AN ABSTRACT OF THE THESIS OF

Mark Christian Ingman for the degree of Master of Science in Water Resources Policy and Management presented on September 14, 2012.
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China's Minqin Oasis once welcomed traders along the ancient Silk Road with rivers, lakes, and lush forests, yet today the region's farmland and grassland are increasingly being engulfed by the sands of the Gobi Desert. The severity of this incremental catastrophe for a declining population of 300,000 residents has brought forth a host of recent water policies to include agronomic water conservation through plastic mulch use, computerized regulation and pricing of groundwater, and water diversions from the Yellow River. This study uses a multi-disciplinary and mixed methods approach to better understand farmer perspectives on why they implement certain water and land use practices in agriculture. The world's farmers currently use the majority of the world's available freshwater and arable land. Modern agriculture and its continued intensification also lead to increases in petroleum based inputs such as agrochemicals and agricultural plastics (plasticulture). Despite the large of impact of the decisions made by the world's farmers on natural resources, little research to date has sought to better understand farmers' perceptions and decision-making processes. Plastic film mulch is a technology that has existed since the 1940's and it has been used in places such as rural China for over five decades. This technology conserves a considerable

amount of irrigation water and it increases harvests, however, use of plastic for mulch causes waste disposal problems and is an expenditure of petroleum through plastic manufacturing. Without a fundamental understanding of why farmers perceive plastic mulch to be valuable to their households and communities, we may not fully grasp why its global application continues to increase year after year. Moreover, a focused study of plastic mulch use at the local level may also allow researchers and entrepreneurs to develop a suitable alternative mulch that does not consume non-renewable resources or result in detrimental plastic waste after its utility has been exhausted. This study uses household level interviews, surveys, and participant observation to better understand why Minqin County farmers in rural China continue to use plastic mulch and how it may influence their standard of living.

The Role of Plastic Mulch as a Water Conservation Practice for Desert Oasis Communities of Northern China

by
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I understand that my thesis will become part of the permanent collection of the Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Mark Christian Ingman, Author

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Note on transcribed Chinese language to Latin script and the use of pseudonyms

In some instances specific Mandarin Chinese terms are identified by italicized font and transcribed into Latin script according to the standard *Pinyin* system. These key Chinese terms are accompanied by English translations. All listed names of participants are pseudonyms in order to protect the confidentiality of interviewees and survey respondents.

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1. Introduction

There is a poem:

'Under boundless sky, on vast plains, cows and sheep can be seen when the wind blows and the grass lowers.'

Originally it was singing the praises of this place of ours. It [drought] began during the Qing dynasty, to the founding of the People's Republic of China, the Reform and Opening, up until these last several years. The Government has spent a lot of money to plant drought-resistant plants. Whether we can change [it] is still uncertain.

- Minqin County farmer[1]

After spending seven hot weeks at my study site in China's Minqin Oasis riding buses, carts, and making good use of my boots, I felt as though I was leaving this place with better sense of farmers' perspectives, insights, and local knowledge. It might be possible for one to imagine this thinning network of villages to be but a "mirage" amidst the vast and encroaching sands of the Gobi Desert. To me, however, the voices of Minqin's farmers remain real and vivid through the writing of this thesis research project. After leaving Minqin County for the final time, I returned to Wuwei City for an interview with a regional government official. This official was a well-groomed man wearing glasses and a collared shirt. Prior to starting the interview he

[1]Chinese: "有一首诗歌'天苍苍，野茫茫，风吹草低见牛羊'本来是歌颂我们这个地方的"

looked at me and said, “I’m not sure why you went through all the trouble talking to farmers. I could have simply told you all the things you wanted to know.” Despite his well-intended comment, I was confident that I did not waste my time talking to the farmers of Minqin County. Rather, it is perhaps for this very reason, the tendency for the voice of the world’s farmers to be neglected, that I personally hold it to be all the more valuable. After all, it is this thinning yet enduring population of people we call farmers who remain the principal stewards of our world’s land and water resources.

Owing greatly to the Green Revolution, modern agriculture has amassed a dizzying number of petroleum-based inputs since the mid-twentieth century. What is not obvious to the everyday person is to what a great extent the plasticization of agriculture (“plasticulture”) has become an additional large petroleum-based input for modern agriculture. A much abbreviated list of plastic inputs found today on farms in both developed and developing countries includes plastic mulch, silage bags, bale wraps, silo covers, pesticide containers, herbicide containers, greenhouse plastic, drip irrigation, irrigation piping, nursery containers, nursery trays, row covers, etc. (Levitan & Barros, 2003). One type of plastic input, plastic mulch, has experienced an unprecedented rate of popularization over the past three decades. Plastic mulch use is now common throughout the U.S., and in both developed and developing countries. Plastic mulch is a modern form of agricultural “mulch” that provides similar functions to traditional organic mulch such as straw or green mulches. One significant difference of plastic mulch is that it is a continuous and impervious sheet of polyethylene film

that covers the lengths of field rows. In China the common thickness (or thinness) is 0.08 mm. A typical way of installing plastic mulch in rural China is pictured in Figure 1.

Figure 1. Plastic mulch application in Sichuan Province, China
Photograph by author. May 2010.

Based on existing literature, my assessment of the amount of plastic mulch used globