income. That said, only
three farms, including the two dairies, appear to be supporting other people such as partners, family members or other dependents with income from the farm. Many of the full-time farmers have partners who are working full-time off of the farm. In addition, all of the mixed vegetable farms and the two dairies hire seasonal laborers who also benefit economically from the farm.

<table>
<thead>
<tr>
<th>Age of Participants</th>
<th>&lt; 40 yrs. old</th>
<th>40 – 50 yrs. old</th>
<th>&gt; 50 yrs. old</th>
</tr>
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<tbody>
<tr>
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<td>8</td>
<td>2</td>
<td>7</td>
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<table>
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<tr>
<th>Years farming</th>
<th>&lt; 5 yrs.</th>
<th>6 - 14 yrs.</th>
<th>&gt; 15 yrs.</th>
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</thead>
<tbody>
<tr>
<td>Number of People</td>
<td>6</td>
<td>7</td>
<td>3</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Race and Gender</th>
<th>Male</th>
<th>Female</th>
<th>White</th>
<th>Hispanic/Latino</th>
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</thead>
<tbody>
<tr>
<td>Number of People</td>
<td>12</td>
<td>5</td>
<td>14</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Land Tenure</th>
<th>Owner</th>
<th>Renter</th>
<th>Laborer</th>
<th>Multiple</th>
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<td>Number of People</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Employment Status</th>
<th>Full-time Farmers</th>
<th>Farmers w/other Jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of People</td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>

The interviews play a central role in the analysis conducted in this study because most of the farmers interviewed have had exposure to some or all of the literature on sustainable agriculture reviewed here. As a result, they all have practical experience growing organically for the local markets in the Rio Grande valley and simultaneously trying to apply many of the principles discussed in the literature. As a result, their experience in many cases serves as a test of some of the theories of sustainable
Location of Participating Farms

Major physiographic and hydrologic features of the Middle Rio Grande Basin.
agriculture in the context of New Mexico’s central Rio Grande valley. In addition to being able to reflect on the feasibility and practicality of many sustainable practices, these farmers are also in a good position to reflect on the trajectory of agriculture in the valley and some of the systems that are intertwined with it. Because of their experience with agriculture, they are also able to reflect critically on local practices and to characterize them as sustainable or unsustainable. In addition to that, they are among the people who are most aware of the resources that are necessary to farm successfully in the valley and as such are aware of the challenges, both current and future, that farms will need to overcome in order to be sustainable. As such, information from these interviews is used to evaluate the sustainability of current practices, the likely viability of implementing sustainable practices from the scientific literature in the Rio Grande valley, and the future trajectory of farming in the region.

The final kind of data that is used in the analysis undertaken here is information regarding the likely conditions that farmers in the Rio Grande valley will face in the future. Sustainable agriculture is defined here to be agriculture that will sustain itself indefinitely along the three legs of the Triple Bottom Line. This means that the agriculture that is in place now must also be able to prepare for the future and to sustain itself throughout that future. In order to best understand what that future will look like, this study uses information gathered from the farmer interviews along with academic projections of climate change and other anticipated future changes to develop a hypothesis about the shape of the future environment, economy and society in which individual farms will be expected to sustain themselves. This vision of the future is, of course, critical to developing a vision of sustainable agriculture.

Farming is, ultimately, the summation of many different human actions that serve to create a managed agro-ecosystem that produces food for the farmer and for the society that supports him or her. Many of the human actions that constitute farming can be separated into discrete categories, since they are generally distinct in farmer’s minds. All of these actions continually influence each other. The way that one aspect of a farming system is tweaked inevitably influences the conditions that affect the other categories. As such, farming is both a set of discrete actions and it is also one integrated system. This study undertakes an analysis of the multiple discrete elements that constitute the
environment, economy and society of farming and it also seeks to create an integrated vision of a sustainable farm.

To begin, after an overview of the environment of the central Rio Grande valley, indigenous and traditional Hispanic farming methods in New Mexico are described in an integrated manner and the overall sustainability of these practices is discussed. This section concludes with an overview of modern farming practices typical in the Rio Grande valley and the issues regarding the sustainability of these practices. This is followed by a brief review of some literature on sustainable agriculture that articulates some of the modern ideas about sustainability and refutes some misconceptions about the necessary economic and social form of sustainable agriculture. The bulk of the study is devoted to an integrated analysis of the discrete actions that constitute farming. The actions selected for this study include: water, water conservation measures, soil fertility, tillage and erosion, crop management, weed control, pest and disease control, seed saving, seed starting, pricing and subsidies, land tenure and access to land, organic certification, labor, job security and farmer training and replacement. First, current practices that the organic and chemical-free farmers in the valley use are discussed and the reasons for these practices are discussed. Next, the sustainability of these practices over the long and short-term is analyzed using agricultural and historical scholarship in combination with the experience of practicing farmers. Finally, ideal sustainable outcomes are proposed for each category and in some cases specific practices are highlighted as best way of achieving these outcomes. The concluding section of paper reflects on the sustainability of current farms in the Rio Grande valley as a whole and articulates a vision for what a sustainable farm in region should look like.
II. An Oasis of Green in the Desert: The Agricultural History of New Mexico’s Rio Grande Valley

Environment

The Rio Grande valley runs geographically, culturally and politically through the center of the state of New Mexico. Beginning with Taos in the north and running past Española, Santa Fe, Albuquerque and Las Cruces as it flows south, the river links most of the important economic and political communities in the state. This is not by accident, because the high desert terrain that characterizes the region is too arid to allow for agriculture based on rainfall alone. As a result, all of the important communities in the state of New Mexico are located along its main waterways. The central Rio Grande valley that makes up the geographic area chosen for this study is the same region that was called Rio Abajo, or "lower river", by the Spanish colonial government. It begins at the bottom of La Bajada hill ("the descent") in the communities of Cochiti Pueblo and La Bajada and runs south through the Albuquerque metro area to the town of Socorro, approximately 120 miles downstream. (See Map A) Although there are many different communities with very different histories and demographics in this region, physically it constitutes a nearly unbroken string of small farm plots hugging the river, all irrigated by gravity-fed earthen irrigation ditches called acequias. In between the town of Bernalillo, through the Albuquerque metro area south to the town of Belen, many of these farm plots have been replaced with suburban subdivisions and other forms of urban development, creating a patchwork of urban and rural land uses throughout this core of the valley, the area home to the majority of its people.

Like most of New Mexico, the central Rio Grande valley has a semi-arid climate, with an average of nine inches of rain fall per year. The native vegetation is characterized by cottonwoods, willows and other shrubs in the riparian areas near the river and by open grasslands with cactus, piñon and juniper shrubs at higher elevations away from it. In addition, the valley lies at an elevation of 5000 feet and enjoys very low humidity. Temperature swings between night and day are large, anywhere from 25 to 40 degrees. As a result, between November and March, when high temperatures hover in the 40s, 50s and 60s, the nights are too cold for any plants to grow. From April to October, however, when the freezes lift and the growing season commences, high
temperatures are rarely less than 80 degrees F and from early June to mid-September, high temperatures regularly top 90 degrees F. This means that growing plants are subject to extreme temperatures during almost all times of year and frost danger continues until high temperatures are higher than optimal for many popular North American crops. More critically, with an average of only nine inches of rain a year, there is very rarely enough moisture in the soil to promote proper crop growth. Fifty percent of the rain that does fall comes in July and August, when sudden thunderstorms known locally as the monsoons provide precipitation in short, intense bursts that can cause flash floods and pose risks as well as opportunities for farmers. During the rest of the year, particularly the spring when crops are young and in need of constant moisture, precipitation is spotty and unpredictable. At the same time, the wind and the sun coupled with the dry air require plants to transpire much more water than is typical in more humid regions. This means that successful agriculture in the valley requires even more water per plant than is necessary in a water rich region.

Related to these atmospheric conditions are the soil conditions. Soils in the region are generally very low in organic material and they are also very alkaline, often with a pH of well over 7 or 8. Most crops that make up the American diet, on the other hand, are heavy nutrient feeders, needing high organic matter content in the soil and preferring slightly acidic soils with pH between 6 and 7. In addition to this, the soil structure of the river valley is unpredictable. Over short distances, soil can change from a thick, hard-packed clay to a loose sandy soil, neither of which are optimal for agriculture. The middle ground, which is loose but sticky soil called loam, is rarely found. As a result, between the alkalinity and the consistency of the soil, an individual piece of land can often need years of remediation before its soil is comparable to highly productive farmland in other regions.

**Indigenous Agriculture**

Despite the difficulties that the climate poses to growing food in the central Rio Grande valley, the region has a long and rich agricultural tradition that can be traced back for at least two thousand years, owing to the abundance of water provided by the river. The first agriculturalists were Native Americans whose descendants are the Pueblo
Indians of New Mexico, the Ancestral Puebloans. These people grew corn, beans and squash for subsistence in addition to a fast-maturing variety of cotton that provided them with clothing. The Ancestral Puebloans who first adopted agriculture in New Mexico relied primarily on rain water for their crops, using a combination of earthen berms, check dams and other water control devices to collect run-off from rain storms and to channel it onto their fields. This remained true even as many pueblos moved off of the cooler, wetter Colorado plateau and down into the hotter, drier Rio Grande valley in the 12th and 13th centuries. In addition to rainwater agriculture, however, the Ancestral Puebloans also dug earthen ditches and created gravity-fed flood water fields much like those that would come to characterize later Hispanic settlement. There is some debate regarding how the Ancestral Puebloans used these ditches. Hill (1998), for example, believes that the growing season limitations imposed by seasonal flooding of the Rio Grande made it impractical for the Puebloans to use these fields for their subsistence crops of corn, beans and squash. Instead, he argues they were used primarily for growing cotton, as well as for producing high water specialty crops like sweet corn and summer squash. Even at hot dry locations like Isleta pueblo, he argues, pueblos had access to enough reliable rainwater fields to produce all of their subsistence from this method alone. Still, given the unreliability of rainfall in the region, it is likely these first acequias constituted a critical part of pueblo subsistence from the beginning. Overall, therefore, the ancestral puebloans used a mixture of irrigation strategies including rainwater and floodwater farming, effectively sustaining pueblo societies in the Rio Grande valley for at least 800 years.

In order to successfully grow food in the Rio Grande valley, Puebloan agriculturalists made every effort to conserve water and to make every rain drop count. In addition to their meticulous systems of rainwater harvesting, at some sites, they used piles of pebbles as mulch when available in order to retain water in the soil and moderate day and nighttime temperatures. (Lightfoot, 1993) More importantly, the crops that the Ancestral Puebloans grew were specially bred and adapted to local soils and climate conditions, meaning that they would produce in New Mexico in ways that corn developed elsewhere has never been able to match. As documented by Collins (1914), Pueblo Indians planted their corn up to 5 - 7 inches deep in the soil in order to take advantage of
extra moisture held there. (as cited in Hill, 1998) In addition to this, upon germination, pueblo corn developed a tap root that, much like other desert plants, immediately began growing straight down in search of water. In this way, the pueblo people could plant their corn in May or June, months when daytime temperatures in the Rio Grande valley consistently reach 90 degrees F and natural precipitation is scarce. Pueblo corn also tolerated drought conditions better than other varieties and produced more kernels under drought than any other. Finally, even under conditions of good irrigation, it tended to outgrow other corn varieties and to produce more food per acre. This locally adapted variety of corn, therefore, proved key to the sustainability of pueblo agriculture in the face of uncertain rainfall conditions.

In addition to making very efficient use of water, the Puebloan practices of rainwater farming had additional environmental benefits as well. As has been documented for rainwater fields at Zuni pueblo (Homburg, et. al. 2003), rain-fed irrigation brings with it large loads of sediment that has built up in the surrounding hills and uplands. When the rainwater is slowed down or trapped on agricultural fields, this sediment is deposited, acting as a natural fertilizer. The application of new soil also helps prevent soil compaction, thus practically eliminating the need for tillage of the soil. Thus, some agricultural fields at Zuni were continuously farmed for thousands of years with no human-powered application of fertilizer or tillage until the modern introduction of tractors. It is likely, therefore, that similar beneficial effects were experienced in all rainwater farm land up and down the Rio Grande valley. In addition to acting as a self-tilling and self-fertilizing system, rain-fed agriculture in New Mexico also has the added benefit of causing more water to infiltrate locally instead of running off into the watershed. This starts a positive feedback process whereby more ground cover is created and more water infiltrates in the next storm. Over the long term, repeated catchment of rainwater is likely to raise the local water table. The reverse of this process, one of desertification, was seen at Zuni pueblo during the late 19th and early 20th century just at the time that the Zuni people were abandoning rain-fed agriculture. (Norton and Sandor, 1997)
Traditional Hispanic Agriculture

The second wave of agriculturalists to occupy the Rio Grande valley were groups of settlers who migrated north from the Spanish colony of Mexico at the turn of the 16th and 17th centuries. Whereas the Ancestral Puebloans had always practiced a mixed subsistence strategy, relying on wild animals for most of their protein and on wild plants to supplement their diet during the low points of the agricultural seasons, the Spanish settlers brought with them a different way of life, one that was reliant on agricultural products for most or all of their diet. Key to this more intensive form of agriculture were the grazing animals that had been imported into Mexico from Europe, namely sheep, goats, cows, pigs, and horses. In addition to providing valuable sources of protein, these animals also contributed greatly to enhancing the fertility of agricultural fields through the use of their manure. In addition to the animals the Spanish introduced, they also brought in a number of crops that would prove complementary to the three sisters planted by the Puebloans. Spring wheat and peas, both staples of the colonial Spanish diet, are cool weather crops that allowed local agriculturalists to plant in the spring and the fall when the three sisters do not grow. Additional grains and legumes that played a similar role to wheat included oats, barley, rye, lentils and garbanzos. In addition to extending the growing season, these crops also extended the area of land that could be used agriculturally, allowing colonists to push into higher altitudes with more reliable rainfall and water supplies. Finally, the Spanish colonists introduced variety into the New Mexican diet by introducing many European fruits and vegetables, principally onions, cabbage, radishes, grapes, peaches, and melons. Over time, this robust suite of crops became successfully integrated with the Puebloan three sisters diet, providing New Mexican residents with reliable food sources year round as well as providing a diverse source of proteins and vitamins. (Sunseri, 1973)

In order for the Spanish colonists to successfully raise many of their familiar crops in any quantity, it was clear from the beginning that they would need access to a regular supply of large amounts of water, something they were unlikely to receive from the rain. As a result, the Spanish communities that were founded in New Mexico relied exclusively from the very beginning on gravity-fed earthen acequias that carried river water to farmers' fields. These acequias were quite literally the lifeblood of all Spanish
communities in the region, tying groups of settlers together via their need to access and use this precious resource. Typically, the Spanish communities founded in the Rio Grande valley would dig their *acequia* systems before anything else in the settlement had been constructed, illustrating the vital importance that floodwater played in the existence of these communities. Beginning at a carefully selected point in the river, they would establish a small dam of brush and logs for the purpose of raising the water level and diverting water into the *acequia madre*, literally the mother ditch. This ditch generally wound its way above the flood plain of the river along the base of the nearby hills or mountains before draining back into the river at an advantageous point downstream. Lateral ditches funneled water off of the *acequia madre* and onto agricultural fields, which were typically long, semi-rectangular parcels that ran away below the *acequia madre* and stretched to the edge of the river’s flood plain. These agricultural fields were generally divided among the settlers for their individual use, while the settlements usually enjoyed a shared commons in the highlands above the river which they used for grazing livestock and harvesting timber. (Rivera, 1998)

Because of the primacy of the need for water in order to survive, and because of the necessity of diverting and managing water as a shared resource, it was the *acequias*, more than anything else, that bound the fabric of communal life in Hispanic New Mexico. With the exception of a few larger communities such as Santa Fe, most settlers in New Mexico answered to no local government, professing instead their allegiance directly to the Spanish crown. As a result, each *acequia* came to function as a *de facto* community government, with its own set of rules and regulations that were set semi-democratically by a council of the male heads of household who relied on the *acequia* for their subsistence. These local institutions proved so strong, in fact, that they have persisted largely intact today in Northern New Mexico, despite sweeping social, political and economic changes in the communities that use them. (IBID)

Because of the many social, political and economic changes that Spanish colonization brought to the Rio Grande valley, the Spanish and Mexican periods in the history of New Mexico have been generally characterized by scholars in a number of different ways. For the Americans who took over the state in the late 1840s, Hispanic agriculture was always characterized as backward and inefficient, a subtext to the
dialogue regarding the *acequia* system and Hispanic and Indigenous agriculture that continues to this day. (Sunseri, 1973) In another light, anthropologists focusing on New Mexico’s Native American population have characterized the Hispanic incursion as environmentally destructive, citing the environmental degradation inevitably wrought by many grazing animals in a fragile landscape and the pressures of growing populations that became apparent just before and after the American conquest. (MacCameron, 1994) Meanwhile, environmental historians focusing on the Hispanic settlers have often emphasized their resourcefulness in creating successful subsistence strategies in a harsh climate, strategies that allowed them to survive and grow for almost 300 years. (MacCameron, 1994)

**The Sustainability of Traditional Agriculture**

In the modern age, it is commonly assumed that any agricultural system that remains "traditional" is a sustainable one. This is largely a reaction to the often unsustainable excesses of industrial agriculture, which some scholars have claimed treats the soil and the living system it operates as a machine. (Pollan, 2006) Traditional agriculture, on the other hand, enjoys a much more intimate relationship with the landscape and the living system it cultivates, and its tools are less powerful, more modest ones that are generally less destructive than those of industrial agriculture. That said, traditional, or pre-modern agriculture is by no means automatically sustainable, as any student of history is well aware. (e.g. Diamond, 2005) In New Mexico, the most renowned instance of an unsustainable pre-modern society involves the rise and fall of the great Ancestral Puebloan society centered on Chaco Canyon. Although the reasons behind that society's eventual decline and abandonment of its best known site are complex and multi-faceted, there is reason to believe that unsustainable agriculture contributed to its collapse. (Stuart, 2000) Evidence collected from the canyon itself and from related sites over the centuries following the collapse show evidence of malnutrition and cannibalism, both largely absent during the canyon's ascendant years. This suggests that the Chacoan system's pre-modern agricultural system failed to produce the necessary food for its residents. In particular, this agricultural system proved unable to perform in the face of the simultaneous pressures of climate change, deterioration of natural
resources and population growth. In this sense, while Chaco’s agricultural system proved able to stimulate growth during the centuries leading up to the society's collapse, it was not resilient enough to sustain this growth under these conditions of stress. (IBID) This situation contrasts with the ability of agricultural system in other contexts in human history to respond to similar periods of stress. As Netting (2005) has chronicled in China, for example, Chinese pre-modern agriculture successfully responded to conditions of high population growth and a diminishing natural resource base by developing productive techniques of intensive agriculture that allowed it to sustain this growth for thousands of years.

In order for traditional agricultural systems in the Rio Grande valley to be considered sustainable, therefore, there must be evidence that they were able to provide sufficient food for their societies over a sustained period of time that included societal growth and change. They also must demonstrate the ability to successfully respond to periods of stress. Finally, as indicated by the Triple Bottom Line, they must be able to show evidence of sustaining all three facets of a strong agricultural system: the environment, the economy and the society. According to these parameters, traditional Hispanic and Indigenous agriculture in New Mexico has a mixed and uncertain record regarding its sustainability. Puebloan agriculture and Puebloan society clearly benefitted and became more sustainable during the centuries that followed the decline of the Chacoan society and the establishment of a new kind of civilization in the Rio Grande valley. During the approximately 800 years that Puebloans have occupied the valley, they have been able to sustain their societies through periods of drought, through epic floods and through dramatic cycles of conquest and liberation, including the demographic collapse brought about by the introduction of European diseases. This fact implies that Puebloan agriculture has been performed in a largely sustainable manner during the recent past, allowing the Puebloan environment, economy and society to sustain themselves and to grow and change as the circumstances dictated. (Stuart, 2000)

In contrast to this situation, the evidence regarding the sustainability of Hispanic agriculture in New Mexico is decidedly more mixed. In the mid and late-19th century, when the most detailed accounts of traditional Hispanic agriculture were recorded, it was still largely an agriculture characterized by small farms, intensive labor and limited
technological investment. In addition to the gravity fed system of earthen *acequias*, Hispanic agriculturalists plowed well into the 19th century using draft horses or mules, which dragged behind them a wooden plow that simply opened a furrow rather than turning the soil. While both this practice and the use of earthen *acequias* were considered inefficient by American colonists, they worked for the Hispanic farmers because they were proven to be both economically and environmentally sustainable. Economically, the Hispanic settlers in New Mexico had been able to feed a growing population throughout their entire existence, and they would continue to do so well into the 20th century. Environmentally, the inefficiencies of the earthen ditches and the wooden plows actually carried long-term environmental benefits. (MacCameron, 1994) Much like the water harvesting systems of the rain-fed pueblo agricultural fields, the *acequias* used throughout New Mexico serve not only to enhance human life but to enhance the natural landscape as well. Functionally, the *acequias* expand the riparian zone of most river valleys, allowing riparian vegetation to become established on the ditch banks and providing a slow steady infiltration of water into the soil that raises the water table and increases local biodiversity. These large riparian areas act like sponges, controlling erosion and retaining water in the landscape. Fleming and Rivera (2013) have confirmed that *acequias* can provide up to as many as 16 different eco-system services to the riparian areas they serve and that the degree to which these services are provided is correlated with the community investment in *acequia* agriculture. The "inefficient" wooden plows, on the other hand, did not break and churn the soil as contemporary American plows did. Instead, they simply opened the soil, making a furrow about six inches deep where the seed could be planted. This practice helped retain much of New Mexico’s topsoil, as compared with that in much of the American Midwest. (MacCameron, 1994)

In addition to these aspects of environmental and economic sustainability of Hispanic agriculture in New Mexico, there are significant aspects of social sustainability to be celebrated as well. As Rivera (1998) has documented, the *acequia* community functioned as a local democracy in Spanish New Mexico, bringing together groups of settlers and creating a sense of community and of place where the outside government was offering none. The strength of this process is reflected by the survival of *acequia*
communities and their institutions to this day, as well as their continued participation in local politics. For many members of acequia communities, in fact, these villages have acted as a safety net in a changing world, especially during times of stress. (IBID) Therefore, traditional Hispanic agriculture exhibits strong mechanisms of social sustainability that reinforce its environmental and economic sustainability as well.

Despite these clear successes regarding the sustainability of pre-modern Hispanic agriculture in New Mexico, however, there are still a number of reasons to question its ultimate sustainability. Most critically, according to MacCameron (1994), areas that saw concentrated Spanish settlement from 1600 until the American conquest showed significant and notable degradation of their natural resource base, particularly water, grass and wood. Around Santa Fe, the decline was so precipitous that in the 18th century, the governor entertained the idea of moving the capital south to the confluence of the Santa Fe and Rio Grande rivers. (IBID) The driving force behind these declines was not acequia agriculture, but over grazing by livestock, particularly sheep. Sheep wool was, for many years, the only major export good that New Mexicans produced for sale to international markets. The result was a consistent overstocking of sheep and a depletion of the high desert grasslands on which the industry relied. This had a negative effect on the local ecosystem, as less ground cover led to increased run-off and erosion during rainstorms, which in turn fed a process of desertification. This contrasted with other areas of New Mexico outside the Rio Grande valley, where raiding by nomadic tribes prevented permanent agricultural communities from establishing themselves. Many of these areas, however, also became subject to environmental degradation once the raiding tribes were conquered. The upper Rio Puerco watershed, for example, deteriorated from a lush valley of small acequia communities to a desert filled with ghost towns in a matter of 50 years. (Diggle and Heib, 2004)

In addition to bringing about serious environmental consequences, the business of sheep ranching in Hispanic New Mexico also helped produce a system of social inequality and injustice that worked against the egalitarian ethic of acequia culture. Under the typical sheep rearing system in place around the turn of the 20th century, rich New Mexicans owned large flocks of sheep and would rent them out to poorer farmers who often owned none. These farmers, who acted as sharecroppers, would rent the sheep
and move with the herd over the course of the growing season, protecting them from predators. By the beginning of the next growing season, they owed the owner something on the order of 25 lambs for every hundred sheep they had rented. Although this left the sharecropper in theory with whatever lambs the flock had produced over 25, the owners of the sheep also charged shepherds for numerous expenses involved with tending the flock and also controlled all of the access to the outside markets demanding wool. As a result, these owners were usually able to charge the shepherds fees for all of the lambs that 100 sheep produced in a year and were able to maintain these poor farmers in a state of perpetual debt to the company store. Thus, the sheep ranching system in Hispanic New Mexico was not terribly different from the tenant farmer system in the Jim Crow south, providing an example of a system that was not socially sustainable. (Ackerly, et. al. 1994)

Another concern involving the sustainability of Hispanic agriculture in New Mexico involves the trajectory of population growth and expansion that characterized the entire Spanish and Mexican period in the region. After the *reconquista* following the Pueblo revolt in the late 17th century, the Hispanic population in New Mexico grew continually throughout the subsequent changes of government until the situation in the late 18th is described by MacCameron (1994) as “exceeding the land’s carrying capacity.” Evidence of the effects of population growth can also be found in Rivera’s (1998) description of villagers in the Mora valley cutting ditches through mountain landscapes to direct water from one river basin to another, in the formation of new villages in more and more remote and agriculturally marginal lands (DeBuys and Harris, 1990) and from the slow fragmentation of farm parcels in the valley into smaller and smaller pieces. In addition to this fragmentation, the farm land, now presumably under pressure from shorter fallow periods, was anecdotally beginning to provide lower yields per acre. (Carlson, 1975) In short, in the approximately 150 years between the *reconquista* and the treaty of Guadalupe Hidalgo, the Hispanic population in New Mexico was degrading its natural resource base and facing the challenge of feeding a continually growing population. Had the residents of the area been left to their own devices, it is an open question whether the environmental and social stresses described here would have pushed Hispanic New Mexico to follow the road of the Chaco Canyon or of pre-modern China.
There were a number of factors, most involving the *acequia* systems, that seem to provide the society with a base from which to innovate and to overcome stress, but there were other established patterns of growth and expansion that did not lend themselves well to creating this resiliency. In any case, because of the opening of the railroad in the 1880s and the integration of New Mexico into first the regional and then the global industrial economy, the sustainability of Hispanic agriculture was never put to the test in the way indigenous agriculture was. Still, the traditions of Hispanic agriculture provide a model for an agriculture that has more of an environmental ethic and a social cohesiveness that is often lacking in modern American agriculture. (Rivera, 1998)

**Modern Agriculture in the Rio Grande Valley**

In 1848, the United States officially took control of New Mexico as a result of the treaty of Guadalupe Hidalgo, and the third and final wave of agriculturalists began to move into the Rio Grande valley. It was during this time that agriculture in the central Rio Grande valley began to reach its limits. By 1880, 97 percent of all irrigable land in the central valley between Cochiti pueblo and Socorro was being farmed, a total of over 50,000 hectares (123,500 acres). (Thompson, 1986) Under this regime the water table in the valley began to rise rapidly, probably due to the large percentage of land under irrigation. Thompson (1986) estimates that typical irrigation practices in the valley can raise the groundwater level in a given field by as much as one meter. With almost no land now fallow, this meant that the entire Rio Grande valley began to act like a giant sponge. As water tables rose, salt from deep in the ground was wicked to the surface, rendering much formerly fertile land unusable. In other fields the water level rose so close to the surface that it created swamp like conditions in which the roots of agricultural crops could not grow. In 1926, for example, a survey found that groundwater levels in 78 percent of the valley lay between 0 and 1.2 meters below surface. (IBID) Ironically, what are generally considered to be the environmental benefits of *acequia* agriculture had become liabilities. In a phenomenon related to the water table rise, *acequías* throughout the valley as well as the river itself began a distinct process of aggradation, a raising of the level of the river channel. This aggradation was likely caused by the rising water table and by large sediment loads in the river that were likely
the result of poor land management and over grazing throughout the Rio Grande basin. As a result of these two phenomena, by 1920, only 32 percent of the 1880 high, or 15,600 hectares (38,500 acres) remained under cultivation. (IBID)

In light of this situation, the state legislature passed a law in 1923 which led to the creation of the Middle Rio Grande Conservancy District (MRGCD) in 1925. The purpose of the conservancy district was to build a cohesive infrastructure throughout the central Rio Grande valley that would effectively drain the agricultural land in the valley, prevent flooding and reduce the sedimentation of local acequias. When created, the Middle Rio Grande Conservancy District incorporated 79 independent acequias into a political subdivision of the state government. This allowed for a more coordinated action and the creation of a basin-wide system of canals and ditches, but it also destroyed the local systems of acequia governance that had sustained agricultural farming communities in the valley for hundreds of years. The drains created by the conservancy district did succeed in lowering the water table, but successive groundwater pumping by the city of Albuquerque and other regional cities has brought about a different kind of problem, as water tables throughout the valley have dropped precipitously since the 1950s. (IBID)

In addition to the creation of the MRGCD, the 20th century saw other wholesale changes in the nature of agriculture in the Rio Grande valley. Full-time subsistence farmers growing corn, wheat, and other grains and legumes have been replaced by part-time farmers growing alfalfa or running pasture for livestock. In addition, in the city of Albuquerque, population growth and demand for suburban and semi-rural houses have covered much fertile farmland with housing sub-divisions and strip malls. This has caused local water tables to drop even further because the groundwater pumping that goes with urbanization has now been accompanied by the loss of aquifer recharge associated with flood irrigated farmland. In 1986, 35,200 hectares (87,000 acres), approximately 68 percent of all possible irrigated land in the valley, was still under agricultural production. (IBID)

Despite the many changes brought about by the creation of the conservancy district and the implementation of industrial agricultural practices, however, irrigation in the central Rio Grande valley remains relatively similar to the irrigation practiced hundreds of years ago by the various acequia associations. Water is moved through the
irrigation ditches via the power of gravity, and it is diverted into and out of ditches using simple metal check gates that cover the ditch intakes. With this one exception, however, most of the agriculture that is practiced along the banks of these ditches using the flood water is completely different from that of 100 years ago.

Whereas most of the farmers who used conservancy district land in the late 19th and early 20th century grew food products for local or regional markets, most farmers currently operating in the central Rio Grande valley grow hay or other forage for livestock. According to the 2007 USDA agricultural census, farmers in Bernalillo, Sandoval and Valencia counties grew almost exclusively hay crops, with only minute quantities of other crops grown. This phenomenon can be explained in large part due to the climactic constraints of the Rio Grande valley, which makes the production of food crops more input intensive and less productive than in other regions. They are also related to the small farm sizes in the valley. Because of the historical legacies of the acequias and the generational subdividing of the land attached to the acequias, farms in the central Rio Grande remain small by any standard, and they are minute in comparison to the farms operated in other parts of the United States. In the three counties mentioned above, between 50 and 60% of all farms are between 1 – 9 acres in size, and the vast remainder are less than 49 acres in size. At this size, these farms as simply unable to compete with large agri-business operations in the production of commodity food crops, even for the local market. As such, the three counties mentioned above produced a total of 775 acres of vegetables crops, less than one percent of the total irrigated land in the valley, despite the growing demand for fresh produce. For most small farmers, since making a living as a farmer is generally not possible on so little land, they switch to hay production, a process that requires little labor, allowing them to dedicate their time to other economic pursuits.

In addition to the change in the kind of crops grown, the production mechanisms used in the central Rio Grande valley have also changed drastically over the course of the 20th century. Modern agriculture has brought with it the tractors for plowing, chemicals for fertilizing, weed control and pest control, and many seeds, including some alfalfa varieties, that are genetically modified in order to allow the crop to resist applications of herbicides. While these innovations have allowed farmers to reap greater and more
consistent yields from their land, they have also come with a number of environmental side effects. Luckily, because large industrial farms do not exist in the Rio Grande valley, these side effects are less pronounced in the region than in most areas of the country. Still, it is worth mentioning a number of the well documented environmental problems with modern agricultural techniques, because many of these affect the Rio Grande valley as well. Excessive plowing, for instance, has been shown to kill soil microorganisms and to induce erosion at rates nearly ten to one hundred times greater than the rate of soil formation. (Montgomery, 2007) In addition to this, chemical run-off from agricultural fields fertilized with chemicals can pollute water ways and the ditch water that farmers use to water their crops. The MRGCD itself sprays its ditch banks year with chemical herbicides, meaning that bee keepers must call ahead of time to avoid having their hives accidentally killed. (Miller, R., interview, Mar 5, 2014) Finally, chemical pesticides and herbicides not only eliminate difficult pests and weeds, they eliminate all beneficial plants as well. As such, populations of honey bees and other pollinators are in decline. In addition, chemical weed and pest control tend to create “super-bugs” and “super-weeds” over the long run, as annual weeds and difficult insects develop resistance to the very chemicals intended to destroy them. This leads to a pesticide treadmill in which farmers turn to more and more destructive chemicals, only to create even more resistant weeds or pests. This cycle, which has been well documented in a variety of settings, is destructive for everyone involved: farmer, soil, ecosystem. (e.g. Humphries, 1993)

For these and other well documented reasons, modern industrial agriculture is not environmentally sustainable on any scale, even at the small scale practiced in the Rio Grande valley. In addition to this, there are concerns regarding the economic and social sustainability of farming as well. Urbanization has long ago sent the price of land in the valley much higher than what it is worth as farmland. As such, no one in the valley can make enough money from farming to pay off a loan on their land, requiring aspiring farmers to own land outright or to have a well-paying side job. In addition, because of the small farm size already mentioned, even those who do own land find themselves in a bit of a double bind. On the one hand, farm equipment such as tractors and combines are not a rational economic investment for an individual small farmer. On the other hand,
this same farmer cannot afford to devote large amounts of his or her labor time farming by hand, because he or she must generally hold another job in order to pay for the land. As such, the economically rational thing to do with farmland is to subdivide it and sell it off as housing, which means that each year more and more farm land disappears underneath suburban neighborhoods and strip malls. In Bernalillo county, between 2002 and 2007, irrigated acres in farm production decreased from 248,000 to 139,000, a decline of almost 50 percent. (USDA, 2007) Without a societal mechanism, therefore, to preserve farmland intact and to price it relative to its value as an agricultural piece of land, it is entirely possible that farms in the most urban parts of the Rio Grande valley, namely the Albuquerque metropolitan area, will eventually become a thing of the past.

Modern, industrial agriculture, therefore, is neither environmentally nor economically sustainable in the Rio Grande valley. Despite this, however, agriculture stubbornly persists in the region, remaining a part of the cultural and social identity of many valley communities. This situation points to a certain amount of sustainability in the social fabric surrounding valley agriculture, particularly traditional acequia agriculture. Although the traditional acequia associations of the past were subsumed into the government bureaucracy through the creation of the MRGCD, agriculture still has a resonance in many communities, who instinctively value the ditches and the lifestyle they used to support. Thus, there are a number of foundations and community organizations dedicated to supporting and preserving traditional agricultural heritage, and many people remember their parents or grandparents growing up on a farm fed by an acequia. As a result of these networks and traditions, a number of farmers and their families continue to farm on their small plots of land in the Rio Grande valley, despite the environmental and economic obstacles. There is a certain sense, therefore, in which the social sustainability of agriculture in the valley is the only leg of the Triple Bottom Line that has allowed the local agricultural system in the valley to remain viable at all. Despite this strength, however, there are still questions about the long term social sustainability of these trends. As the current generation of farmers retires, fewer and fewer of their children are interested in farming, leading to a dwindling supply of farmers. In addition, the current generation of adults has many memories of local farms owned by their parents, grandparents or other relatives. Once the generation in power can no longer remember a
generation in their family that was connected to a farm, however, it is unclear if this social, cultural energy will persist. Therefore, to varying degrees, on all three legs of sustainability postulated by the Triple Bottom line, modern agriculture in the Rio Grande valley is in danger of failing to persist.

Artisan Farming: A Growing Movement to Revive Agriculture

Despite the relatively dire circumstances faced by conventional agricultural operations in the Rio Grande valley, there is one sector of the region’s agriculture that is growing and each year gaining more and more attention. Many small farmers, worried about the unsustainable environmental and economic trajectory of conventional agriculture, have turned to producing organic and/or chemical-free specialty crops and food stuffs for the local market. Many of these farms are very innovative and successful, and it is for these reasons that there is a growing hope that artisan farming, as it is sometimes called, may play a key role in reinventing and revitalizing agriculture in the Rio Grande valley. As can be expected with a burgeoning market, small scale organic growers are still a small minority among farmers in the central Rio Grande valley. The USDA's agricultural census (2007) lists 37 farms and 148 acres of land in organic production in Bernalillo county. In addition to these official numbers, it is likely that a good portion of the 279 acres devoted to vegetables in the same year are also part of this movement, as many growers involved in these specialty markets do not seek organic certification. The numbers regarding local harvests of hay on the other hand for Bernalillo county total 6,590 acres, almost 20 times the amount dedicated to organic or vegetable crops. Still, there is no doubt that the buzz generated by the local food movement and the market that it is creating is drawing new farms and farmers into the mix every year, inspiring hope that this kind of farming will one day reflect a large share of the region's agriculture. Responding to the critiques of modern industrial agriculture described above, these artisan farmers deliberately try to market themselves as "beyond organic", farmers whose ideals remain true to the original premises of the organic movement.\(^1\) As such, they tend to brag about how they hold themselves to standards

\(^1\) for a detailed explanation of the history of the organic movement, see Pollan (2006).
above and beyond those imposed by the U.S. Department of Agriculture (USDA) in its organic certification process. In addition, they emphasize their role in revitalizing the local economy of farming communities in the Rio Grande valley, finding new and creative ways for local farms to survive and to keep money in the region. Because of this dialogue, many people consider these artisan farmers and their farms to be examples of sustainable agriculture. In this line of thinking, they represent environmentally sound and sustainable agriculture practiced in a way that allows the farmer to make a decent living economically. As a result, the word "local" has become almost a brand in and of itself at farmers markets, restaurants and alternative supermarkets, and many consumers patronize these locales and buy local food precisely because they believe it to be a sustainable food alternative along all three legs of the Triple Bottom Line. It is for this reason that this study targets these local, artisan farmers in order to solicit their expertise regarding sustainability in the region.

Can Small Farms Be Sustainable?

Before proceeding to describe the insights and conclusions of local farmers regarding sustainable agriculture in the Rio Grande valley, it is important to touch on the issue of scale, one that come up throughout the study. It is often assumed in the United States that small farms, particularly those of the size found in the Rio Grande valley, could never produce enough food to feed the large, complex societies that they are a part of. This line of thinking assumes that small farms are "backwards" and "inefficient" compared with the large-scale, mechanized agriculture that currently provides the vast majority of food in the United States. Thus, small farms such as those that are a part of this study are often marginalized in political and economic policy since it is assumed that they can do no more than provide food for niche markets in small quantities. In point of fact, however, study after study has shown that small farms are actually more productive per unit of land than large-scale mechanized farms. (Pollan, 2006) As such, the notion of constructing a sustainable agricultural system around small-scale farms is not a question of production capacity, but one of social and economic organization. As Robert Netting describes in Smallholders, Householders (1993), numerous agricultural systems around the world, including many countries with population densities much greater than those of
the U.S., are supported by small farmers, many of them who use simple, ancient technologies. These small farms generally produce less food per unit of labor than large-scale mechanized farms in the United States do but instead produce much more food per unit of land through intensive labor practices.

There are a number of ways to explain the advantages that smallholders, as Netting labels his study group, have over larger farmers, most of them having to do with crop management, labor intensivity, and the use of local knowledge. Precisely because of mechanization, large-scale farmers in the United States are required to treat their soil as a kind of machine. Fields must be level, crops must be evenly spaced and most importantly, crops in any particular field must be the exact same variety, planted and harvested at the same time. This allows the farm machines that a given farmer has to successfully prepare the soil, plant the seeds and harvest the crop over a large expanse of land using very little labor. In contrast to this situation of uniformity, small farms rely and take advantage of diversity. For a small farmer who works with hand tools, for example, multiple crops can be planted in the same field at the same time, taking advantage of different micro-climates and soil types. In addition, to this, the smallholder does not have to make room in the field for his or her machines. Therefore, while large farms must leave wide rows between crops in order to allow tractor access, smallholders need only enough space to walk in between the crops. As a result, in Japan, a country with a tradition of small-holder agriculture and full access to modern technology, farmers produce 10 times more food per acre than in the United States. Even countries without modern technology produce double or triple the amount of food per acre as modern industrial farmers in the United States. (Netting, 1993)

In addition to producing more food per acre than industrial farms, there is reason to believe that in many cases, smallholders practice agriculture more sustainably than large-scale farms. The fundamental, underlying reason for this, according to Netting (1993), is an economic necessity to maximize the productivity of their land rather than the productivity of their labor. In making this argument, Netting calls for a reformulation of the understanding of agricultural history, one that typically assumes that agriculture progresses from small-scale with simple technologies to large-scale with industrial technologies. Instead, he argues that agriculture should be understood as progressing
from extensive agriculture, in which land is abundant and labor is scarce, towards intensive agriculture in which, as population grows, land becomes scarce and labor becomes abundant. In systems of extensive agriculture, he argues, even ones driven by simple technologies, agricultural practices are often unsustainable environmentally. In systems of intensive agriculture, on the other hand, the high availability of labor and the economic requirement that farmers make money on less land than before combines to lead to innovations that increase the environmental sustainability of farming. Ironically, Netting argues, in many cases sustainable agriculture has developed from situations in which farmers no longer have access to enough land to let land go fallow, a situation that intuitively implies a march towards an ecological disaster.

One example of this dynamic can be seen in the ways that extensive farms in the United States and intensive farms described by Netting deal with pests, weeds and diseases. Because large, industrial farms are required to plant large tracts of land in a single variety of a single crop, their crops are much more vulnerable to pests and diseases. In addition, it is prohibitively expensive for these farms to control weeds by hand. As a result, industrial herbicides, pesticides and other chemicals, which happen to be produced using large amounts of fossil fuels, are the only practical method for large mechanized farms to get away with large-scale monocropping. Small holders, on the other hand, face less pressure from pests and diseases because they grow multiple varieties of multiple crops. When they are faced with an outbreak, their farms are small enough that they can deal with some of the problems using available labor and others using organic innovations based on local materials. More importantly, their multiple cropping scheme often keeps the pests diseases from spreading throughout the entire farm and their economic situation is not decimated by the failure of one crop. In both cases described here, farmers are managing their farms in a certain way as a matter of economic necessity, but the result for the small-holder is a more sustainable one.

In addition to the advantage enjoyed by small holders in environmental sustainability, there are also reasons to believe that smallholding agriculture is more economically and socially sustainable than industrial agriculture as well. Economically, industrial farms often specialize in one or two commodities and as such are subject to the vagaries of the capitalist market and commodity prices. Small holder farms, on the other
hand, generally earn money from a variety of cash crops, allowing them to be more resilient. More importantly, small-holder farms also act as a safety net for household members by producing food and other goods that do not have to be bought in the capitalist marketplace and thus will be available even when cash income isn't. This is part of the strong social and cultural infrastructure that most small-holder farming communities build around each farm, similar to the patterns seen in the *acequía* communities of New Mexico. In most small holding communities, the farm is generally owned by older family members, who see the land as their retirement and also the major source of wealth that they will leave to their children. As a result, small holders have a strong incentive to make permanent improvements to the land in the name of being able to sustainably farm it during and after their lifetime. In addition, their children, who learn the trade of farming while growing up, generally serve as highly trained farmers to replace parents once they retire. (Netting, 1993) This contrasts with industrial agriculture, where land is treated as a commodity that can be bought and sold. In this scenario, farmers do not plan for the long term agricultural productivity of their land, because they can always sell their land and buy another property. In addition, there is no ingrained structure of inheritance to make sure the farm continues to be used as such.

As Netting (1993) carefully documents, therefore, smallholders have sustained and continue to sustain large and complex modern societies. When evaluated in terms of sustainability, these small-holding agricultural systems tend to be more sustainable than their contemporary, extensive counterparts. Among the most well-known examples he cites of small holder societies are the wet rice agriculturalists in Asia, who have supported growing populations via small-scale agriculture for thousands of years. China, for instance, has the largest population and some of the highest population density of any country in the world, yet its population is fed almost exclusively by smallholders intensively farming 2 to 5 hectares of land. The small-holder farmers in China are so efficient with their use of land, in fact, that during the 1960s when the communist government attempted to modernize agriculture by gathering large tracts of land together in collectives and mechanizing the operations, wide spread food shortages and famine followed, counter to expectations that modernization would improve food production. Japan, another country reliant on irrigated plots of rice, supports a population of mostly
part-time small farmers who, as mentioned, are able to grow ten times more food per unit of land as large industrial farmers in the United States and Canada. Bangladesh, one of the most densely populated countries in the world, supports its population of over 144 million people via a similar system, intensive farms run with simple technologies. (IBID) These examples and numerous other show that small holders can and do support complex societies with dense populations. In fact, contrary to the bias described above regarding the superiority of industrial agriculture, the indicators on sustainability imply that smallholders may be better equipped to supply the food for modern and future societies over the long term.

**Caught in the Middle - The Smallholder and New Mexico**

For demographic and historical reasons, there are significant obstacles to reforming the economy of the United States and creating a food system based on small intensive farmers. As Netting himself documents, land in the United States has always been cheap and abundant. Even the family farms that are often romanticized as the ideal of a long-lost, agrarian America were generally hundreds of acres in size and actively pursued strategies that maximized labor at the cost of the land. Today, given the cost of labor in the United States, a shift to a smallholder economy is challenging at best because smallholder agriculture requires large inputs of labor in order to maximize use of land, something that is not yet economically rational in most parts of the country. In fact, to call for a move towards a food system based on small-holder agriculture is to call for a complete reversal in the trajectory that the U.S. agricultural system has taken over the entire course of American history. Today, only about 2,000,000 farmers provide all of the food produced in the United States, an astronomically low number for a country with a population of over 300 million. A shift to a small holder model would require many times that many people to move into agriculture, whether part-time or full-time. This shift, because of the technological and logistical hurdles involved in preserving and transporting mass quantities of food produced by small-holders, would also require a shift to a more local and regional food system, one that would require a substantial relocation of the country's population. To put this fact in perspective, two local farmers interviewed for this report independently estimated that one acre of irrigated land could produce
enough food for one person. The MRGCD currently irrigates approximately 87,000 acres in the Rio Grande valley, meaning that about 87,000 people could eat exclusively food produced in the valley. In the event of a shift to a more regional food system based on small-holder agriculture, the remaining 900,000 people in the valley would likely be forced to relocate elsewhere, probably to the small towns in the Midwestern farming belt that have been deserted over the past 100 years. While small holder agriculture can be seen as a sustainable ideal to be pursued, therefore, it is likely that a sustainable food system for the United States would instead involve a number of compromises between these ideals and the economic reality of cheap, abundant land and expensive, scarce labor.

Despite these very real and practice obstacles to moving the United States into a food economy based on the small-holder model, however, there is still good reason to believe that this model is a practical one to pursue with regards to the agricultural economy of the Rio Grande valley. Most importantly, the existing situation of small farmland parcels patch-worked into urban and suburban areas already reflects land-holding patterns in countries with successful small-holding agricultural industries. Unlike many other rural areas of the country, where land is cheap and farms are sold by hundreds or thousands of acres, the Rio Grande valley's irrigated farmland is already divided up into individual blocks of generally less than five acres a piece. In addition, the desirability of farmland as a place to live and the tense situation regarding water rights means that land is expensive, so there is little opportunity for land consolidation. As a result, unlike other places in the U.S., farmers in the Rio Grande valley have a strong economic incentive to maximize the productivity of their land, a situation very similar to that faced by the smallholders Netting describes. In contrast with the situation confronted by most smallholders, however, labor in New Mexico is also relatively expensive and relatively scarce. This, coupled with the price of land, creates the double bind described earlier that has made farming in the valley economically unattractive. While this double bind has to a large extent pushed New Mexicans out of agriculture, however, the farms that remain still enjoy one advantage not experienced by the smallholders in Netting's work, which is cheap and available fossil fuel energy. Under these conditions, farmers in New Mexico have been very creative, using fossil fuel
energy as best they can to become as efficient as possible both with their use of labor and their use of land. Still, fossil fuel energy presents distinct challenges for sustainability because fossil fuels are ultimately a non-renewable resource that cannot be produced locally. The remainder of this report explores the ways in which local farmers are navigating this situation as they struggle to build sustainable farms and to grow the Rio Grande valley into a community supported by a strong, sustainable local food system built on the backs of a unique version of American smallholders.
III. From Theory to Practice - Developing the Nuts and Bolts of Sustainable Agriculture in the Rio Grande valley

A. ENVIRONMENT

Farming in the Rio Grande valley is a very unique endeavor, one that involves a number of seeming contradictions and hybridizations. As described in the previous section, agriculture in the region is both labor intensive and reliant on fossil fuel energy. It is also heavily based in tradition but very modern in practice. It is economically impractical, yet socially lucrative. Most critical to this line of study, it is slowly dying yet in the process of reviving. In order to best understand the composition and variability of Rio Grande valley farms, therefore, this section of the report reviews agricultural practices in the Rio Grande valley piece by piece. Each section that follows describes current practices as described by the farmers interviewed. It then evaluates each practice with regards to its sustainability and ends by making recommendations regarding ideal sustainable outcomes in each category, at the same time suggesting practices that seem promising in terms of moving existing farms towards these sustainable outcomes. The practices reviewed here include water, water conservation measures, soil fertility, tillage and erosion, crop management, weed control, pest and disease control, seed saving, seed starting. In addition to these farm practices, a number of social and economic factors are reviewed that influence these practices and play important roles in the long term sustainability and reproduction of farms themselves. These include farm income, land tenure and access to land, organic certification, labor, job security and farmer training and replacement.

Water and Irrigation

In the dry, semi-arid climate of the central Rio Grande valley, water is the most critical and the most precious resource for local farmers. Most conversations about sustainability in the region begin and end with water. In general, the amount of water that growing plants receive is seen as the most critical variable affecting plant growth and yield. As such, most opinions on the issue are fiercely held and there is unlikely to be a
single magic bullet solution. Water is also one of the issues that is most regional and political in scope, meaning that while every farmer has their opinion about how the water systems in the valley should work, the changes are also the most difficult to implement because of the need for widespread cooperation and, most importantly, political will.

**Current Practices:** As discussed above, the traditional irrigation of the Rio Grande valley was flood irrigation, a practice which continues to this day. Flood irrigation relies on surface water, which is diverted from the Rio Grande and sent through an intricate network of earthen *acequias* to local farmers. This water is moved into different ditches via metal plates that serve as check gates to raise the water level or shut-off gates to move water into or out of a ditch. Generally there is a principal ditch, or *acequia madre*, that moves large amounts of water from region to region. From these ditches, small lateral ditches convey water to farmer's fields, where a final gate is opened. From here, the water is allowed to run until it has covered the entire field, sometimes a few inches deep. Although the details vary from ditch to ditch, most farmers receive water once every 14 days, although some farmers noted that in the past when water was plentiful they irrigated once a week. (DeSmet, M., interview, Feb 25, 2014; Armijo, K., interview, Feb 26, 2014) Conversely, during the drought year of 2013, when all irrigation water was shut off on July 1 due to low flows in the river, farmers were only allowed to water once every three weeks. The irrigation season run by the MRGCD is 8 months long, running from March 1 to October 31 when there is sufficient water.

In addition to flood irrigation, most of the farmers interviewed also practice a form of hose irrigation known as drip irrigation. Drip irrigation requires pressurized water, and is usually pumped from a well with a motorized pump. It can also be connected to municipal water supplies or engineered to work with gravity-fed water system. The water is first pumped into a pipe which transmits the water to the field. At the field level, the pipe system runs the water perpendicular to each bed. At the end of each row of crops a valve is connected to the pipe and a piece of thin black plastic is attached with holes every 12 inches. This black plastic, known as drip tape, is run the length of the row, ideally with a hole placed next to each crop being planted. When the motorized pump is turned on, water flows through the pipes and drip tape and about a
drop of water per second drips directly onto the roots of the plants in the field. Each farmer has a slightly different watering rhythm for their drip system regarding how often they use it and how long they water. This reflects one of the advantages of drip, which is that each farmer has complete control over how much and how long they water. As such, among the farmers interviewed, some of them use flood irrigation but all of them, with the exception of the two dairies, use drip irrigation. More specifically, all of the interviewees use drip irrigation to raise vegetables, while the flood irrigation was used to grow hay, alfalfa or grains such as blue corn. Finally, some farmers use the flood water supplementally on their vegetables and some of them also use it to establish a cover crop in their vegetable plots over the winter.

The reason for this division of labor is quite simple, flood irrigation is considered difficult, wasteful and unreliable while drip irrigation is more productive, uses water efficiently, and is completely under an individual farmer's control. One agricultural extension agent explained a number of reasons why drip irrigation was preferable to most farmers,

Spaces between growing beds or rows can be left unwatered, which means they're gonna grow much less weed growth, which reduces your weeding labor tremendously. Another advantage is the seasonality thing; you can start earlier and go later than you can with ditch irrigation. You're gonna get less water borne contaminants, be they weed seed or potentially even chemicals. .... You can do what's called fertigation, which is to inject water soluble fertilizer into the line and apply it to the drip irrigation. It's a very targeted way to also accomplish fertilization. ... It's also more productive per unit of land and per unit of water. (Viers, J., interview, Feb 5, 2014)

Along with these reasons, perhaps the greatest advantage of drip irrigation is that water is constantly available for farmers, whenever they need it. This means that seeds and seedlings can be watered daily with a little bit of water and larger plants can be watered more deeply as the season progresses. Water can also be delivered to individual rows as needed.

In contrast to this situation, most farmers expressed varying degrees of frustration with the system of flood water irrigation managed by the MRGCD. Some of them told stories about farmers who lost their crops because of not receiving water when they needed it. (Acosta, R., interview, Feb 23, 2014)
Last year the water got cut off in the first week of October. I had just planted my winter cover crop. It didn't come up, so all my 150 dollars of seed went to waste. They didn't say what day they were going to cut it off. They just said 'sometime in October'. So you don't know, you just have to hope. ... You can't be dependent on the ditch water for any of this. (Wegrzyn, D., interview, Feb 19, 2014)

Still other farmers found problems with the political nature of the ditch water,

Isleta pueblo has the original water rights, so we'll be on this 40 hour stretch of watering, I've been awake for 40 hours working straight watering everything and then the (Isleta) pueblo guys get up at 8:00 in the morning and they'll check in and all your water goes down. You call the ditch rider and he'll tell you he can't do anything about it, the pueblo's watering. (DeSmet, M., interview, Feb 25, 2014)

The most common observation regarding the acequia system, however, is that there is not enough water to go around. At the time of this study, the Rio Grande valley and the state of New Mexico are entering their sixth consecutive year of drought, with no foreseeable end in sight. As a result, reservoirs throughout the state have dropped to low levels not seen for years, and many are almost empty. For many of the farmers interviewed, this situation is not one they expect to end. Instead, given the predictions regarding climate change, which forecast a reduced surface water flow throughout the southwest of at least thirty percent, many farmers view the current drought conditions as a new normal for surface water irrigators. Thus, even those farmers with more positive feelings regarding acequia irrigation claimed that they were switching to drip irrigation out of necessity. (Armijo, K., interview, Feb 26, 2014) In an uncertain world, there is nothing that farmers would prefer to hang on to than complete control over their source of irrigation.

**Sustainability:** Despite the qualms of most local farmers regarding the flood-water irrigation system in the Rio Grande valley, a number of them were still able to recognize its importance in preserving the long term sustainability of agriculture in the region. As described previously, the earthen acequias of the Rio Grande valley and flood water agriculture actively recharge the local aquifer, meaning that water levels in farmer's wells have actually been maintained throughout the years via floodwater farming. (Thompson, 1986) Thus, even the drip irrigation systems that these farmers admire are actively dependent on flood irrigation. As one farmer explained,
This property is completely dependent on a well. We need to recharge the well somehow, and flood irrigation gives us the opportunity to do that. One good reason even to open up this (fallow land) to flood irrigation is to recharge the well. It'll make this place last longer. (Chrisp, E., interview, Mar 2, 2014)

In a stroke of irony, therefore, the MRGCD, which was created to lower water tables throughout the Rio Grande valley, is now in a position to raise the water table that is rapidly dropping as the city of Albuquerque and other municipalities pump groundwater. In addition to this, the MRGCD's reliance on surface water places a very effective check on farmers who might otherwise use too much water if they were only pumping groundwater. As an example, the water shut off in mid-summer of 2013 prevented excessive water use during a drought year, forcing farmers to do without, and preventing further depletion of the ground water. This may be extremely frustrating for individual farmers, but is likely to be more environmentally sustainable over the long run.

Despite the environmental benefits of flood irrigation, however, as many farmers indicated in their interviews, the current acequia system run by the MRGCD is unlikely to be sustainable over the long term due to concerns about climate change and over-appropriation of water rights. While the irrigation shut offs during the fall of 2012 and the summer of 2013 are also signs of a cyclical drought pattern in the southwest that also affected water supplies in the late 1970s and early 1950s, they are also signs of the advancing effects of climate change on the water supplies in the central Rio Grande valley. According to Coonrod, as the climate warms over the course of the 21st century, stream flows even under conditions of normal rainfall are likely to be reduced by as much as 30%. (cited in Fleming and Rivera, 2013) This, combined with the fact that water rights in the Rio Grande basin are already oversubscribed leads most farmers to think that there simply will not be enough water to irrigate the 36,000 hectares that the MRGCD currently supplies. Thus, despite the environmental benefits of flood irrigation, without a restructuring of the irrigation system in the Rio Grande valley, the aberration of 2012 and 2013 may become a regular occurrence. This situation is unlikely to be economically sustainable, as there is no structure in place to protect small farmers from losses that they may incur during drought years. In such an environment, farmers may decide never to plant rather than risk the loss of an investment.
There are, therefore, serious concerns about the sustainability of the flood irrigation supply if not the practice, and the assessment regarding the sustainability of drip irrigation is not much better. As already noted, drip and flood irrigation systems are ultimately connected, even if they seem to be separate since one is ground water and the other is surface water. Still, flood irrigation plays an important role in recharging the ground water, especially if farms are pumping more water to grow their crops than the water that falls every year as precipitation. Most farmers interviewed expressed concerns that their groundwater levels were dropping, and as such they did not see their drip system as sustainable. (e.g. West, J., interview, Mar 3, 2014) In addition to concerns about ground water levels, drip systems are also much more reliant on non-renewable sources of energy than flood irrigation. All of the farmers interviewed used electric pumps to pull ground water out of the well and channel it into their drip lines. While one farmer described a gravity-fed drip system he had worked out in the Manzano mountains east of the valley, the flat bottom lands of the river valley are not likely to be suitable for this purpose. (Chrisp, E., interview, Mar 2, 2014) Thus there is concern that if non-renewable sources of electricity were to run out over the long term that the pumps to run the drip system would no longer be viable. More pressingly, most farmers described the drip tape that conveyed the water from pipes to the plants as a cyclical three to six year investment, because over time salts from the ground water clog the lines and farm equipment punctures them beyond repair. According to one farmer, he was aware of some bigger farms that replaced their drip tape every year simply because of the difficulty of putting it back onto spools in the fall and winter.

That’s a lot of trash generated, especially if you’re an organic farm and you’re kind of representing yourself to stand up for certain ideals and you’re having those massive dumpsters full of drip tape every year. It’s kind of incredible. (Matlick, S., interview, Feb 25, 2014)

Thus, the amount of trash generated by drip tape, and the constant input of energy and fossil fuels needed to make the drip tape, also place the sustainability of current drip systems in question.

**Sustainable Outcomes:** In order to ensure a reliable, sufficient water supply for farmers in the Rio Grande valley for years to come, there are five outcomes that should
be pursued. First and foremost, water rights need to be evaluated with respect to the reasonable scientific projections of climate change scenarios so that those who have water rights can have a reasonable assurance regarding when and how much water they will have. As part of this evaluation, the MRGCD must do everything in its power to make the use of ditch water efficient. In addition, new guidelines should be developed so that water rights are more flexible and transferable, in order to accommodate the different needs of different farmers. With regards to flood irrigation, some form of community participation regarding the ditch water should be implemented in order to give farmers a more local control over how their water is used. Finally, individual farms need to develop diverse watering systems that rely on multiple sources of water and allow farmers to grow crops through a variety of watering schemes. These water systems should be made of durable or renewable materials and not rely on regular inputs of fossil fuel-based products.

As is discussed in the previous section, there is a great deal of apprehension and frustration regarding the flow of water in the ditches. Flood water irrigators in New Mexico have long had to deal with dry years when the ditch water was not available, but with the prospect of climate change looming, most farmers have the sense that there will never again be enough. Although this prognosis is likely an exaggerated one, it is certainly true that in order for the irrigation systems in the Rio Grande valley to be effective, all the farms with water rights must have a reliable supply of water in most years. This means that preparations need to be made for the future so that as average flow in the Rio Grande does drop, the MRGCD does not end up with a situation where a large group of farmers consistently has too little water. In this scenario, all farmers will slowly abandon *acequia* flood water in favor of more reliable sources such as ground water, a very unsustainable scenario. In other scenarios where hard choices are made, however, and some farmers lose their water rights in order for other farms to continue to function adequately, *acequia* water will be able to survive as a practice.

An additional and related solution to the reality of falling surface water flows in the Rio Grande is the imperative to pursue a program of efficient use throughout the MRGCD. As, one farmer noted, much water could be saved simply by laser leveling all fields in the Rio Grande valley, avoiding the scenarios where, as he claimed "farmers will
put 10 inches of water on one end of the field in order to get an inch of water on the other." (Morgan, M., interview, Feb 27, 2014) Other farmers noted that a good amount of ditch water is used for watering lawns and other non-agrarian uses. One farmer claimed that her neighbor used ditch water to keep down the dust in his horse stall, despite fervent protests on the part of the ditch rider. (Miller, R., interview, Mar 5, 2014) Another farmer pointed out that no one really knows how much water each farmer in the system uses because no one meters the amount of water that is released onto each field. She suggested that simply by measuring the water used throughout the system, that change might be affected once the disparities between farmers became clear. (Wegrzyn, D., interview, Feb 19, 2014)

Other possible solutions to water right reductions include more flexible allowances for the use of water and possible seasonal water right solutions. Many vegetable farmers, for example, would like to be able to store ditch water in order to run it through a drip system little by little when they need it. This would help them use less of the ditch water and it would also make the resource more reliable so that it could be used for vegetables. Another solution would be to give vegetable farmers ditch rights only three or four times a year, in order to recharge their wells and establish their cover crops. Even more basically, some farmers would like to be able to transfer ground water rights to surface water rights and vice versa. One farmer even noted that, in times of great water scarcity, many of the rules and regulations of the state water engineer did not make sense, and that more flexibility is needed to allow for creativity in order to make things work. (Moody, J., interview, Mar 6, 2014) In addition to evaluating the quantity of water rights and the users of these rights, therefore, measures should be taken to make water use in the valley more efficient and more flexible.

Aside from the concerns posed by climate change, many of the issues that farmers brought up with regards to acequia irrigation stem from their lack of control and lack of voice in how the watering system is operated. While many of the individual qualms that ditch users had with their system have been around for as long as the acequias, however, this lack of control has not. In contrast to the current situation, most traditional acequia users were parciantes, implying a literal "part" ownership of the ditch and the water in the ditch. The acequia associations traditionally would make decisions during meetings
of the parciantes, and the mayordomo, who made decisions about the use of ditch water during a given year, was generally a parciante as well. This kind of direct democratic institution allowed each acequia to make local decisions regarding the use of water. Rather than using blanket procedures and rules, the parciantes gave the mayordomo the power to use discretion in deciding that, for example, a certain plot of vegetables might receive more water than another plot of pasture. Given the diverse set of land uses that the acequia water is diverted for today, the merits of such a system might be able to solve many of the complaints detailed here. Some acequias, for example, might decide not to allow anyone to use ditch water for the purpose of keeping a lawn. Others might recognize that a certain farmer was growing vegetables for the market and as such would allow him or her to pump the water into a cistern and use it for his or her drip system. Still other acequias could develop local procedures for who receives water during years of low flow and who doesn't. Most importantly, if acequia users were again allowed to be parciantes, they might no longer feel left out of the decision making process, but instead would have to acknowledge that they had the power to propose the changes in their ditch that they wanted to see. As most interviewees made clear, the fact that ditch water is administered by a government agency separates ditch users from the way in which their water is managed, creating disillusionment with the acequia system. Restoring some of this connection and direct participation may be critical to making the MRGCD's acequia system socially sustainable over the long run.

In addition to adapting the flood water system to make it more user friendly and more reliable, the final outcome that came out of the interviews is the need for all farms to move aggressively towards a watering strategy that relies on multiple water sources and that does not rely on large inputs of non-renewable materials. In the short term, this need is being met as many farms formerly reliant solely on acequia water switch to drip irrigation. Interestingly, however, when asked to describe a sustainable watering system in the Rio Grande valley, almost every farmer interviewed began by talking about the use of rain-water harvesting, even though only one farmer had a rainwater system of any kind in place. This is likely because rainwater is the only truly renewable source of irrigation water. Unfortunately, however, the rainwater that comes off of domestic roofs or barns is sufficient to maintain trees and landscaping around the farm itself, but is typically not
enough to grow food on the scale of a farm. Instead, in order to successfully harvest water for growing crops, farmers who wish to diversify beyond their acequia and their drip system must begin to look towards the ancient indigenous agricultural practices based on rain-fed agriculture. In these systems, indigenous farmers worked together to build flood control systems on local arroyos and other rain catchment features in the landscape. Much like the acequia systems, rain fed agriculture was often a communal water investment that helped bring water to individual plots. What is tricky about this is that, ultimately, water harvesting for a farm needs to occur on the scale of a landscape, a landscape that most farmers will not have permission to tweak because it is not on their property. If this political hurdle can be overcome, however, there is great potential for agriculture based on water harvested from parking lots and other impervious surfaces that the modern urban landscape has strewn all up and down the valley. Already, there are a number of parks and green spaces in the city of Albuquerque that act as rainwater catchment and flood control facilities. Learning how to farm these spaces with rainwater may be one more step in the direction of sustainability. Another step might be the identification of sites in the Rio Grande valley where rain-water irrigation can still be a viable alternative, perhaps even the edges of large retail parking lots.

In addition to the diversification of watering strategies required of farms in the coming years, the other great challenge will be to switch to water systems that are not reliant on regular applications of non-renewable resources. As most farmers noted, the drip tape currently used for drip irrigation is in constant need of replacement and is made of plastic, a petroleum product. This, plus the reliance of most drip systems on pumps powered by coal-fired electricity, were the most commonly cited examples of the regular inputs of non-renewable resources that most farms rely on to irrigate their crops. In order to avoid using these materials, a number of farmers suggested installing solar panels to power the pumps, while others suggested that perhaps a drip system could be constructed out of durable materials and engineered to work via gravity. One example of this is that of a farmer in Socorro county who constructed his own drip system out of solely PVC pipe rather than PVC pipe connected to drip tape. (Hyden, 2014)

Whatever the specific solutions, it is clear that the future of agriculture in the Rio Grande valley calls for a diversified water strategy. Over the short term, this involves
modifications in the system of flood irrigation to make it more reliable for individual farmers, more locally controlled and more flexible with regards to the way water is apportioned and used. It also involves initiatives to make the system more efficient through large-scale initiatives to level fields and eliminate unnecessary uses of water. For individual farms, on the other hand, the future calls for the integrated use of drip and flood irrigation, as well as a recognition that both are connected and that both may be necessary in order to keep the other viable. Finally, the future is also one that calls for innovation and for experimentation with the oldest source of irrigation in the southwest, the rain. Given the uncertainties and extreme weather that climate change may bring, farmers will need to have every trick in their water bag ready in order to be able to grow food successfully in the years to come.

Water Conservation Measures

In addition to harnessing and using all available water sources, sustainable farming in the Rio Grande valley requires the use of techniques to conserve water and to make every drop used in the field count. In the dry air and heat of the high desert summer, much of the water that is applied to growing plants is lost to evaporation before it is ever used by a plant or animal. In addition, high intensity summer rainstorms drop large quantities of water in a short time frame, meaning that the soil saturates quickly and the rest of the moisture often runs off the landscape, making it effectively lost to local fields and watersheds without some kind of intervention. Finally, any plant located in full sun requires large quantities of water to transpire in order to grow healthily, especially most of the plants favored in local vegetable markets. Therefore, water conservation measures implemented in the field are critical in terms of reducing evaporation, increasing infiltration during rainstorms and decreasing the amount of water demanded by crops for evapotranspiration. Most farmers are aware of these effects and the farmers interviewed described various measures they use to conserve water.

Current Practices: When asked about practices they used for water conservation, most of the farmers interviewed began by mentioning drip irrigation. Unlike sprinkler systems and flood water, drip irrigation applies water directly at the roots of the plants, so more of the water is absorbed by the roots and much less is lost to evaporation than with
sprinklers or flood irrigation. As noted in the previous section, other farmers spoke of the benefits of laser leveling floodwater fields so that water covers the entire field evenly and less water can be used to achieve the same results. (Morgan, M., interview, Feb 27, 2014) Beyond these irrigation system techniques, however, the most common water conservation strategy mentioned by farmers was the use of mulch. Mulch, a layer of material on top of the soil, is a direct barrier that serves to conserve soil moisture by preventing evaporation and suppresses weed growth, providing two important services to the farmer. Like many of the techniques that work well in agricultural systems, mulch is a prevalent feature of all biological systems and an important part of the carbon cycle that sustains plant growth in natural ecosystems. In natural systems, mulch decomposes on top of the soil, creating systems of "biological tillage" and acting as a fertilizer for plants underneath. It also conserves soil moisture by reducing evaporation, moderates soil temperature by protecting the soil from direct exposure to the elements and increases water infiltration by slowing down raindrops at the point of impact and preventing soil compaction. When used correctly in agricultural systems, organic mulch has the same properties as those described in natural systems. (P.R. Hobbs, 2008)

Despite these multiple advantages, however, the majority of farmers interviewed do not use organic mulch, and none of them use it on a large scale. Farmers who use mulch in all of their garden beds generally use a black plastic mulch, whereas other farmers who use organic mulch tend to use it only in certain limited situations, particularly with the practice of growing garlic over the winter. The reason, as one farmer explained, is primarily one of economics, Organic mulches are super expensive, not as efficient and a lot more time consuming to spread. I used to live in Vermont and people would sell moldy hay for mulch hay super cheap. Here, we don't have that problem and it’s really pricey. ... To buy it would be economically prohibitive. I would need football fields’ worth to do everything, because you want it to be thick. ... It has to be thick enough to retain the water and suppress the weeds. (Matlick, S., interview, Feb 25, 2014)

This economic rationale held true even for the one farmer interviewed who tended an alfalfa field along with his vegetable operation. Even though he raved about the benefits of alfalfa as a mulch product that could then be dug into the soil to improve soil fertility, he admitted that it was more important for him to sell most of his alfalfa and that he did
not use it on all of his vegetable beds. (Moody, J., interview, Mar 6, 2014) Another farmer disliked organic mulches because she considered them to act as perfect blankets that protect harmful insects and allow them to multiply, especially when used over the winter months. (Heatherington, K., interview, Mar 5, 2014) The final water conservation practice that many farmers use are row covers, a series of hoops and a light fabric that cover rows of vegetables. Farmers use these for many different purposes, including pest control and frost protection, but they also mentioned that a number of cool weather plants better tolerate the heat of the summer under the partial shade of the row cover.

**Evaluating Sustainability:** In many ways, the economic imperative to use plastic over organic materials is unfortunate because while black plastic mulches do prevent evaporation and suppress weeds more effectively than organic mulches, they are a petroleum product made from non-renewable materials. The use of non-renewable materials in and of itself is not necessarily unsustainable if these materials are locally available or abundant and used sparingly. Petroleum made plastics are none of these things for New Mexican farmers, however, and they have the additional environmental cost of generating large amounts of inorganic waste on a regular basis, making them an unsustainable practice. An additional downside of black plastic compared to organic mulches is that they do not contribute to soil fertility nor do they permit water infiltration during rainstorms. In addition to this, the plastic serves to warm the soil temperature, which can be a boon in cooler months, but over the long hot growing season may increase the evapotranspiration required by the growing plants. Despite this, plastic mulches are for many farmers an economically sustainable choice because they are more cheaply available than organic mulch. Even the organic mulches, typically straw, may be environmentally unsustainable if they are brought in from distant places such as the Midwest. As a result, while black plastic mulches contribute in some ways to the economic and environmental sustainability of a farm by saving it money and reducing its water use, they are far from an ideal, sustainable solution to water conservation. The other conservation measures mentioned, such as the use of row covers and drip irrigation represent a similar kind of intervention, a non-renewable material that is used to solve
one environmental problem, but one that requires constant economic input, generates a significant amount of waste and does not otherwise contribute to the integrated organic system of the farm.

**Sustainable Outcomes:** As described at the outset, an effective water conservation strategy in the Rio Grande valley must effectively conserve existing moisture in the soil, deliver moisture in an efficient way, moderate soil temperature, increase water infiltration from rainwater and concentrate rainwater in desired places in order to be environmentally sustainable. In order to be economically sustainable, it must also rely on locally abundant resources that are easy to use on the farm. Of available strategies for conserving water, the use of organic mulch is by far the most effective water conservation strategy because it provides three out of the five named environmental benefits: water infiltration, soil temperature moderation and water conservation. Because it is cost prohibitive to import all of this mulch onto a small farm, however, farmers in the Rio Grande valley should look for other ways to gather the mulch they need. The Puebloan agriculturalists, for instance, used pebbles, a locally abundant material, as a mulch in many of their fields. (Lightfoot, 1993) In the absence of the availability of such a material, however, the most straightforward option may be for farms to grow their mulch themselves. To a certain extent, this mulch can be leaves that are raked and bagged every fall, grass clippings from nearby lawns, and even weeds that farmers pull up by the handful. In order to comprehensively mulch an entire farm, however, farmers may have to invest some of their land in growing mulch or they may have to be willing to purchase some of it from hay farmers.

One innovative way of growing mulch as described by one farmer is called a living mulch system. Under this system, three foot rows of cash crops are interspersed with three foot rows of a living mulch, which is generally a leguminous cover crop such as clover or alfalfa. The cover crop serves to control weeds in between the crop rows and also to attract pollinators. At the same time that its roots fertilize the soil its stalks and leaves can be mowed regularly and applied to the cash crop beds as mulch. This mulch will add nitrogen to the soil as it decomposes and also provide all the other benefits of organic mulch described above. In addition, the living mulch in the aisle will increase water infiltration and encourage the growth of soil microorganisms in an area that for
many farms is a rather inert zone. Most importantly, it will actively out-compete the weeds, instead of the simply suppressing them like dead mulches do. (Morgan, M., interview, Feb 27, 2014) In the absence of the kind of land or water situation needed to implement either a living mulch system or a system of cover cropping for mulch and pasture, however, the remaining option available to a small farmer looking for organic mulch may be to find and harvest free sources of organic mulch. In Albuquerque during the fall, many leaves and other organic wastes ideal for mulch are bagged and placed on the side of the road to be taken to the dump. If these materials were somehow redirected by the solid waste department to farms, it is possible that they could promote the use of more organic mulches and all the benefits they bring.

In addition to the use of organic mulches, farmers in the Rio Grande valley should actively spend more time looking to reduce the evapotranspiration burdens on the vegetables they grow. The simplest way to reduce evapotranspiration in many vegetables is to plant them in partial shade. The agricultural extension agent interviewed stated, in fact, that most market vegetables perform much better with about 30% shade coverage. (Viers, J., interview, Feb 5, 2014) While row covers and shade cloth are one solution to the creation of a 30% shade condition, it is both more sustainable and more organic to create shade with other plants. By planting trees at carefully selected locations on the north and west side of a farm plot, for example, certain crops will receive partial shade during the hottest summer months when the sun is most intense and full sun during the less intense spring and fall months. This reduces the water these crops need and increases plant growth. In addition, the tree's deep roots bring up nutrients from deep in the soil, and the leaves that fall from the tree can be used as part of the organic mulching system on a farm. In situations where tree planting is economically impractical or before the trees have become established, shade can also be produced by rows of tall, upright plants like corn interspersed among the rows of vegetables. An additional strategy is intercropping, or growing two or more crops in the same bed. Throughout the Americas today, corn is often intercropped with beans and squash, because of the way the three crops, also called the "three sisters", assist each other. Corn, a sun-loving plant, grows up first and provides shade for beans and squash. As the corn plants mature, their stalks serve as trellises for the beans and the squash as well. (Alteri, 2004) A similar effect has
also been noted for basil and tomatoes, with tomatoes providing the shade for the basil. (Moody, J., interview, Mar 6, 2014) Whatever the exact strategy used, it is clear that local farmers need to do all they can to increase the amount of shade their crops receive.

The final water conservation measure to be discussed here is the thoughtful re-direction and collection of rain water within each farmer's field. As described in the previous section, all the farmers talked about the importance of rainwater harvesting as a watering strategy, but few actively had systems in place to do so. Earthen berms along the downslope edges of fields are simple strategies to contain run off within the field. In addition, planting crops in basins or furrows also allows water to collect at the base of the plant where the root ball is. These and other locally specific engineering techniques should be used effectively in order to direct and control rainwater, allowing farms to maximize the use of the rain that does fall.

**Soil Fertility**

Under conditions of high rural population densities, as farm sizes become smaller and smaller, one of the greatest concerns for the sustainability of agriculture is the maintenance of soil fertility. The fertility, or condition of the soil is what allows farmers to produce reliable yields year after year, and it is also one of the first things to become stressed as more people are forced to grow more food on less land. This is because, under conditions of land abundance, soil fertility can be renewed by fallowing a field. Left fallow, an agricultural field will grow native vegetation again, and after a period of some years, the vegetation can again be cleared and the soil will be newly fertile. Under conditions of slight land pressure, this process can be managed more directly so that fallowed fields are planted with nitrogen fixing cover crops such as alfalfa or clover. These cover crops are then turned into the soil before they produce seed, when they are most fertile. Under conditions of land scarcity, however, when farmers face economic pressures similar to those currently faced by farmers in the central Rio Grande valley, most farmers do not have access to enough land to allow some if to lie fallow. They need to grow crops on all of their land every year. In many cases, they need to grow two or three crops in a field over the course of the year. This situation requires that farmers find ways to renew soil fertility besides fallowing and cover cropping. This requires the
application of fertilizer to the soil in relatively large quantities relatively frequently. (Netting, 1993) Not all methods of fertilization are created equal, however, and many fertilizers used in modern farming are not sustainable environmentally under any circumstances. In order for a small-holder system of farming to be sustainable, therefore, the small holders must also find a sustainable way to fertilize the land in such a way that allows them to grow intensively without damaging their local environment. This is equally true in the Rio Grande valley, where farmers are intent on squeezing as much production out of their land as possible.

Current Practices: In order to maintain soil fertility, farmers in the Rio Grande valley currently buy a large number of manufactured compost products that are made both locally and in markets far away. These products are generally spread on top of crop beds and tilled in in the spring, where they decompose and provide food for the growing plants. While each farm has slightly different preferences for the exact ingredients of their compost, every farm interviewed buys a form of composted manure and applies it as thickly as economically possible. Typical products that are mixed in with this manure include blood meal and bone meal as well as occasional marine products like fish emulsion or crushed oyster shells. This process of soil fertilization has its roots in the traditional agricultural practices of spreading animal manure on fields in the fall or winter and letting it decompose before turning it under in the spring, but it has become notably more modern and petroleum dependent. The biggest difference is that the animals do not live on the farms whose soil they nourish and the green wastes that are mixed in with their manure do not come from the farm, either. Instead, the manure and green wastes are taken by compost-making companies from various sources in the Albuquerque metro area, composted at a central location and delivered to the farmers after it has been professionally processed. This means that the animals involved in fertilizing the organic farms in the Rio Grande valley are in no way associated with that farm and the farmers have little say or control over how that animal is cared for and what it gets fed. The same could be said to a greater degree for the manufactured products such as blood and bone meal that farmers mix with their compost. The origin and processing of these products is
to a large degree well beyond the time or ability of most farmers to fully investigate or control.

Of the compost making companies in the Rio Grande valley, the one most commonly cited by the farmers interviewed is a company called Soilutions. Located in Albuquerque's south valley, Soilutions collects organic waste products from around the city of Albuquerque and creates compost that is approved for use on certified organic farms, even though Soilutions is not itself certified. The product that Soilutions produces is a fantastic blend of premium compost that no individual farm could hope to match through their own individual compost pile. This is because Soilutions has access to what they claim is "at least one percent of the waste stream generated by the city of Albuquerque," as well as large heavy machinery that allows them to process woody green waste such as trees and shrubs. (Dods, W., interview, Apr 9, 2014) By collecting waste from all around the city, Soilutions is able to also process yard waste, kitchen scraps from restaurants and grocery stores, and horse manure from stables. Because of the large quantities of waste they deal with, Soilutions is able to build exceptionally large compost piles that conserve moisture and to devote large quantities of water exclusively to making compost. They estimate that each cubic yard of compost they produce contains about 30 gallons of water that they pump from their well. They sell this compost product to farms by the cubic yard and explain that organic farmers are among their best, most reliable customers. (Dods, W., interview, Apr 9, 2014)

The other widely mentioned soil fertility practice that most farmers described is the use of cover crops, also known as green manures. Although the specifics for each farmer differ slightly, the use of a cover crop involves planting a crop not meant for consumption on a bed that is not currently in use. When the farmer is ready to plant that bed with a cash crop, he or she proceeds to till that cover crop into the soil. The ideal time to till these crops in is when they begin to flower, before they have sent some of their nutrients into their seeds. (Viers, J., interview, Feb 5, 2014) In the case of leguminous cover crops such as clover, vetch, or alfalfa these cover crops add valuable nitrogen to the soil while grass cover crops such as wheat or sorghum provide carbon in the form of organic material. Many farmers described this practice as one of "feeding the soil". One farmer maintained that that ideal practice for any farm involves fallowing at
least 50% of a farmer's land every year, so that as many crops are being tended to feed the soil as are being grown to feed the farm's living beings. (Morgan, M., interview, Feb 27, 2014) Finally, some farmers mentioned crop rotation and minimal tillage as important aspects of soil fertility. These two techniques will be discussed in subsequent sections.

**Evaluating Sustainability:** Much like traditional Hispanic farmers and the small holders interviewed by Netting (1993), the small farmers interviewed here rely primarily on farm animals, leguminous cover crops and organic waste products to maintain soil fertility. The form in which they use animal wastes, and the process by which it reaches their farms, however, are very different from the relatively sustainable process used in traditional agriculture. The most important difference is that traditional farmers relied on animals that were raised and cared for on the farm to provide fertilizer for their crop fields. These animals were fed by crops grown on the farm, helping to process much of the organic waste a farm generated and converting that waste into manure, which was spread directly on the field to compost. This system limited environmental externalities involving the rearing of animals, externalities that are generated in large quantities today through the conventional production of animal feed and the system of factory farms that has been developed. Correspondingly, modern day vegetable farmers in the Rio Grande valley do not have the space, the time or the money to raise their own animals, so they must go elsewhere for manure. In the Rio Grande valley, this generally means that they go to places like Soilutions.

Soilutions receives waste products produced by the industrial economy and the suburban neighborhoods of the Rio Grande valley as well as manure from local horse stables. (Dods, W., interview, Apr 9, 2014) Most of these waste products that Soilutions receives are generated as a result of unsustainable practices throughout the Rio Grande valley. For example, the horses whose manure is used are likely fed conventionally grown hay or alfalfa, alfalfa which may be genetically modified. In addition, these horses may be given regular doses of antibiotics if they are kept in close quarters and regularly get sick, a practice which may promote the creation of “super bugs”, or antibiotic resistant bacteria. Finally, green waste that is mixed with the manure is
generated by groundwater pumping that is draining Albuquerque’s aquifer or is part of the large quantities of food that are trucked into the valley each day. Perhaps most critically, in order to process and compost all of this waste, large inputs of fossil fuels are required, first to transport the waste to Soilutions, second to operate the diesel powered heavy machinery required to process the waste and third to transport the compost out to a farm. What was a very simple, local, sustainable cycle of soil fertility has become an immensely complex, regional, fossil fuel dependent cycle of soil fertility. This cannot be considered sustainable because it leads farms to rely on a product that can only be made via unsustainable processes. The same is likely true to a greater extent of other compost products that farms buy, since these products may be manufactured far from the Rio Grande valley and likely rely on more fossil fuel usage than Soilutions does.

In contrast to the use of compost products, the use of green manures or cover crops has fewer complications regarding its involvement in the industrial farming system. While no farmer noted that they were saving their own cover crop seed, the problems involved with the production of cover crop seed is not nearly as problematic as the problems involved with the current life cycle of farm animals. Still, if cover crop seed that farmers are using is being produced conventionally on industrial farms, this too may be a step away from sustainability.

**Sustainable Outcomes**: In order to develop a sustainable system of soil fertility, farmers in the Rio Grande valley will need to develop a system that does not rely on fossil fuel energy for transportation and that uses sustainably made products. Finally, the process of making the compost cannot be so labor intensive as to prevent the farmer from being able to tend to his or her other duties. This means that farmers will need on-site or very local access to large quantities of sustainably produced manure and green waste. Because none of the farmers interviewed were involved with making their own compost, none of them suggested specific solutions to this. With regards to the generation of local green waste, the most effective solution from the literature involves the system of conservation agriculture, where crop residues serve as the green waste that can be mixed with animal manure. (e.g. Hobbs, et. Al., 2008) Farmers have to deal with crop residues anyway as part of the normal cycle of business, so they would not have to invest
significant time and energy searching for additional sources of green waste. Finally, a living mulch system in between the rows would also produce a good amount of green waste that farmers would regularly deal with anyway, and so would not require additional labor. An example of a farm that successfully implemented soil fertility measures using primarily crop residues can be found in Fukuoka (1978). Meanwhile, one farm in Montana eventually ceased to add compost to their soil at all after years of successfully using a living mulch system. (Atthowe, 2014)

In addition to the sustainable, local production of green wastes, a sustainable soil fertility system must also have access to sufficient quantities of sustainable animal manure. In order to do this, a small farmer in the Rio Grande valley could own and manage animals that provide manure for their crop land or they would need to arrange to access manure from a neighboring farm. Given the quantities of manure required for sustainable fertilization, this may require farmers in the valley to sell vegetables and meat or dairy products or to work together with another farm that sells the product that they do not. With regards to how animals can be raised sustainably, one attempt is being made to do so by DeSmet Dairy in Bosque Farms, New Mexico. This dairy owns about 20 cows which graze on 33 acres of irrigated pasture and are not given antibiotics as part of their diet. This makes them the only grass fed dairy in New Mexico and the only dairy that does not enclose its cows 24 hours a day. (DeSmet, M., interview, Feb 25, 2014) By allowing their cows to live outside, the DeSmets have found that their animals are much healthier and that their fields are healthier as well, thanks to the regular input of manure they get. In USDA inspections of the milk sold by the dairy, for example, they routinely get bacteria counts so small that the inspectors cannot even accurately count them. They are so convinced about the cleanliness of their milk, in fact, that they sell it raw, without pasteurization. (IBID) Under a sustainable regime of soil fertility, a dairy farm like the DeSmet Dairy could work together with a vegetable farmer, exchanging waste products. In this scenario, vegetable farmers could get access to animals and animal products without having to spend time and money investing in equipment and developing a market for animal production. It would also avoid the delicate situation described by Netting (1993), who claims that many small-holder fertilization regimes require farm animals to confined during the growing season so that they do not wreck the crops. If a dairy or
meat farmer worked with a vegetable farmer, then the vegetable farm could serve as a winter pasture for the animals, avoiding this confinement necessity.

**Tillage and Erosion**

According to Hillel, tillage has been practiced by agricultural societies since at least 3000 BCE for a number of reasons. (cited in Hobbs, et. al. 2008) For a number of critical reasons, however, it is a practice that has recently been questioned more and more in all circles of agriculture. From giant industrial farms in the Midwest to small-holder farms in Latin America, no-till agriculture is a growing movement that looks to achieve the same results that tilling does without the detrimental environmental cause by bare ground and loose soil. This section discusses the attitudes of farmers in the Rio Grande valley regarding tillage.

**Current Practices:** Most farmers interviewed regularly till their soil in the spring before planting. For some, this is the only time they till, while others till before each successive planting. This means they will till some beds in the summer for fall planting and hoop house beds in the fall. Most farmers use rototillers to till, either attached to tractors or used separately. One farmer described a tool he used called a shank that loosens the soil without flipping it, supposedly protecting the microorganisms often destroyed by tillage. (West, J., interview, Mar 3, 2014) Some farmers use tractors to till, although a surprising number do not own a tractor and do not use a tractor for tillage. In general, most farmers claimed that tractors are too large of an investment for the small farms they operate. (e.g. Chriss, E., interview, Mar 2, 2014) As such, some rent tractors, while others simply use smaller tools.

Most of the farmers interviewed are aware of the expanding literature regarding no-till or conservation agriculture, and many articulated ways in which they have modified their techniques to reduce tillage. Some have developed permanent beds in order to till only small strips of land rather than the whole field. (Sanchez, M., interview, Feb 20, 2014) Others have made efforts to limit the depth to which they tilled. (Wegrzyn, D., interview, Feb 19, 2014) Still, most farmers believe that vegetable crops require annual tillage in order to produce as they are expected to. (e.g. Sanchez, J.,
interview, Feb 20, 2014) Much of the rationale for this involves the machinery that farmers use to plant. One farmer noted that anything designed for no-till is prohibitively expensive and many farmers explained that the seeders they use are designed for smooth beds with loose soil. (DeSmet, M., interview, Feb 25, 2014) A couple of farmers noted that no-till with vegetables is possible on a smaller scale as long as the work is being done mostly by hand. (Chrisp, E., interview, Mar 2, 2014; Morgan, M., interview, Feb 27, 2014) For one of these farmers, no-till is a technique best used for planting grains, something he had personally practiced. (IBID) Despite this widespread acknowledgement of no-till, however, few farmers have personally attempted it, with the exception of Minor Morgan from Rio Grande Community Farm and Mike DeSmet from DeSmet dairy. Both of these farmers are actively experimenting with modifying existing equipment to allow them to use no-till effectively on their farms. Erik Chrisp from Abundia farms has also experimented with no-till vegetables in the large garden he tended before he moved to the farm.

None of the farmers interviewed expressed concerns with erosion in their own fields, many of them citing the flatness of the land or the laser leveling that had been done to explain that most water and soil were not running off. Still, in principle, many farmers noted that spring in the Rio Grande valley is a very windy season, and that this coincides with the time when most farmers plow their fields. As a result, a number of them anecdotally described the days when they would "watch the topsoil fly by". (e.g. West, J., interview, Mar 3, 2014) One farmer described this piece of evidence "The only evidence that scares me is this old tree stump and you can tell where the ground level used to be because the roots go out. It's like two feet up. And that's in a field that doesn't have anything growing on it." (IBID) There is reason to believe, therefore, that erosion may be a long term issue in the Rio Grande valley, but farmers are not aware of any data to support or refute this claim. Regardless, most farmers believe that tilling is a necessary evil given the dense clay soils most of them farm in and the difficulty of composting organic mulch in the valley's dry air.

Evaluating Sustainability: Hobbs, et. al. (2008) list seven reasons why tillage has been determined to be critical to successful, sustainable agriculture. The most
important of these are the reduction of soil compaction, the incorporation of organic matter and nutrients into the root zone, a reduction in weed germination and control of soil-borne diseases. While providing these short-term benefits to the farmer, however, tillage also comes at a cost to the environment, particularly when practiced on the large scale characteristic of modern agriculture. The costs associated with this practice are all correlated with negative environmental consequences that result from the bare ground and loose soil characteristic of newly plowed agricultural fields. Most critically, loose bare soil is easily carried off by wind and rain, resulting in high rates of erosion on plowed agricultural fields. Montgomery (2007) estimates that the loss of top soil to erosion worldwide is occurring at a rate 10 to 100 times faster than the natural production of soil. Given this, he estimates a 500 to 2000 year life span for the typical agricultural zone before the top soil has disappeared and the land becomes unproductive. In reality, there may be even less time, as Montgomery's calculations assume that soil formation under agriculture is continuing at the same rates seen in natural systems.

In addition to concerns about erosion, plowing and bare ground also reduce soil health, both physically and biologically, by reducing water infiltration, causing soil organic matter to oxidize and destroying soil structure through frequent disruption. (Hobbs, et. al. 2008) Joran Viers (Interview, Feb 5, 2014) described the soil as being home to microorganisms that each occupy very specific depths and provide a food web for the soil. Tillage destroys this structure by churning the soil and moving microorganisms to depths where they do not belong. In addition, the oxidization and aeration caused by tillage actually kill a good number of these organisms.

In addition to these environmental concerns, tillage represents a major economic investment of both time and energy in agricultural operations, making it an expensive proposition and one of the major agricultural contributors to global climate change. These effects are of even greater concern given that chemical fertilizers are allowing farmers to plant year after year in the same fields without the fallow periods common in many traditional agricultural systems. This means that every year a greater and greater percentage of land is laid bare during planting season, resulting every year in greater environmental impact. (e.g. Pollan, 2006) Additionally, in many cases, tillage does not always provide the supposed benefits of reducing soil compaction and weed competition.
In cases where biological pores in the soil are destroyed by tillage, greater rather than lesser compaction can result. Tillage also brings many weed seeds to the surface, allowing for a greater percentage of weed seeds to germinate even if the absence of established weeds provides young crops with a temporary advantage. (Hobbs, et. al., 2008) Over the long run, this process also encourages the production of fast-growing, invasive annual weeds at the expense of deeper-rooted, slower-growing perennials because the annuals are able to produce seed quickly and thereby survive frequent episodes of tillage. Over periods of many years in consistently tilled soil, therefore, annual weeds evolve to grow faster and to become even more invasive. In some cases, this has allowed them to overrun and suffocate crop land. (e.g. Neill and Lee, 2001)

As farmers worldwide become aware of the problems posed by deep, repetitive tillage, they have become drawn to alternative techniques. The most promising no-till technique is called conservation agriculture. Conservation agriculture is defined by the Food and Agriculture Organization in this way

Conservation Agriculture maintains a permanent or semi-permanent organic soil cover. This can be a growing crop or dead mulch. The function is to protect the soil physically from sun, wind, and rain and to feed soil biota. The soil micro-organisms and soil fauna take over the tillage function and soil nutrient balancing. Mechanical tillage disturbs this process. Therefore, zero or minimum tillage and direct seeding are important elements of Conservation Agriculture. A varied crop rotation is also important to avoid disease and pest problems. (P.R. Hobbs, et. al. 2008)

Conservation agriculture and other agricultural systems of minimal or no tillage mimic natural processes of tillage and fertilization by maintaining a permanent or near-permanent layer of mulch on top of permanent crop beds. At the appropriate moment, new seeds are planted into this layer of mulch manually or via seed drills. As already discussed, organic mulch has many beneficial effects regarding water conservation, and in this system it also serves to induce biological tillage, allowing for the maintenance of healthy soil conditions even in fields that are being harvested on a yearly basis. Additional benefits of conservation agriculture include a reduction in the use of diesel or other fossil fuels, lowering production and labor costs. Soil compaction and weeds, on the other hand, can be more of a problem than under traditional tillage, but manageable ones. (P.R. Hobbs, et. al., 2008)
There are, therefore, a number of promising aspects of no-till agriculture that may make it more environmentally and economically sustainable for farmers. Despite this, however, it is difficult to declare the tillage practices used in the Rio Grande valley unsustainable without more information regarding the performance of the valley's soils and crops under such a regime. As long as certain conditions are in place such that the rate of soil formation equals or exceeds the rate of soil erosion, tillage may be perfectly sustainable in this respect. On the other hand, tillage based on fossil fuel energy sources is not sustainable, and the evidence indicates that even if fields are tilled with renewable energy sources, it may not always be the optimal situation for growing crops because of the destruction it does to the microorganisms. A more compelling reason for farmers to consider moving to a no-till system, therefore, lies in the economics of no-tillage. The energy required to till a field is expensive, as it consumes large amounts of fuel, requires farmers to spend time laboring and because it requires farmers to invest in expensive equipment. If farmers can modify their seeding equipment for a no-till system, no-till reduces greatly both the labor costs and the fuel costs involved with spring planting. The DeSmet dairy, for example, reduced fuel costs by 60% after switching to a no-till system and they have actually experienced increased pasture growth in doing so. (DeSmet, M., interview, Feb 25, 2014) Thus, for both economic and environmental reasons, no-till is a promising alternative for farmers pursuing sustainability.

A major obstacle to the implementation of no-till practices, however, is the instinctive resistance that many long-time farmers have to practices that appear to fly in the face of thousands of years of tradition. As Mike DeSmet explains,

You gotta get past that old school way of thinking. There's my dad's way of how things are supposed to be and then there's my version. The more I learn about soil health and water conservation and all these different things, I start changing the way I'm doing things. My dad will be like, 'You're crazy, nothing's going to grow in the ground if you don't go till it. You gotta rip, disc, level, do all this stuff. It's that old mindset they've had in the last 50 years. (IBID)

Another farmer, explaining why some farmers don't believe in no-till, used similar language.

A lotta people are against no-till. ... For us, we notice the difference in plants when you go and till. When you disrupt the soil, all it does it aerate it and help it.
We used to live in Tajique and a lot of the ladies we rented from were against it. ... I just don't think it's a good idea. (Sanchez, J., interview, Feb 20, 2014)

This demonstrates that farmers who use no-till must be willing to take a risk despite being told not to do so by many experienced growers. Whatever the science says, many farmers simply will not believe that no-till will work until they see it. Still, the prevalence of no-till in the conversations recorded here is a sign of attitudes beginning to change. One farmer suggested that no-till was already becoming more acceptable in other farming circles across the country, meaning that it should eventually permeate to New Mexico as well.

I haven't seen any bad reports on no-till agriculture. I haven't seen anything that says this really isn't working for me, I'm gonna get my tractor out there and break the soil again. I'm watching You Tube videos of Iowa and Illinois farmers, these rednecks who are definitely not doing this because they're hippies, who are convinced that this is the way to go. It seems to be catching on like wildfire in the Midwest. (Chrisp, E., interview, Mar 2, 2014)

Thus, the sustainability of tillage practices in the Rio Grande valley is definitely one that requires future investigation. While there is no hard evidence to indicate that tillage is unsustainable, there is also limited evidence regarding the benefits of no-till in the high desert environment and clay soils. If cultural attitudes towards no-till continue to shift, it is possible that this experiential data may become common knowledge before too long.

**Sustainable Outcomes:** As mentioned above, the desired outcomes for any sustainable farm regarding its tillage practices are to till in a way that soil formation is equal to soil erosion and to till in a way that preserves the structural integrity of the soil, particularly the micro-organisms that live in it. While the most secure way to ensure this situation is to convert to a no-till system, there are likely other ways in which these outcomes can be obtained using limited, targeted tillage. Tilling in strips or only in permanent beds is one way to limit tillage, as is tilling at shallow depths in order to only prepare a seed bed. Another method that a number of farmers discussed that would allow them to still plant in loose, smooth soil is to top dress beds with compost and plant directly in the compost rather than tilling it in. (Acosta, R., interview, Feb 23, 2014)

Finally, most farmers agreed that no-till in New Mexico is something that can be
practiced only after the soil has improved to the point where the clay has been broken up and the soil is in good condition. As such, no-till agriculture is still very much a new concept among New Mexican farmers, but the potential economic benefits along with the possibility for improving soil health could lead to a change in attitudes in the years to come. This shift would encourage the innovation that farmers said was necessary to develop affordable and effective no-till seeding equipment and to develop organic methods for killing cover crops. A switch to no-till would also allow for farmers in the valley to begin to develop strategies similar to conservation agriculture, using organic materials created on the farm as organic mulches and moving away from industrial compost. If such a system could be successfully established in the climate of the Rio Grande, it would solve many of the greatest problems faced by agriculturalists in the region.

**Crop Management**

Another important facet of sustainable agriculture involves crop choice and location. Modern industrial agriculture relies increasingly on the practice of monocropping, which typically consists of large chunks of land being dedicated only to one crop. This lack of biodiversity is risky on a number of levels and unlikely to be sustainable for at least two reasons. First and foremost, single crop varieties tend to rely on certain nutrients and minerals in the soil while not using others. This process requires farmers to replace nutrients critical to their chosen plant yearly while not taking advantage of other nutrients that are naturally available. The most efficient way to do this is with chemical fertilizers whose negative environmental effects have already been discussed. In addition, large stands of single crops are more vulnerable to diseases and pests, especially as the practice is repeated over the years. Combatting these diseases and pests requires large applications of pesticides and other toxic chemicals that have negative effects on the agro-ecosystem as a whole. (Pollan, 2006)

In contrast to monocropping, there are four sustainable crop management practices that help to create an agricultural landscape that takes advantage of all available soil nutrients and is naturally resistant to large outbreaks of pests or diseases. These are crop rotation, inter-cropping, agro-biodiversity and multiple cropping. Crop rotation,
commonly practiced around the world, is the practice of planting different crops in the same place year after year. Although the specifics of crop rotation differ from farm to farm, the general principle is to rotate crops that return nutrients to the soil with crops that feed on these same nutrients. Additional rotations may also include crops that take advantage of different nutrients. Informal agricultural parlance tends to group crops into three categories with respect to their nutrient diet: heavy feeders, light feeders and heavy givers. A typical crop rotation may involve a heavy feeder, followed by a light feeder, followed by a heavy giver, followed by a year or two of fallowing the land or using green manures.

Intercropping is the practice by which two or more crops are planted together in the same area. The most well-known example of intercropping is the three sisters of the Americas - corn, beans and squash - which were traditionally planted together by Native American farmers. Intercropped cultivars generally provide each other with nutrients or produce conditions that allow the other to thrive. For example, in the three sisters patch, the corn provides shade that help both the beans and the squash and it also acts as a trellis that the bean can climb. In addition, the bean plant is a legume, so it fixes the nitrogen in the soil that the corn feeds on, while the squash has a tendency to sprawl along the ground and suppress weeds that can compete with both. In addition to nutrient balancing and trellising, other intercropping situations take advantage of different maturation rates of various crops and of the different shapes of various crops and their root systems.

Agro-biodiversity refers to the diversity of crops that a farmer grows on his or her land at a given time. In natural systems, bio-diversity is key to producing the greatest amount of organic growth per acre of land, in maintaining soil fertility and in controlling pests and diseases. This includes the use of deep rooted perennial crops that feed on different soils than the annual crops and bring nutrients from deep in the ground to the surface. As such, the most ecologically stable form of agriculture is one that grows a large variety of crops, including perennials, in order to achieve these same three benefits. (Thrupp, 2000)

Multiple cropping is the practice of using the same field or the same row to grow a number of different crops in a given year. In a sense, it is similar to crop rotation, except it is a crop rotation that takes place within the same growing season. In contrast to
single-cropping, which leaves the field inert and the earth barren for a significant portion of the year, multiple cropping keeps something growing in the field all year round while at the same time allowing the farmer to grow more food.

**Current Practices:** Farmers in the Rio Grande valley find themselves in a similar economic position to the smallholders described by Netting (1993). In order to make farming economically worthwhile, they need to squeeze as much production out of their land as is physically possible without mining their soil's nutrients and causing production declines. As such, because all of them are pursuing organic methods for production, they use all of the crop management techniques described above. In the Rio Grande valley, multiple cropping is most common with cool weather crops such as greens and root crops, which are planted in the spring and fall. Warm season crops such as tomatoes, corn, squash, peppers and eggplants are only planted once. Finally, many use cover crops over the winter for summer crops and some use summer cover crops in places where spring crops were grown. Year-round cropping in the central Rio Grande valley is made possible by hoop houses, which are simple plastic structures held up by hoops about twelve feet high that allow cool season crops to be planted over the winter. Of the farmers interviewed, five have a hoop house which they use for production. The remainder grow crops from March to November.

In addition to multiple cropping, all of the farmers interviewed practice some form of crop rotation. Because of the large suite of crops most farmers grow, few have a strictly organized crop rotation system. Instead, all of them follow the same general rule: don't plant something in the same place twice. In addition to this, many farmers rotate their crops by group. Tomatoes, peppers, eggplants and potatoes, for example, are all part of the same family and as such often a planted in one place one year and moved as a block the next year. Other crops that can move as a block include the famous three sisters, root crops, and leafy greens. (e.g. Matlick, S., interview, Feb 25, 2014; West, J., interview, Mar 3, 2014)

In addition to these systems of rotation, most farmers practice limited systems of intercropping or companion planting. Basil and tomatoes are often, but not always, planted together as are corn, beans and squash. One farmer described a system of
intercropping with beneficial plants that he uses to ward off pests. This farmer planted marigolds in every row, spaced every 5 - 10 feet, and used a number of other flowers that act as potent deterrents for typical local pests. (Chrisp, E., interview, Mar 2, 2014)

Finally, as evidenced by the large variety of crops each farmer planted, all the farms interviewed have high counts of agro-biodiversity. The one exception to this rule is a farmer who primarily grows green chile as a cash crop, but even his farm has three to four different cover crops, greens grown in a greenhouse and a small vegetable garden. (Armijo, K., interview, Feb 26, 2014)

Evaluating Sustainability: All of the techniques described here and used by small farmers in the central Rio Grande valley are very successful and sustainable ones. They plant a wide variety of crops, preventing the build-up of soil borne diseases or insect pests and making use of all the different nutrients available in the soil. In addition to this, they practice intercropping and multiple cropping, allowing them to make a living economically and to produce more food on less land. Finally, they are conscious about moving their crops around in the fields because of the dangers involved with planting the same crop in the same place year after year. All of these practices are, for the most part, sustainable. The one caveat here is that the intensive planting exemplified by intercropping and multiple crop rotations in one year requires a very high nutrient load in the soil, so it is reliant on an intensive fertilization regimes. This is why one farmer postulated that most of the small vegetable farmers were in fact taking more nutrients out of their soil than they were putting in. (West, J., interview, Mar 3, 2014) Intensive fertilization and planting is possible for farmers because of the wide array of fertilizer products that they can currently buy. Therefore, multiple cropping is ultimately not sustainable unless farmers can successfully replicate current soil fertility regimes under conditions of more scarcity.

Sustainable Outcomes: Sustainable crop management practices, which likely include all four of the strategies discussed here, need to meet a number of thresholds. First of all, the farmer must be able to grow enough food to make a living. In order to do so, it is important that the farmer not be practicing poor strategies of crop management
that negatively affect yields year after year. This generally calls for crop rotation or intercropping that uses nitrogen fixing legumes along with other plants that provide essential nutrients. In addition, farmers must not be facilitating the build-up of soil borne diseases or insect pests via their crop management practices. Lastly, the agro-biodiversity of the farm must be great enough so that the farm is resilient and can survive economically and environmentally if one crop or another is lost. For the most part, the farmers interviewed all pursue practices that meet or exceed these three thresholds. The only common concern expressed is the desire of a number of farmers to fallow and/or cover crop more of their land, something they feel they are prevented from doing so because of the need to grow enough food to make a decent living. (e.g. Matlick, S., interview, Feb 25, 2014) This will always be an issue for farmers with farms the size of those in the Rio Grande valley and is a reason why these farmers must keep a close watch on soil fertility.

**Weed control**

Weed control is one of the most essential aspects of any agricultural process. All agriculturalists actively attempt to provide excellent growing conditions for their chosen plants and to cultivate those plants at the expense of plants they don't find useful. It is generally claimed that every weed that grows represents a loss of nutrients that would otherwise have gone to the selected crop. (e.g. Peachy, et. al. 2004) As such, weed control is an integral part of any agricultural system, and one that farmers in the Rio Grande valley continue to wrestle with.

**Current Practices:** Similar to monocropping, the use of herbicides is one of the practices that small-scale farmers in the Rio Grande valley will not even consider. On the contrary, most of them are very open about advertising that they do not use them in order to distinguish their operations from industrial agriculture. Many of the farmers even go so far as to point out that organic certification still allows for the use of certain, approved herbicides, which practices on the farms interviewed "beyond organic." As one farmer explains,

"Within the realm of organic certification, you can still get away with spraying. If we spray, it will just be something like soapy water. They (organic farmers) can..."
still use pyrethrum, which is pretty strong stuff. I guess it’s biodegradable, which is why its organic, but that stuff can hurt you. (West, J., interview, Mar 3, 2014)

Instead of using chemicals, therefore, almost all farmers interviewed control weeds by traditional means. For most farmers, this involves a combination of mulch, tilling, hoeing and hand weeding. The mulch around the base of the plants is used to suppress the weeds. Weeds in the walkways between plants are often tilled or hoed in, and for more sensitive or delicate situations, weeds are controlled by hand pulling. A number of farms hire helpers specifically for the task of hand-weeding during the most difficult times of year. (Acosta, R., interview, Feb 23, 2014; Apodaca, T., interview, Feb 20, 2014) Some farmers specifically do not till under their weeds because they are concerned about the negative effects of tillage. Instead, these farmers may control weeds through mowing, cutting the weed off at the ground level. (Morgan, M., interview, Feb 27, 2014; Chrisp, E., interview, Mar 2, 2014)

**Evaluating Sustainability:** There is good reason to believe that most farmers interviewed are correct in believing that herbicides, even organic ones, are not sustainable. While herbicides on large-scale farms generally represent a tremendous savings in labor that allows these farms to save money, the use of herbicides comes at a great cost to the environment. Although all plants that are not the desired crop do represent potential competition for resources, many plants that are considered weeds also serve important purposes in the local ecosystem, providing food and pollen for insects and animals. In addition, the diversity of plant life represented by weeds naturally maintains soil fertility with no inputs required, hence the traditional practice of fallowing agricultural fields. Therefore, a system in which all weeds are killed and eliminated also limits the potential for the maintenance of soil fertility, and repels or kills beneficial insects and pollinators. To make matters worse, this technology has recently spawned the creation of genetically modified crops that resist the application of certain herbicides. This allows these chemicals to be applied during the growing season as well, rendering such fields biologically inert except for the selected crop. But one example of the millions of beneficial species that are being affected by this process is the collapse of the formerly abundant population of monarch butterflies that feed exclusively on milkweed.
flowers, a common weed in the Midwestern U.S. Finally, the extensive use of herbicides also contributes to the pollution of ground and surface water associated with industrial agriculture. (Pollan, 2006)

By avoiding the use of herbicides, farmers in the Rio Grande valley avoid participating in practice that is very unsustainable environmentally. There are a number of additional complications, however, that must be resolved in order for a farm to weed sustainability. In most traditional agricultural systems, weeds were controlled by tilling the soil, which helped to bury weed seeds and to eliminate established perennial weeds, thereby giving the selected crops a head start over the weeds that inevitably came up. For the rest of the growing season, as weeds emerged, they were then pulled by hand from the soil or tilled in. This continued more or less until the selected crop was well established and provided a canopy of shade, out-competing most remaining weeds and preventing further germination. This process, while effective, has two possible environmental effects that can become unsustainable over the long-run. The first of these potential side-effects is the excessive use of tillage, something that, as was discussed in previous sections, is shown to damage soil chemistry and to kill the microorganisms that create life. The second involves the creation of an agro-ecosystem in which only the farmer's crops and the fastest, most invasive weeds are allowed to reproduce. In short, while the humans tending crop fields try their best to pull or till all the weeds competing with their crops, it is likely that through human error or given the many tasks that divide a farmer's time, some weed, somewhere will reproduce. In a system in which the farmer tills every year and tries as best he or she can to eliminate all weeds via that come up afterwards, the weeds that will escape the farmers attention are the ones that go to seed the fastest or that are best able to invade via rhizomes from the edges of the field. Over time, this means that the farmer can create "superweeds" in his or her field, weeds that go to seed faster and invade more rapidly than the farmer can keep up. This combined with tillage, which produces conditions specifically built for fast-growing, invasive plants, can eventually tip the balance in a farmer's field away from the crops he or she wants to grow towards the "superweed." In extreme cases, this can lead to some rather absurd situations. (e.g. Neill and Lee, 2001) One particularly invasive weed in the Rio Grande valley is bindweed, a collection of plants in the morning glory family (*Convolvulus*) or false morning glory
(Calystegia) that can climb large crops and pull them down. This plant can have roots up to six feet deep, making it impossible to eliminate, even in the driest, hottest conditions. As such, one farmer told the story of another farmer who got rid of bind weed by bringing in a back hoe, digging six feet deep, and inverting the soil of his field, pulling up soil from six feet underground. (Morgan, M., interview, Feb 27, 2014)

In addition to the danger involved in creating "superweeds", traditional weeding practices are also labor intensive, something that is not economically favorable for farmers in the Rio Grande valley. One farm reported spending over 90,000 dollars on paying laborers during the 2013 season, most of them responsible for weeding. (Apodaca, T., interview, Feb 20, 2014) A number of other farms hire people primarily to act as weed pullers during peak times of year and some farmers interviewed insinuated that this is the primary responsibility of the low-paid interns hired by some farms. This situation leads to a number of difficult, complicated situations.

For most farmers, labor is generally accepted to be their largest yearly expense and is also unreliable. From the point of the laborers, however, the work offered by the farms is temporary, seasonal, pays at best a minimum wage, and offers no benefits. In addition, it is hard physical labor performed outdoors in all weather conditions. As a result, all farmers interviewed reported a high turn-over among their laborers and explained that they were required to train their laborers every year in plant identification and other basic practices. This situation, therefore, suits neither the farmer nor the laborer, and pay ultimately requires a different solution in order for farms to be economically sustainable.

**Sustainable Outcomes:** A sustainable weed control process will not produce "superweeds" but will instead encourage the production of beneficial weeds and slow-growing weeds that are easily controlled. Thus, weeds will be re-envisioned. Instead of seeing weeds as the enemies of their chosen crops, farmers will see weeds as potential allies if properly controlled. In addition, a sustainable weeding process will not produce environmental side effects such as those produced by excessive tillage or herbicides. Finally, this process will suppress weed growth as much as possible in order to reduce the tedious work of hand-pulling and other labor-intensive control mechanisms. The most
common weed suppression system discussed by farmers in this report involves the use of mulch to prevent weeds, although other methods may serve as well. Because of these weed suppression measures, farms will no longer need to hire seasonal laborers for back-breaking, low-paying jobs but will instead be able to manage weeds with labor provided by the farm staff.

Although there may be a number of weeding systems that fit these criteria, one way in which many of these conditions can be met in an integrated way involves the implementation of a system of conservation agriculture. As described earlier, conservation agriculture involves the use of no-till practices, which includes a layer of organic mulch that serves many beneficial purposes, including weed suppression. The key difference with regards to weeds in a conservation agriculture system is that it encourages slow-growing perennial weeds instead of fast-growing annuals. In general, perennial weeds require less labor cost to control, will help to maintain soil fertility by bringing up nutrients from deep within the soil and, most importantly, can serve to outcompete the most invasive and dangerous weeds. In conservation agriculture, instead of tilling weeds in, most weeds are simply mowed to the ground, and the plant litter then serves as mulch on the growing crops. (Hobbs, et. al. 2008) In some cases, this has been successfully integrated with a living mulch system akin to the one described earlier in the section on Water Conservation Measures. One farm that used this kind of weed control system in Montana, in fact, had so little weeding work, that 6 acres of vegetable production, including all the weeding work, were successfully managed by two women, one of whom worked full time off the farm. (Atthowe, 2014) Thus, a reduced-till living mulch system is one that may be able to reduce the labor involved in weeding to the point where a small-scale farmer in the Rio Grande valley may be able to achieve the same environmental results without having to pay such a high price economically.

**Pest and Disease Control**

Pest and disease control refers to any actions taken by a farmer to combat a disease, insect or animal that is eating or destroying the crops he or she has planted. This encompasses a wide array of situations and practices that are understood and dealt with in
different ways. Naturally, within this category there is a wide array of practices that are clearly sustainable, clearly unsustainable and everything in between.

**Current practices:** Most of the farmers interviewed do not have significant problems with pests, likely because of the diverse cropping strategies they use. Still, there are a number of crops and specific pests and diseases that almost every farmer mentioned. The most widely mentioned problem is a disease known as curly-top virus that is passed by an insect called the beet leafhopper and that affects many crops, primarily tomatoes. There is little that can be done regarding the prevention of this disease, so most farmers simply plant more tomatoes than they expect to need. The most common pest mentioned were squash bugs, an insect that feeds on squash and carries diseases that the plant and all of its relatives: zucchini, cucumbers, melons and watermelons. The other pest that came up most often in the discussions were aphids, a cool weather pest that feeds on crops colloquially known as the brassicas - broccoli, kale, cabbage, turnips, etc. While all of the farmers described experiences that they had had with these and other pests or diseases decimating part of their crops, most of the farmers viewed these losses as something they have to accept as chemical-free farmers. Many of them, in fact, plan for such losses, particularly regarding cash crops like tomatoes. (e.g. Wegrzyn, D., interview, Feb 19, 2014) In addition to this attitude, however, most farms described certain substances that they apply to their crops to control pests when the situation appears to be getting out of hand. In general, these substances are relatively common household items like liquid soap or vinegar, but some farmers apply more potent organically approved substances such as neem oil or pyrethrum. These applications are always targeted to specific areas and infested regions of the farm, and are never done in broadcast, as with industrial farms. Additional strategies for pest control mentioned by individual farmers include purchasing sticky tape that acts as an insect trap and the selective application of row covers, a practice that prevents most insects from landing on the crops. (e.g. West, J., interview, Mar 3, 2014) Squash bugs were the only pest most farmers treated by hand, usually by picking them off and drowning them or feeding them to chickens. With regards to diseases, according to the farmers, the most common reaction to finding a diseased plant in the field is to pull it, as often there is not another
reasonable alternative. (e.g. Armijo, K., interview, Feb 26, 2014) The farmer who had the most problem with diseases was also the farmer who practices the least diverse cropping strategy.

**Evaluating Sustainability:** The farmers interviewed here practice a relatively sustainable form of pest control. Because of the diverse suite of crops most farmers grow, pests do not build up the same way that they do on large, monocropped fields. Instead, the pests that farmers in the Rio Grande valley deal with tend to be concentrated on certain plants, making the situation easier to manage. Some of the pest strategies, including the hand picking of squash bugs, are labor intensive, and as such may contribute to the difficult labor situation discussed in the previous section. The use of organic chemicals such as neem oil and pyrethrum are less sustainable practices, since these chemicals are manufactured using fossil fuel energy and because they are costly and destructive to other beneficial insects as well as the pests they target. In addition, because some farmers pride themselves on using no chemicals at all, this is one place where a few farmers may end up sulllying the reputation of the “local” brand. Still, the limited way in which these chemicals were used suggests, but does not verify, that this spraying does not affect the agro-ecosystem of these farms in a significant way. Another practice that may or may not be sustainable is the introduction of beneficial insects such as lady bugs and praying mantis. While such insects may be able to establish themselves and sustainably breed on a farm, there is a concern because these insects are generally purchased via mail from companies located in California. This practice introduces insect genes that evolved in much more temperate regions of the country into the gene pool of insects in the Rio Grande valley, something that could compromise the resiliency of these insect populations over the long term. This practice would also not be sustainable in the case that farmers decide to buy insects in the mail each year, a practice that is also not sustainable because of the fossil fuels involved in transportation.

**Sustainable Outcomes:** According to Alteri (2004), many traditional farmers do not consider insects to be pests because it is only with the modernization of agriculture that the populations of herbivorous insects that feed on crops have risen to a level worthy
of the name. Instead, traditional agriculture created agro-ecosystems that controlled insect pests via mechanisms similar to those present in natural ecosystem. Given this evidence, it seems that the best solutions involving pest and disease control, much like weed control, involve good systems for prevention. A sustainable pest strategy for a farm in the Rio Grande valley should primarily revolve around the creation of an agro-ecosystem that controls insect pests and diseases with little effort on the part of the farmer. The second condition that farmers should look to meet is the maintenance of good healthy soil in order to encourage robust, healthy plants with strong natural insect resistance. This mimics the sustainable way in which pests and diseases were dealt with by pre-industrial agricultural systems.

Among the mechanisms that traditional agricultural systems used to prevent pests are intercropping and agro-biodiversity, two things that are also beneficial to farmers as crop management tools. In addition to this, many traditional farming systems use certain plants or crop varieties as diversions. These so-called "trap crops" attract pests away from vulnerable crops and keep them occupied with more resilient, less valuable ones. Another system of natural insect control is called "push-pull" and involves the planting of diversionary plants away from sensitive crops and the planting of repellant plants around sensitive ones. (Alteri, 2004) Finally, farms or fields located near to forests or other natural ecosystems tend to be high in natural predators that help to control pests without any additional intervention from the farmer. While no one farmer can successfully manage the land surrounding their farm to mimic this situation, this could be one of the issues around which farmers could rally as a group in order to call for the protection of the local eco-system.

In addition to these practices, a few farmers mentioned other additional strategies that could be implemented more broadly. A few farmers talked about the importance of raising chickens and letting them loose in the garden during winter to eat overwintering bugs. (Heatherington, K., interview, Mar 5, 2014; Miller, R., interview, Mar 5, 2014) One farmer mentioned that he was planting a pollinator garden. This practice involves maintaining perennials on and around the farm land, particularly flowering ones, that attract pollinators as well as many beneficial insects. (Armijo, K., interview, Feb 26, 2014) With regards to diseases, as most farmers noted, there are some diseases in the
local environment that are impossible to control, so the best plan is to plant extra and plan for some disease die-off. With regard to curly-top virus, the agricultural expert mentioned the technique of planting tomato plants in partial shade, a habitat that leafhoppers tend to avoid. (Viers, J., interview, Feb 5, 2014)

**Seed saving**

One of the most intimate parts of agriculture, and one that has fundamentally shaped the character of agriculture over the years, is the relationship of a farmer to his or her seed. The fundamental difference between agriculture and other means of subsistence is the act of saving seeds at the end of one growing season and the deliberate planting and cultivating of these seeds in the next one. This process has changed and evolved with agriculture for thousands of years.

**Current Practices:** The majority of the farmers interviewed do not save most of their own seed. Instead, they typically purchase seed every year from organic seed companies such as Johnny's Seeds or High Mowing Seed Company. These seeds come from plants that are grown in New England. In addition to this, each farmer has a handful of crops that they save successfully each year. In general, where one person claims they have tried to save seed from a certain crop and failed another person has succeeded. A few farmers expressed a goal or a desire of saving all of their own seed, but none of the farmers interviewed claimed to be planting mostly seed saved from the previous year. The plants that farmers most commonly save seed from include tomatoes, garlic, and peppers, especially chile peppers.

**Evaluating Sustainability:** During the 10,000 or so years that humans have been practicing agriculture, seed saving has allowed plants to co-evolve with the agricultural systems that they are a part of, allowing each farm to develop crops adapted to the specific micro-climates and soils of that farm. In short, when a farmer plants a seed on his or her land for the first time, there is some uncertainty how that seed will react to a new microclimate, new soil conditions, and even a new regime of care. At the end of that first year, however, the farmer will save seed from the plants have performed the best
under the local conditions of the farm and these plants will spread their genes among the following year's crop. As this process continues, each farm, even those located near one another, will over time develop unique varieties of crops that are uniquely suited to their farm's local conditions. Over thousands of years, this had led to a stunning genetic variety of cultivated crops, each with its own distinct characteristics. It was this process, for example, that allowed Pueblo Indian farmers in New Mexico to develop corn that is specifically adapted to the dry, high desert climate of the Rio Grande valley.

During the course of the past century, however, this process has begun to swiftly reverse, as mechanized, industrial agriculture and the capitalist marketplace have placed great incentive on successfully planting a very restricted suite of crops and crop varieties that grow uniformly and sell well. In addition, scientists have developed new crop varieties called High Yield Varieties designed to produce bumper crops. These plants do produce more food per plant than the heirloom crops saved by traditional farmers, but only under perfect conditions of high application of mineral fertilizer, perfect irrigation conditions, smoothly tilled fields, and lands freed from weeds and pest competition via chemicals. Meanwhile, the heirloom crops that are perfectly suited to specific local environments and that require few outside inputs to produce large yields are disappearing. Thrupp (2000) chronicles the alarming rate at which the agro-biodiversity represented by these heirloom crops is being lost and describes some of the consequences of this disappearance. In short, urgent action is required to encourage farmers to continue to plant and save heirloom seeds adapted to their environment. The situation is particularly dire in the United States, where some seeds, particularly corn, are now genetically modified so that they cannot produce a second generation of offspring. There is little doubt that the current system of seed saving and selection for large industrial farms is not sustainable.

With regards to the seed practices of small-scale farms in New Mexico, the picture is not much better. The seed companies that most farmers buy from are located far away and operate on a large scale, implying that they use large amounts of fossil fuels on their farm and that the yearly presence of seeds in New Mexico in the spring requires an equally large fossil fuel input simply to transport them. In addition, seeds that are bought every year must be paid for, adding one more economic burden to cash strapped
farmers. Most concerning, however, is that year after year, farmers are importing seed from places like New England and planting it in New Mexico's unique climate. Even though many of the farms specialize in heirloom varieties of crops, and as such are helping to preserve some of the genetic diversity that is otherwise being lost, they are preserving genetic diversity specifically adapted to New England and not to the central Rio Grande valley. The consequences of this is that crop varieties specifically adapted to New Mexico are not being developed, and with each passing year, another opportunity is lost to renew this process that once created hardy, desert tolerant plants. Under the current conditions - in which water can be applied as needed via drip irrigation, plentiful compost from industrial composting facilities allows farmers to change their soil chemistry and industrial products such as row covers provide protection from sun and wind - the deficiencies of these crop varieties can generally be managed. Despite the availability of these tools, however, there is little doubt that New Mexico-adapted crops would produce more for these farmers than crops coming in from far away. In response to this situation, a number of seed companies, particularly Native Seeds Search in Tuscon, have helped revive interest in the heirloom crops that indigenous peoples in New Mexico, Arizona and northern Mexico developed over thousands of years of agriculture in the desert climate of the southwest. Unfortunately, many of the crops grown by current farmers based on market demand are not the same crops as those which exist in desert tolerant varieties. High value market crops such as tomatoes, lettuce, bell peppers and carrots, to name just a few, were not grown in the southwest until recently, and as such do not exist in a desert adapted form. On the other hand, corn, chile, beans, winter squash, and peas are common crops for which an abundance of southwestern heirlooms exist.

Sustainable Outcomes: If, as many farmers predict, the long-term future of agriculture in the Rio Grande valley is one that must grow food without acequia water and without drip irrigation from well water, then it is imperative that this agriculture begin to develop drought tolerant crop varieties that can grow with infrequent bursts of large amounts of water. In addition, these crops will also have to be able to tolerate high alkaline soils, as well as heavy clay or sand, since it is unlikely that future farmers will
have access to Soilutions compost. Finally, it is important that these crops also be bred to transpire less water than they currently do. All of these adaptations cannot be bought from Vermont or Maine, they must be made patiently by local farmers planting and saving their seed year after year. Saving seed from the crop varieties that farmers currently plant is a good start to this process, and it would certainly improve crop yields for local farmers over the long term, but these plants would still be adapted to the high water, high compost regime of the present. In order to prepare for the future, it is also imperative that farmers begin breeding seeds that will be ready for the New Mexican climate of the future. In addition to saving seeds for current production, therefore, current farmers would also be served by creating small plots of land simulating the future conditions they expect to face. To give an example, if a small garden were engineered next to a tool shed or other small structure, rain water could be harvested from the roof of that structure to water the crops. These crops could then be fertilized only with locally available materials and protected from pests and weeds by hand. Over time, much as the Pueblo Indians were able to develop corn varieties that survived and produced even under what seem like impossibly dry and hot conditions, local farmers could perhaps develop similar varieties of other crops. In the meantime, when farmers do have to buy seeds, they should make every effort to buy them from seed companies such as Native Seeds Search that are located in the southwestern United States.

In addition to developing market crops that are locally adapted to the New Mexico climate, local farmers should also attempt to develop markets for the varieties of heirloom crops that are currently available, so that these varieties can also continue to evolve with the changing climate. Among the valuable heirloom seeds that can be found through seed companies and that are easily marketable are sweet corn, a wide array of chile peppers, melons, watermelons, and even onions. Other crops that would be more valuable in terms of reviving subsistence agriculture are flour corn, beans, wheat, and soup peas. Finally, farmers should actively participate in seed swaps and seek out other local farmers who do have heritage seeds, particularly Hispanic and Native American farmers who may have seed that goes back for hundreds or even thousands of years.
Seed Starting

One of the most delicate and difficult parts of agriculture involves the planting and successful germination of the seeds that the farmer intends to grow. This is because getting seeds to germinate in the high percentages required for successful agriculture requires very specific conditions, both in the atmosphere and in the soil. A farmer who unwittingly plants his seed too early, too late, waters it too much or waters it too little, may lose more than half of his or her crop before the growing season has even begun. Even after the seeds have germinated, the young seedlings must also experience very specific soil moisture, temperature and nutrient conditions in order to grow robustly, another condition of successful agriculture. As a result, over the years agriculturalists have devised numerous tricks to help seeds germinate and to care for the young seedlings as they grow. Some of these tricks involve methods to ensure better germination of seeds that are sown directly in the ground, while others are intricate systems of staring seeds in pots, intensive seedling care and transplanting.

Current Practices: In the Rio Grande valley, as in many places with a cold winter, most home gardeners and farmers raise vegetable seedlings, particularly of vegetables like tomatoes and of leafy greens in potting soil in containers indoors or in greenhouses during February and March, when the danger of frost is still high. Many of the farmers interviewed have seeders that allow them to then plant seedlings directly into the beds. With this system, a good many crops get between one to two months of an extended growing season and farmers obtain more consistent germination results. For crops like tomatoes, peppers and eggplants, the ability to raise them early is key to making these crops profitable, because it allows the harvest to begin in June or July rather than August or September. For some seeds, starting them indoors may extend the growing season even more because the soil temperatures outside are such that they cannot be planted directly in the soil until well into the growing season. Because the seeds are also more likely to germinate in potting soil in controlled temperatures, it also allows farmers to save money on seed.
Evaluating Sustainability: The use of special techniques to start seeds and care for seedlings is not simply an advent of modernity. To note some examples in traditional agriculture, agriculturalists in southern Mexico used mud dredged from the bottom of local canals, or *chinampas*, to start seeds because this mud was rich in nutrients and loose enough to allow for the germination of small seeds like tomato seeds. The seeds were planted in small one-inch squares of mud and later transplanted into fields when they were bigger. A similar system was developed in parts of China with rice seedlings. (Netting, 1993) A key difference in between these traditional systems of seed starting and modern techniques, however, lies in the inputs that these processes require. In modern agriculture, for example, farmers and gardeners alike use small plastic pots and potting soil to start many vegetable crops. Plastic is a fossil fuel product that cannot be considered sustainable. In addition to this, potting soil as it is currently manufactured is not sustainable either. Peat moss is the main ingredient in potting soil and peat moss is currently being harvested at a rate faster than it can replenish itself. (Hyden, 2014) In addition, there are no naturally occurring sources of peat moss in New Mexico, so most potting soil has its origins somewhere in the northeastern United States or in Canada. Finally, starting seeds early requires the use of a greenhouse of some kind, and it often requires a heater in order to ensure that seed pots are warm enough to allow seeds to germinate. Although greenhouses can be constructed more or less sustainably, most current farmers have hoop houses that rely on expensive and non-durable plastic materials to provide the cover that retains warmth and allows sunlight to enter. Because this plastic material requires frequent replacement, it cannot be considered sustainable. The heaters for the seed pots also run on electricity produced by coal-fired power plants, so they are also not sustainable.

Despite these environmental qualms, however, there is little doubt that seed starting greatly improves the economic sustainability of farms in the Rio Grande valley. Most critically, seed starting extends the harvest season of many popular market crops by at least one or two months. Economically, this makes a huge difference to local farmers, who can sell tomatoes and other popular crops from June or July until October, almost four months. If farmers were to start these seeds in the ground in April, then they would only be able to sell tomatoes for two months. Thus, seed starting allows farmers in the
Rio Grande valley to double their income from some of the most popular crops. In addition to extending the growing season, planting in pots allows farmers to exercise much more control over the seeds they are starting. By keeping their seeds in pots, they can keep water levels and temperature levels much closer to the precise middle ground that seeds prefer for germination. The heaters for the seeds pots are also particularly important because they allow farmers to ensure high rates of germination in the cold months of early spring and in the hot months of mid-summer when they are starting fall crops. Without this temperature control, it is likely that a great many of the crops that these farms plant could not be started at all with the reasonable certainty required for doing business.

**Sustainable Outcomes:** A sustainable farming operation must be able to start all of the seeds that it needs to survive economically at the appropriate time. It must be able to start all of these seeds without a significant cost to the environment. In the current market, all the farms interviewed definitely require some kind of seed starting mechanism in order to start the popular market crops they sell at the appropriate times. In order for this process to become truly sustainable, however, the materials used in the process need to change. The seed starting containers, for example, should become more durable and permanent, rather than something farmers replace every few years. More critically, farmers should begin to experiment with ways to make their own potting soil. One farmer described a potting soil mix he had used on a farm in North Carolina that consisted solely of worm castings and decomposed leaves, or leaf mold. (West, J., interview, Mar 3, 2014) These renewable materials are both ones that farmers in the Rio Grande valley could easily obtain, and once the systems to make them were in place they would likely save the farmers money because they would no longer have to buy potting soil.

In addition to strategies that would allow seeds to be started using renewable or durable materials, farmers should also pursue direct seed farming, meaning farming that does not involve any pots or potting soil. In order to successfully do this, farmers would likely need to be able to create a market for crops that are more suited to direct seeding, such as corn, beans and other grains and legumes. In addition to this, direct seeding of
crops that are traditionally grown in pots might serve as an insurance crop and/or a late maturing harvest to supplement the other crops.

B. ECONOMY AND SOCIETY

Pricing and Subsidies

All agricultural systems require mechanisms for conserving the harvest during years of great surplus and for maintaining its people's livelihood during years when crops fail or do not produce as expected. The supply and demand mechanisms of the free market, however, which are supposed to regulate the behavior of producers, do not properly do so in agriculture because the information producers require to do so does not come until it is too late. Year after year, farmers producing commodity crops for the free market face the dual uncertainty of bad weather which destroys their crops or good weather that creates a bumper crop and lowers the price of their commodity to the point where they will be selling at a loss. As a result, governments and other organizations around the world have devoted great time and energy to leveling out these great swings of fortune for agriculturalists. This section discusses how prices and government subsidies affect farmers in the Rio Grande valley.

Current Practices: With the exception of the three farms that are not dedicated to growing food for the market, all of the farmers interviewed claimed that their farming work paid for itself. While none of them professed to be making significant quantities of money, all of them said that it makes them enough money to validate the time and energy they invest in it. This reflects the fact that small farmers in the Rio Grande valley are able to sell their produce for a price that is slightly more than the amount of money they spend producing it. While all farmers claimed to be making money, however, none of them found it to be a lucrative operation, and some claimed that a second job was necessary to make ends meet. (e.g. Wegrzyn, D., interview, Feb 19, 2014) The reason for this is that, in general, the local market prices are not much higher than the production value of the crops and climate limitations restrict sales to approximately six or seven months out of the year. Two farmers, both single men, stated that all of their income
came from farming, but the remainder of the interviewees characterized farming as something that made them enough money to justify doing, but not enough money to live off of. A number of interviewees stated that, of all the working farms they knew, all were subsidized by someone or something, and most benefitted from land costs that were close to zero, either because they owned the land outright or they rented it for a very low cost. (Wegrzyn, D., interview, Feb 19, 2014; West, J., interview, Mar 3, 2014) Other farmers characterized the current farming system as "the grant system", referring to the large number of federal grants available through the USDA that help farmers to install equipment and make other capital investments, among other things. These grants, they claimed, allowed many farms to remain afloat when they otherwise wouldn't have been able to. (Sanchez, M., interview, Feb 20, 2014)

**Evaluating Sustainability:** In the United States, farming is rarely a profitable occupation, even for full-time farmers with large land-holdings whose operations are fully mechanized. Large corn farms in the Midwest, for example, produce crops at almost a dollar more per bushel than they sell them for. The only reason these farmers stay in business are government subsidies that are designed to keep the price of crops low and to encourage more production than the market would otherwise demand. (Pollan, 2006) In contrast to this situation, most of the farms interviewed are not subsidized by the government for their produce, so they must set their prices higher than the amount of money they invest in producing their food. This automatically relegates these farms to niche markets since they simply cannot compete with the prices offered by wholesale grocers. As such, responsibly produced food is generally too expensive for the average middle or working class consumer to afford. Thus, while there may be unmet demand for local food at market prices, the subsidies of large farms prevent this demand from being supplied. One farmer claimed that even he himself couldn't even afford the price of the produce he was growing. He characterized the work he was doing as growing vegetables for rich people. (Acosta, R., interview, Feb 23, 2014)

More importantly, although most of the small farmers interviewed are not subsidized for the crops they grow in the way that corn farmers are, many of them still are subsidized via grants distributed by various government agencies. Whether or not
these farms would be solvent without these government programs is beyond the scope of this study, but the fact remains that many of them are able to invest in infrastructure improvements without having actually earned the money to buy these things. Thus, as some farmers implied, even the small farms reviewed here may not be financially solvent without the subsidy of infrastructure paid for by the government and special situations involving a low cost for accessing land. (Sanchez, M., interview, Feb 20, 2014) In this light, the current situation with regards to the income farmers make and the prices they set is not likely to be sustainable economically. Because of the myriad government grants and funding opportunities available, farmers do not have a great incentive to save their earnings and invest in capital, since the government may foot the bill. This allows farms to stay in business and to make investments even when their actual economic performance may not justify them doing so.

**Sustainable Outcomes:** A truly sustainable farming system would require that all food is sold for a price that reflects the investment put into producing it. In addition, government subsidies should be used sparingly and should help make corrections to the markets in order to ensure the economic, social and environmental sustainability of farming operations. This change would make responsibly produced food affordable for a middle class consumer, providing the proper economic incentive for the creation of a local food market that met all demand. In the context of the Rio Grande valley, this could take a number of forms. A number of programs have been created to allow low-income residents of the valley to use food stamps or other vouchers at local farmers markets. Unfortunately, however, one farmer complained that it has not been implemented whole-heartedly by government agencies, effectively decimating the profit he formerly made from farmer’s markets in low income communities. (Moody, J., interview, Mar 6, 2014) If this program were prioritized, it could serve to reverse this trend, creating more of a market for local food. A more comprehensive reform would undo the subsidies given to large industrial farms that currently distort the market, bringing the actual price of food into line with the cost of producing it. Finally, in a sustainable farming system, government would not take it as a responsibility to fund infrastructure for small farmers but would instead use subsidies to ensure
environmentally responsible farming, perhaps paying farmers for fallowing land, especially during drought years. These subsidies could also be used to help farmers conserve water, laser level their fields or perform other tasks that benefit the community as a whole.

**Access to Land and Land Ownership**

Land ownership and access to land have long been some of the most complicated and important issues dealt with by farming societies. This is no less true in the Rio Grande valley, where the land ownership structure and the real estate market provide some of the greatest barriers to the development of a local farming economy.

**Current Practices:** Of the farms interviewed, nine of them are farmed by the owner and four of them are working on rented land. All of the renters made statements expressing desires they had involving the establishment of perennial plants on the property or regarding infrastructure improvements they would like to make, but none of them claimed to be willing to do so on a rented property. As one tenant put it, he had no interest in working hard just to improve someone else's property value. (Natale, M., interview, Mar 2, 2014) While this is a common sentiment, however, the ability of aspiring farmers to own their own land in the Rio Grande valley is quite limited. With development prices of over 70,000 dollars an acre being charged for most pieces of available farmland in the valley, farmers are unable to afford the mortgages that would pay for a good piece of farmland. Instead, aspiring farmers can either look for a job that will pay the mortgage or they can rent land, which many land owners are willing to do at low cost.

**Evaluating Sustainability:** People who own their own land generally have a much higher investment in that particular piece of land and are willing to make the capital investments necessary to make agriculture sustainable. As Robert Netting (1993) points out, even in traditional societies with supposedly communal land use patterns, farming responsibilities are almost always divvied up in ways that closely resemble private property and are based on usufruct, the idea that a person has the right to reap the
benefits of their own labor. As such, even in communities without western notions of private property, the right to tend a particular plot of land and to dispose of the food grown on that land are generally an individual's or a family's for life and those rights are passed down from parents to children, so long as they continue to actively farm the land. In general, the land only passes back to the community or the communal leader when there is no one ready to maintain it as a farm. (IBID) The principal reason for this is that a system based on individual land assignments allows each person or family to farm for themselves and to make decisions about how much food they need, how much work they will do for that food and how that food will be consumed. Thus, the work an individual does is directly connected to the reward they receive from it, and they have great autonomy in choosing the form of that work. In addition, private property or de facto private property provides the incentive for farmers to make long-term investments in their land such as planting fruit and nut trees, draining swamp land, building irrigation ditches, and making any other labor and/or capital intensive investments that improve the quality of the farm land. In general, Netting claims, these large investments are only undertaken when a farmer knows that he or she will reap the benefits of that investment and that they will pass it on to their children.

Given this conclusion, the economic reality of land and land access in the Rio Grande valley is not sustainable. Farmers who do own land generally have to acquire a large secondary source of income to pay for the mortgage or to buy the land outright, while farmers who don't own the land can farm full time but only for as long as the owner desires. As one farmer explains, "In the long run, if that land owner wants to develop housing, wants to go back and build a retirement home, etc, that farm and that intentionality you put on that land is gone. That is not sustainable." (Wegrzyn, D., interview, Feb 19, 2014) Under the current system, therefore, many farmers have no incentive to invest in their land and all of the hard work they put into farming and improving the soil could disappear at any moment. In fact, most land-owners have an economic incentive to convert farmland into something else. As a result, often the very existence of a farm on a valuable piece of land reflects the conscious choice of the land owner not to profit from their land to the fullest degree and instead use it for agriculture. This is another example of how the social weight and cultural resonance of farming serve
to keep farmland in production in the Rio Grande valley. That said, over the long run there is a great potential for economic incentives to slowly overwhelm the social and cultural will unless formal structures are put in place to keep them from doing so.

**Sustainable Outcomes:** A sustainable mechanism regarding access to land would provide farmers with a way of owning the land at a price that reflects the value of the land as farmland, not as many urban lots. It would also give farmers the incentives to make permanent, long-term investments to improve their land. Finally, it would help to slow the conversion of farmland to urban land and ensure the long-term persistence of farm land in the region. One potential mechanism to achieve these outcomes is called a land trust. Under this mechanism, a farm is designated specifically as farm land, and all non farm-related development on it is frozen, meaning that legally the land can only be used for farming. In this situation, the value of the land is automatically reduced to the value it has as farm land because it can no longer be developed. In addition, because it now must be bought and sold as a farm, the owners have a strong economic incentive to make long-term investments in the land that improve the value of it as farmland. It also provides a good mechanism by which a farm can be sold from farmer to farmer and it can also be passed from generation to generation, depending on the inclinations of those involved. This is also a very effective way for a public that values farming to in effect subsidize pockets of farm land within the city. In essence, the public is willing for someone to buy a property at well below market price in order that the property maintain itself as a working farm. Unfortunately, the current situation presents a number of bureaucratic or political obstacles to the creation of land trusts. Two of the properties currently being farmed had applied or were in the process of applying for certification as a land trust. Both had been rejected by Bernalillo county functionaries. (Wegrzyn, D., interview, Feb 19, 2014; Natale, M., interview, Mar 2, 2014)

**Organic Certification**

Organic certification is the very cornerstone of the organic movement, now a billion dollar industry. Without an inspection by the USDA and an approval by that inspector, a given farm cannot call its products "organic". These rules and these
approvals, therefore, have become critical in allowing farms to market themselves as environmentally responsible food producers. Still, there is a great debate surrounding the sustainability of organic agriculture as it is currently defined by the USDA, and as such the farms interviewed in this study make different choices with regards to this process.

**Current Practices:** Of the farms interviewed, four are certified organic, while nine have decided not to pursue certification. When asked to elaborate, however, all of the nine who are not certified described their practices as "beyond organic." This is clearly a strategy on their part to distinguish themselves from the industrial practices of large organic farms and to market themselves as more environmentally responsible. As many farmers explained, the process of becoming certified is cumbersome and requires a lot of time and money, while the benefits of being certified are often not worth these investments. As one farmer explained,

> I feel like the USDA's organic certification is much less looser than what I consider to be true organic growing. We grow with stricter standards than the USDA demands. I don't use any herbicides or pesticides, even those that are organically safe. I feel like I'm growing with strict standards, I don't really feel like I need the pat on the back from the USDA to feel better about what I'm doing. 75 - 80% of my sales are to restaurants and so my relationship with chefs and telling them how I grow food, they don't need that certification either to feel good about purchasing from me. We sell at the Co-op a little bit and it would probably help on the shelf a little, but also local is becoming its own brand and gaining power. ... For marketable reasons, I haven't felt like my business would benefit from going through all of that paperwork. (Matlick, S., interview, Feb 25, 2014)

All of these sentiments were common ones echoed by other farmers, even those who were certified. (Sanchez, J., interview, Feb 20, 2014) Many expressed disdain for lax regulations that allowed the use of herbicides or pesticides of any kind and all of them emphasized the way that their business relies more on an intimate relationship with the consumer than on a certificate. One farmer described organic as "just a brand", but a brand that you have to pay for. (Acosta, R., interview, Feb 23, 2014) Echoing this sentiment, another farmer who is certified organic complained that with the current squeeze on government budgets, the USDA seemed as if it had another agenda beyond ensuring good quality food,
The Organic program itself all runs underneath the USDA, which all runs underneath the farm bill, so they're always looking for more money and now they're in the squeeze where they can't make their budgets, so that's where their priority is. It's not about helping the farmer, it's really, how do you get money from the farmer so we can balance our budget. So on the organic side, we're worried about the integrity of the product and they're not. ... We could do more stuff with the money instead of paying them to give us a headache." (Sanchez, M., interview, Feb 20, 2014)

For most of the farmers in the Rio Grande valley, therefore, Organic Certification is not seen as something that actually indicates environmentally sound practices, it is instead a bureaucratic hoop that some farms are willing to jump through because of specific markets they serve. This is especially true for the farms that sell at local grocery stores like Whole Foods. In general, however, it is something most farmers would like to see reformed.

**Evaluating Sustainability:** The creation of the organic food industry and organic certification is, like the burgeoning local food movement, a response to the excesses of industrial agriculture. The term organic implies that the process of growing food does not use synthetic chemicals, that it relies on products that are made from renewable, biodegradable resources. In theory, organic food is better for the planet and better for the people who eat it. Because organic food is in this sense a valuable commodity, it has become a multi-billion dollar industry. As with any large industry, however, the regulation of organic food is complex and there are many loop holes that allow certified organic farms to do things that many people do not consider organic. In many cases, large organic farms in places like California are simply replicating the processes of industrial agriculture but are using biodegradable chemicals instead of synthetic ones. While this is certainly an improvement with regards to the environment, many people are critical of organic agriculture because they believe that it does not truly represent ethical, responsible principles that the word organic implies. Much like the word "natural" has been used so often in marketing as to lose any real meaning, many people now consider organic to be traveling a similar path. (Pollan, 2006)

As comments from the farmers interviewed here make clear, therefore, the organic certification program is not a good long-term strategy for branding their products.
and distinguishing themselves from industrial agriculture. Instead, many of them rely on the "local" brand, one that they do not have to pay for or get certified. The downside of this, as one farmer noted, is that some local farms are growing conventionally but are still benefitting from the good reputation of all the other local farms that are practicing what they call "beyond organic". (Matlick, S., interview, Feb 25, 2014) Over the long run, this has the potential to weaken the brand "local", and may not be sustainable. A couple of farmers described local as a fad, and therefore as something that may go out of style.

While this evaluation puts into question the sustainability of the “local” brand, one thing that most all farms consider to be sustainable economically is their relationship with their customers. As many farmers explained, they are able to sell their product and market themselves accurately because their customers take enough time to get to know the farms they run and the production methods they use. This kind of relationship allows consumers and farmers to express their desires to each other and to adapt to the needs of the other. Over the long run, it will also allow customers to steer away from farms they consider unethical or unsustainable and will help sustainable farms to build a strong customer base. As one dairy farmer explained,

"I think it’s more important for people to come to the farm. One of my customers just left. She wanted to come see the farm and see where her cheese comes from. I think that is more important. They can see what we're doing with the animals, see what we're feeding the animals. ... Talking with a lot of the restaurants that we sell to, they want to know the farmer, they want to know where it comes from, they want to know what the goats are being fed. That is what's important to them right now, not necessarily being non-GMO or Organic." (Lobaugh, M., interview, Feb 17, 2014)

Therefore, the relationship with the customer that most small farms maintain is the most important piece of the economic sustainability of each farm. These relationships allow customers to independently verify the quality of the product and they allow farms to tailor their practices to the desires of their consumers. This relationship is one that can and will evolve sustainably over time.

**Sustainable Outcomes:** A sustainable response to the question of organic certification would be to create a different mechanism that would provide a certain amount of independently verified assurance that a given farm was practicing responsible,
chemical-free growing methods similar to those described here. A certification or a labeling process that allowed a farm to be branded as "chemical-free", for example, would help to distinguish between local farms, helping to distinguish between local farms that grow conventionally, those that follow the more lax organic standards and those that follow more strict chemical free ones. These conditions could also be met if the standards for organic agriculture were updated and required to be chemical free. Given the political difficulty of this solution, however, it seems more feasible for local grocery stores or food system activists to create a locally run certification service that serves the Rio Grande valley. Ultimately, however, active customer involvement may be the best way for farmers to assure their customers of their environmentally sustainable practices and to avoid the complexities of creating an effective certification process.

**Labor**

In any farming society, labor is often one of the more complicated aspects of running and managing a farm. Many agricultural systems have an inconsistent and cyclical need for large amounts of labor. In the North American spring, for example, labor need is high for plowing and planting, but while waiting for the crops to mature, labor needs may be much lower. At harvest time, the labor needs of a farm may spike up again before dropping again during the winter. As such, successfully managing these seasonal shifts in labor necessity is a critical part of the economic sustainability of any farm.

**Current Practices:** Most of the farms interviewed hire part-time workers on their farm at various points during the growing season. Most of these workers are paid minimum wage and work 40-hour weeks while demand for their labor exists. In general, farmers hire extra labor when they need help with weeding, or with harvesting and going to farmer's markets. In addition, three farms hire interns. Interns are generally people who want to learn how to farm, and in return they typically offer one year of work to a farmer in exchange for food from the farm and a small living stipend. While some farmers in other areas offer housing to their interns, none of the farms interviewed here do. One farm hires three interns every year for the entire growing season, another hires
two, and another hires one part-time intern. In addition to interns, many farms solicit volunteer help from their customers when facing a severe labor backlog. One farm, for example, offers a reduced price membership in their CSA in exchange for four hours of labor per week. (Wegrzyn, D., interview, Feb 19, 2014) When asked what their greatest cost burden was on a yearly basis, most farmers listed labor as their first or second biggest expense. (e.g. Apodaca, T., interview, Feb 20, 2014; Acosta, R., interview, Feb 23, 2014)

**Evaluating Sustainability:** As was touched on in the section on weed control, there is little that is sustainable about the system of labor that most farmers in the Rio Grande valley use. Most farms hire different laborers every year and as such are forced to train these laborers every year. The jobs that these farms provide are generally physically demanding jobs for low pay, and they are both temporary and do not provide many skills that are transferable to other jobs. Most importantly, the jobs are poorly paid, with most laborers earning minimum wage or less in the case of farm interns. Despite paying very poor wages, however, the jobs that most farms provide are often the greatest expense undertaken by a farm. This situation has led some farms to advertise for and hire interns, a practice that other farmers question the morality of. One farmer described some interns as "modern slaves", explaining that they performed hard, manual labor for 45 hours or more a week in exchange for a basket of produce and a small stipend that is generally barely enough to cover housing. (Wegrzyn, D., interview, Feb 19, 2014) Thus, although the intern program represents a way for farmers to get labor in exchange for sharing their knowledge, it is far from the magic bullet to solve the contradictions described here, because it may not be sustainable if this understanding begins to permeate the public sector.

**Sustainable Outcomes:** A sustainable solution to the labor problems faced by farms in the Rio Grande valley is both one that would decrease the cost of labor for a farm and would also allow them to hire long-term permanent workers with reasonable compensation. In order to meet these conditions, farmers must be creative and resourceful. As discussed in the section regarding weed control, the use of preventative
measures and systems such as conservation agriculture may be able to help farmers deal with some of the seasonal labor logjams by reducing the need for manual labor. In addition, since most farmers are not able to pay better wages, they must be able to offer something besides money in order to attract laborers who stay on the farm long-term. For many people, the lifestyle associated with farming is sufficient enough to convince interns to accept the low pay, but it is important that the internships offered by farms be educational and otherwise worthwhile. If this is not the case, and interns are simply used as a source of cheap labor, this system is unlikely to be sustainable. For farms who run a CSA, another attractive option is to ask members to volunteer on the farm and to include this in the price of the produce. The farm that sold working shares on its CSA described the process as an educational one for the members who participate,

We like to teach people about farming. ... We encourage people to bring their kids, so they learn about where vegetables come from and about how much goes into getting it to the market. It's been a really good thing. They learn about composting. They help us harvest. They see how long it takes to pull garlic out of the ground and what it takes to dry it. We had them plant and harvest potatoes, so they saw the whole process. (Wegrzyn, D., interview, Feb 19, 2014)

In this case, rather than creating a couple of part-time, underpaid jobs, Red Tractor Farm decided to meet its labor needs while performing another an educational service, connecting its clients to their vegetables.

Another similar educational transaction to that offered by Red Tractor Farm is the use of WWOOFers (Willing Workers on Organic Farms). WOOFers are generally travelers who willingly volunteer their time to work on organic farms for a short period of time, not typically for an entire growing season. Two of the farmers interviewed relied on WWOOFers for some of their labor, and they described the relationship as one of mutual convenience. They, as farmers, could get temporary labor for cheap, usually in return for housing and food, while the people volunteering their labor got a place to stay during their travels. According to the farmers, some WWOOFers volunteered their time because they wanted to learn farming, while others did it simply as a cheap way to travel. Either way, this is another kind of exchange that allows farmers to trade something besides money for the labor they need.
Job Security

Farming, even under the best of circumstances, is a risky endeavor. Due to frost, drought, hail, flooding, pests or disease, a farmer can lose all or most of his or her crop in a given year. Given the extreme weather forecasted by climate change scientists, it is likely that crop failure will become more and more common over the coming centuries. As a result, a sustainable farm must have a strategy for dealing with crop failure. This is especially true in a region like New Mexico, where rainfall is unpredictable, the climate is highly variable, and the likelihood of failure is relatively high. Thus, any farmer who relies on their farm as their only source of income must have strategies in place in order to deal with crop failure and other vagaries associated with farming.

Current Practices: Of the farmers interviewed, none of them had a specific plan in place for dealing with crop failure. One farmer, in fact, had gone back to school and is thinking about quitting farming because of a series of accidents beyond his control decimated his crops during previous years. (Moody, J., interview, Mar 6, 2014) Other farmers expressed a faith that their business is on safe ground and their jobs are secure. (e.g. Matlick, S., interview, Feb 25, 2014; Lobaugh, M., interview, Feb 17, 2014) One group of farmers in Albuquerque's south valley, however, has developed a unique model that serves as a hedge against crop failure. This group of farmers formed what is known as the AgriCultura network, a network of small farmers in the south valley who farm small plots of land but who all sell together in order to be able to increase their market power. At the time of the interviews, this network contains 9 growers who can sell their surplus produce to the network. This network is large enough to have a contract with Albuquerque Public Schools, among others.

Evaluating Sustainability: The cooperative marketing model that the AgriCultura network represents has a lot of positive aspects with regards to social and economic sustainability. For one thing, by establishing this kind of network, individual farmers are no longer quite so isolated in their work. Instead, they have a network of fellow farmers to go to with questions about agricultural and marketing techniques. More importantly, they can collectively sell a greater variety and quantity of produce than they
could individually, allowing them to coordinate in order to sell large amounts to large buyers. This allows them to obtain a guaranteed contract for their produce, reducing the risk of growing too much. In addition, because they are a network of different farms, they spread the risk of crop failure evenly among all farmers so that if one has a failure, the others can pitch in a little more in order to meet the order. Over the long term, this network also has great potential to serve additional needs that individual farmers may be unable to meet themselves. For example, this network is well positioned to work together to breed and develop local seed stock, to buy heavy equipment collectively, or to offer work trades during times of seasonal peak labor. They could also work together to advocate for the establishment of land trusts and other political needs of farmers. If all of these potential initiatives are one day brought to fruition by the AgriCultura network, it could evolve into a very sustainable part of valley agriculture, particularly socially and economically.

Another important feature of the AgriCultura network is that it is simply a network, it is not a collective or a cooperative. Thus, the network allows farmers to maintain their own autonomy. The means they can still go to farmers markets and other places as individuals, and no one person has the power to direct the resources of the network in any one direction. This situation prevents potential abuses of power or corruption and still provides sufficient incentive for farmers to work hard, knowing that they will reap the benefits of their extra labor. As one member of the network, explained, however, the main drawback to working cooperatively, is the inevitable gossiping and infighting involved in running the network and in taking credit for its successes. (Acosta, R., interview, Feb 23, 2014)

**Sustainable Outcomes:** In order to protect the job security of local farmers, mechanisms need to be developed that allow farmers to work together and to collaborate and to develop associations of farmers that will help their members make it through unproductive years. These cooperative or associations should be democratic, egalitarian and preserve the independence of individual farmers. In this respect, the cooperative model exemplified by the AgriCultura network has much promise for small farmers in the Rio Grande valley. As the AgriCultura network demonstrates, the cooperative model
allows farmers to sell their produce to buyers who need large quantities of food and who need consistent delivery of food. While one farmer may have trouble getting as many tomatoes for one week as he or she promised, nine farmers working together have a much better chance of success. These farmers can also work together to market their crops, to purchase expensive equipment, or to do anything else that an individual farmer may not have the capital or the willingness to do alone. Additional opportunities exist in cooperatives for the development of the local looping of waste products, making more efficient systems of composting and animal raising. The cooperative model would allow animal and vegetable farmers to work together, for example, so that the waste products from one farm could be used by the other. These mutually beneficial arrangements could be developed at a low cost or even for free.

**Farmer Training and Replacement**

In order for a farm to be sustainable over the long run, it is critical not only that the farm land be maintained in a state of fertility, but also that the people who manage and work the farm successfully reproduce themselves. Sustainable agriculture, as proposed in these pages, is a highly specialized, skilled form of labor, one that requires the mastery of numerous different skills as well as a detailed understanding of the local environment and the crops that are grown on the farm. As such, it is important that the farm have in place systems for passing on knowledge of farming from one generation of farmers to the next. It is also important that the farm have access to enough able bodies to perform all the necessary tasks and that these able bodies can be sufficiently trained in what they have to do.

**Current Practices:** As mentioned above, three farms interviewed use interns, or apprentices. Two other farms use WWOOFers, or traveling farm volunteers. Many of the other farms, while not having formal apprentice programs, have younger people working and learning from the older owners or managers of the farm. Four of the people interviewed were younger workers who were learning from older, established farmers. A more formal example of agricultural mentorship and training can be found in the origins of AgriCultura network, which made a point of attempting to find young people who
knew nothing about farming and training them formally. As such, it is clear that there are systems in place in the Rio Grande valley allowing younger farmers to learn the trade from older, established farmers. What is not in place, however, is a system of inheritance that allows farmland to pass from one farmer to another farmer. When asked what would happen to their farm when they stopped farming, almost every farmer expressed hope that they would find someone to take it over, but not one of them indicated that they had found that person or had a detailed plan to do so. Some farmers expressed hope that their children, nieces or nephews would continue their work, while others expressed hope that they could mentor someone when they were about ready to retire in order to pass the farm on to that person. (e.g. Armijo, K., interview, Feb 26, 2014)

With regards to the availability of people who were ready and willing to become farmers, however, most people interviewed expressed a positive view about the future. Despite the economic difficulties of farming, almost all of the interviewees felt that there would always be people interested in farming and that the difficult economic situation is not enough to keep people off of the land. A number of farmers noted that they were part of a generation and of a movement that was moving back towards the land just as their parents and grandparents had left it. As one farmer explained,

People love farms. Either they have this connection to it of growing up on one, or their grandpa was one. If they don't have that connection, their exposure to it is so exciting. Not necessarily the farm work, but just growing food. There's not too many professions in this day and age where if you tell someone that's what you do, they can feel almost 100% good about what you do. I'm not saying we deserve this, but people do. ... You go from a no name to an angel in a lot of circles. And I think that's gonna fuel farming. (West, J., interview, Mar 3, 2014)

Comments like these reveal the basic cultural and spiritual connection that many people in the Rio Grande valley still feel towards farming and that are likely to keep pushing people into farming despite the economic disincentives. One farmer noted that he has farmed for many years "at great risk to my health and sanity" despite consistently losing money and facing other difficult personal situations. (Moody, J., interview, Mar 6, 2014) This points to some underlying structures that promise to help maintain the social sustainability of farming, namely society-wide approval of the work and the willingness of government and other interests to subsidize farmers in various ways.
Sustainability: According to Jared Diamond (2006), sustainable agriculture is very complicated and reliant on local knowledge. For example, in New Guinea, children who were sent off the farm to pursue education were then unable to perform competently as farmers upon returning home after finishing their degrees. This suggests that successfully running and sustaining a farm involves a long-term, sophisticated training program by which young farmers can learn their trade. In parts of the world with a strong tradition of small-scale, intensive agriculture, this training program generally involves the transmission of knowledge from parents and grandparents to their children as the children grow up. The children have the incentive to learn the trade because they know that one day they may inherit the farm as their own. (Netting, 1993) In the United States, however, where farming is no longer a family tradition and even children brought up on farms have a myriad of other opportunities to choose from, the family transmission model is no longer a realistic one for the transmission of knowledge and the perpetuation of a sufficient population of farmers. Instead, there are a number of effective alternative channels through which aspiring farmers can hope to learn from experienced ones.

In some ways, these current systems provide a very sustainable method of farmer training, while on the other hand they are also fraught with unsustainable obstacles. On the one hand, there are plenty of systems, both formal and informal, by which aspiring farmers can learn the trade. On the other hand, current cultural norms regarding property and inheritance make it likely that most farms will pass into the hands of non-farmer owners once the current farmers retire. There is no guarantee that these new owners will be willing to forgo a monetary pay out in order to keep the land in production. In addition, the economic situation described by most farmers is definitely a large psychological and technical impediment to many aspiring farmers. While it is clear that some people will be determined enough to farm no matter the circumstances, other people who may otherwise have wished to farm may find themselves intimidated by the prospect of working two jobs or relying on a partner or a government grant to subsidize their habit. While the interviews made it clear that many people are becoming farmers because nothing will stop them, there are likely more people who wish they could farm, but find themselves unwilling or simply unable to take the economic risk necessary to do
Thus the sustainability of farming with regards to the income it offers to the farmer is still an open question.

**Sustainable Outcomes:** A sustainable system of farmer training and replacement for the Rio Grande valley would effectively train farmers to become successful farmers upon finishing their training. Most importantly, it would also train a sufficient number of farmers to meet the demand for local agriculture in the valley and it would facilitate these people with becoming farmers by providing them with easy access to land and equipment. In addition, aspiring farmers wouldn't necessarily have to begin farming from scratch, but could, under the right circumstances, take over farms that already improved by experienced farmers.

In order to secure this kind of future for the valley, farmers should begin to think about concrete solutions for handing down their farms. A number of farmers mentioned the idea of mentoring someone for a couple years before they retired and let their mentees run the show. (e.g. Armijo, K., interview, Feb 26, 2014; Lobaugh, M., interview, Feb 17, 2014) This situation is effective only if the farmers are able to successfully advertise and find someone interested in taking over for them. One farmer, however, has advertised this for a couple of years and has not found anyone interested. (IBID) Thus, farmers may need to begin thinking about this situation earlier in their careers. Instead of advertising for replacements, therefore, farmers could look for potential heirs among their workers and apprentices. The apprentices who perform really well could be offered longer term jobs and after the relationship has been firmly established, they could be offered to take over the farm. Another way of passing farms from farmer to farmer may be the land trust mechanism discussed earlier. This would allow aspiring farmers to buy already active, improved farm land from existing farmers at a price that reflected the land’s value as a farm.

Whatever the mechanism farmers choose to use, a farm enjoys the greatest shot at being sustained when there are multiple people in a position to inherit it. One solution to this problem is best represented by Sunflower River in Albuquerque’s south valley, a farm that has been bought cooperatively between five people. This farm has a charter and a vision statement that make the land into a legal community. With five owners, not
only are they able to share the labor, they also have realistic hope that someone will be able to take over the farm when they decide to stop farming. Finally, they have the ability to add new owners whenever they find someone suitable, so that as they age, they can add new owners well before any of them retire, allowing the new owners a chance to learn the trade. This allows for a cycle to become established where the retirement of any one person will not affect the farm as a whole, but rather that farm itself will become a kind of self-sustaining entity, with the people involved in it coming and going as needed. (Heatherington, K., interview, Mar 5, 2014) Under this kind of model, farms truly become part of a community and it takes the pressure off of individual farmers, allowing them to be more human.
IV. Putting it All Together - What does a Sustainable Farm in the Rio Grande valley look like?

The preceding sections have analyzed sustainable farming piece by piece, making specific recommendations with regards to various aspects of farming in the Rio Grande valley. Farming, however, is not a set of discrete, separate actions, but is rather an integrated system. Practices on one part of the farm affect practices on another and actions taken with regards to one aspect of farm management often will have unseen consequences on others. This is evident simply from reviewing each of the sustainable outcomes described in each section, as certain solutions are repeated for many different categories. Therefore, in order to craft the most effective plan for sustainable farm management in the 21st century Rio Grande valley, it is important to try and stitch all of the practices discussed here into one cohesive farm plan. As such, this section draws on the evidence, both academic and experiential, discussed in these pages and attempts to synthesize these conclusions into one cohesive farm plan. Although this endeavor is necessarily fraught with peril because the local conditions of each specific farm may make some or all of this impractical for specific operations, the goal of this section is to lay out an ideal, a vision that planners involved in agriculture and farmers can pursue as they craft policy and grow food. An effort is made, therefore, to describe the conditions that sustainable farms must meet and to suggest some practices that may be promising while acknowledging that practices will inevitably vary from farm to farm due to local contingencies and personal preferences.

Future Farms in the Rio Grande Valley

The final question that was asked of all farmers interviewed for this study was the following:

"Given what we know today about future conditions in the Rio Grande valley, what would the ideal, sustainable farm look like?"

Although there was considerable variation among the answers given, the answers addressed a number of themes that are consistent with much of the literature and science discussed here. More importantly, the answers helped provide a window into the issues about which particular farmers were most concerned with regarding the long-term
sustainability of their farms. Interestingly enough, these answers reflected a large mix of themes, environmental, economic and social, all of which are perceived to threaten the sustainability of existing farms. Many of these themes, along with other themes that arose in the course of this investigation, and observations taken from academic literature, are used to arrive at the following description.

The sustainable farms of the future in the Rio Grande valley will grow a mixture of crops and livestock. These two legs of valley agriculture will feed each other as well as the farmers, as the waste products from one will be used by the other. As such, the animals will be fed crop residues as well as crops grown locally and they will be occasionally harvested to feed the farmers. On the other hand, the animal manure and all other green wastes generated in the valley will be composted and used to feed the crops grown on the farm. These crops will also be fed through the use of green manures and other soil fertility practices such as the use of mulch.

In this sustainable farming system in the Rio Grande valley every farm will be different, and the diversity of farms will be great. Of critical importance, however, is that the farmland within the valley will be devoted to a wide variety of agricultural activities that will, quite literally, feed each other. As such, some land will be devoted to cash crops that provide income for individual farms and potentially can be traded on a regional market. These cash crops will not be the only thing grown in the valley, however, they will simply be the most prevalent crops. In addition, fields will be rotated with cover crops to feed the soil and each farm will grow a diverse suite of animals, vegetables, grains, legumes, fruits and nuts for their own personal consumption. These foods will serve as the valley farmer’s primary means of subsistence. Finally, some farms will have greenhouses or hoop houses made out of durable materials that serve to grow vegetables in the winter and allow for certain crops to be started ahead of time in pots. These pots will also be made out of durable or easily replaceable materials and the potting soil used in them will be a mixture of compost and leaf mold.

In addition to the crop lands in the valley, some land will serve as pasture, while other land will serve to produce animal feed and organic material such as hay or alfalfa that can be used as to feed animals during the winter and to mulch the cash crop fields and/or the vegetable gardens. In one way or another, the manure produced by the
pastured animals will be spread on the cash crops and the vegetable gardens as well. Some of the farms will have small dairy barns for milking animals while others will have facilities dedicated to animal slaughter and processing. Finally, some land in the valley will serve as habitat for pollinators and wildlife. The exact distribution of all of the different land uses described here will be left to future communities to decide, but efforts should be made to integrate these land uses as much as possible and they should definitely not be segregated exclusively into large geographical blocks.

In order to meet the conditions necessary to produce these multiple land uses, farmers in the Rio Grande valley will begin to work together to form simple, local systems of waste reuse and organic inputs. While all of the land uses described above may be too many in number and the labor involved too complex for one farm to support all of them, they could easily be handled by small groups of neighboring farms. These farms will be formally organized into cooperatives similar to the AgriCultura network, in which small individual farmers will work together to market their produce. Each cooperative will ideally be a self-sustaining unit as well, in which all waste products are recycled. In order to achieve this, each cooperative will have different farms that specialize in different aspects of agricultural production. For example, a cooperative of nine farms may include three dairies and meat processing farms, three vegetable operations, and three grain and hay operations. Perhaps there could even be one farm in this system dedicated solely to the production of compost. In addition to marketing and exchanging useful waste products, sustainable cooperatives will also provide other services for their member farms, such as the collective ownership and use of tools, the creation of seed banks, and even some kind of crop insurance. They will also serve as a united front to negotiate for the farmer's collective interests with the government or other powerful outside forces. More critically, cooperatives will arrange work trades of some kind between farms in order to alleviate the labor backlog different farms experience during different times of the year.

In order to grow the crops and the animals and in order to sustain the health of the system itself, future farmers in the Rio Grande valley will abide by a number of sustainable practices such as those discussed in this report. With the possible exception of certain cash crops, particularly vegetables, these farms will do no regular tillage of the
soil. Instead, using conservation agricultural principles, organic mulch will be spread wherever possible over existing croplands. This mulch will not be imported, but will be sourced from the farm or the cooperative itself, whether via a living mulch system, via a local hay farmer, or through the collection of organic waste products such as leaves and crop residues. This mulch will help create systems of biological tillage and will actually build the topsoil in the valley instead of slowly destroying it. It will also reduce the weeding load of most farms and will create an ecosystem that supports native, slow-growing perennials at the expense of invasive, fast-growing non-native weeds.

In order to provide water for the farm and its inhabitants, the sustainable farms of the future will use a diversified strategy of irrigation and water harvesting. First, small earthen berms and swales will regulate the flow of rain water on every property, channeling rain water to existing perennials or even established annual crops. Farming cooperatives or larger organizations will also manage local arroyos and other rainwater collection features in order to use the water for human consumption. As such, future societies in the Rio Grande valley will meet all livestock and domestic human water needs through a system of rainwater harvesting and gray water that makes use of all available impervious structures and surfaces. During rain storms, storm water will be directed into local and regional collection systems where some of it can be stored for community use, and some of it will help to grow a riparian corridor along the water control features. As part of this system, some crop and/or pasture land will also be irrigated by rain and graywater. Hopefully, someone will convert part of a former Wal-Mart parking lot into a rain-fed corn field. In order to maximize the yields on these rainwater-fed pieces of land, farms will plant them primarily with southwestern heirloom crops such as pueblo corn and they will also be actively breeding and developing crops designed to grow under current conditions caused by climate change. Not just these, but all of the seeds used by each farm will be collected yearly from their own harvest or traded for locally with other farmers.

In order to grow vegetables, farmers will use a drip system, powered either by gravity or a solar-powered pump. This drip system will be made of readily available materials that can either be made and disposed of organically or that have long lifetimes, as long or longer than a given farmer. The farm will also have access to a system of
flood irrigation that they use to grow their grains and manage their pasture. This system of flood irrigation will be gravity-fed surface water diverted from the Rio Grande, but managed by a local *acequia* system much as traditional Hispanic *acequias* were managed, through an egalitarian, democratic board of *parciantes* where each farm with irrigation rights will be represented by one household member. This board of *parciantes* will elect a *mayordomo* yearly in order to distribute the water equitably and to manage conflicts during times of drought. Most importantly, the water rights to the *acequia* system will be carefully apportioned, so that throughout the Rio Grande valley, no more water rights will be held by individual *acequias* than would be available in the flow of the river during its driest cycles. While the Middle Rio Grande Conservancy District may still exist, they will be responsible only for the management of water on a regional scale, and will negotiate directly with the *mayordomo* from each *acequia* regarding yearly water distribution. Under this system, each *acequia* will be able to create rules and water use schemes that reflect the local conditions faced by each small group of farmers.

Unlike the many farmers of the 20th and 21st centuries, the sustainable farmers of the future will see themselves as a part of nature and not separate from it. As a result, they will not see the need to appropriate 100% of all resources for themselves, but will instead seek to enrich their lives by enriching that of the world around them. This means that the *acequias* will remain earthen, open air ditches, and the water that leaks from the *acequia* will serve to support a small riparian ecosystem, including shade trees, shrubs, aquatic insects and birds, etc. These creatures and this ecosystem will also help the local farms by providing mechanisms to control pests that cost the farmers nothing. In addition, farmers will do their best to support shade trees and flower gardens on their farm that provide habitat for pollinators, beneficial insects and birds. These mini-ecosystems may also provide organic material for mulches as well. In addition, farmers will expect nature to take a portion of the crops they grow, and they will not use destructive chemicals in a vain attempt to obtain 100% yields. When plant diseases are found to be present, for example, the diseased plants will simply be removed. Pests will be controlled, not eliminated, using various constructive techniques, including companion planting, trap cropping and attracting beneficial insects. Finally, farmers will intimately know the weeds present on their farm and they will create conditions that naturally
suppress weeds and also that use weeds to their benefit. For example, where possible
they will use weeds as mulch, tolerate less invasive weed where they do not affect crop
yields and even learn to use the weeds as food sources during lean years.

In addition to the sustainable agro-ecosystem that future farmers will create, they
will also be part of a robust, healthy economy. As populations worldwide stabilize and as
people migrate out of the Rio Grande valley in search of land of their own, the
sustainable farmers in the Rio Grande valley will eventually come to produce the
majority of the food in the valley. Only a few exotic food stuffs such as oranges, rice and
some salted fish may be imported from places like California and Texas. Prices for food
will be regulated not by the government, but by the free market, which will allow farmers
to ask more for their food than the money they spend producing it. Economically,
therefore, farms will survive primarily through the sale of their cash crops and wage work
by family members. Some of this wage work may be outside the farm, but much of it
will be work in value added production and marketing done for the cooperative. In
addition, farms will not be required to pay the government for organic certification.
Instead, customers will ensure the quality of the product because they will have
relationships with their local cooperatives and they will personally know the farms that
produce their food. Because government subsidies will not affect the market,
cooperatives will be able to invest in infrastructure like green houses, commercial
kitchens, pasteurizers, etc., as the funds from farming became available. This will allow
the farmers themselves to provide a diverse suite of services for their customers,
including storing, marketing and distributing their food without losing that money to a
middle man. This will keep the price of food relatively affordable for the consumer as
well as the farmer. The government, on the other hand, will play a less invasive role,
providing services such as transportation systems, facilitating markets, and affordable
education. It will not, however, renew the myriad regulations supposedly written in the
name of health and safety that make small-scale local production costly and often illegal.

Lastly, sustainable farmers of the future will not be anxious about their ability to
access land or about the conversion of farmland to urban land uses. Each farm in a
cooperative will be owned and operated by a family unit, which will be defined very
broadly to include any group of people that live and work on the farm. In general, each
family unit will consist of three generations, the first being older people that have farmed the land and are currently in retirement. There will also be a middle generation that is responsible for the operation of the farm and the management of the money and a younger generation that is learning the farming trade as part of their education. The land for the farm will generally be passed down through "family" units, but the land will not split into separate parcels for younger generations, nor will one person inherit the farm. Instead, farm management will be done collectively, and everyone who is legally part of the "family" will be a part owner of the farm, provided they are of a certain age. People will be able to voluntarily renounce this should they decide they do not want to work on the farm, and new people can be included in this "family" once they have shown sufficient integrity so as to be accepted by all current owners. In the case that no one in the "family" wants to continue farming the land, the land will pass into a land trust managed by the farming cooperative, and ownership of the land will be passed to another family contingent upon their investment of both time and money in the farm, along with three years or so of proof that they are using the farm for agricultural purposes. Under these circumstances, farming the Rio Grande valley will be sustainable, and the communities that live in the area will able to sustain a rich cultural life as the climate once again stabilizes and new ways of living are envisioned by human societies.

**Concluding Thoughts**

The description included above describing the sustainable farm of the future reflects the great distance that stands between the current situation of agriculture in the Rio Grande valley and the conditions necessary for sustainable agriculture. While the farms interviewed for this project are generally the most sustainable alternative that consumers in the Rio Grande valley have with regards to where to buy their vegetables, they are not themselves wholly sustainable. Instead, they are most definitely a hybrid, as practice some parts of agriculture sustainably and do other things unsustainably. Among the things these farms do most sustainably are crop management, pest and disease control and to a certain extent, weed control. They are generally still searching, however, for more sustainable ways to use water, to conserve water, to fertilize their soil, to till
effectively, and to start and save their seeds. Finally, all of the farms find themselves caught in an economic system that under-values their product, provides a number of economic disincentives preventing land from being used for agriculture, and does not provide them job security. Over a longer time frame, while many of them acknowledge a burgeoning interest in their kind of farming, society still lacks effective mechanisms to maintain individual farms and to provide aspiring farmers with land of their own. In addition, many of the issues that farmers struggle with regarding water use are generated from larger, regional societal issues and political tug of wars. Most importantly, the economic obligation that farmers be very efficient with their labor requires the use of large amounts of fossil fuels and discourages the labor intensive practices that are often the most sustainable.

In order to create the conditions for truly sustainable agriculture in the valley, therefore, a complex mixture of farm specific, local, and regional systems all must reform and work in concert in order to ensure that agriculture in the Rio Grande valley can sustain itself over the coming centuries. Many of the conditions described above are conditions that farmers can begin to work towards almost immediately, conditions that are very much under their control to create. Some of these include implementing practices using minimum or no tillage, attempting to incorporate organic mulch, installing rain-water catchment systems and saving their own seeds. Others, such as the formation of cooperatives, require collective action at the local level. Finally, many of the issues highlighted here, particularly those regarding water, the price of food, and organic certification, are regional and national issues that require concerted political action. As such, the pursuit of sustainable agriculture is one that must be undertaken by many people working at many different levels. Hopefully, this document will help all the people who need to be involved - farmers, planners, advocates, and government officials - to envision a sustainable agricultural future for the Rio Grande valley. With a shared vision in mind, perhaps real change can be achieved in time to prepare for the upcoming rigors of climate change.
V. Works Cited


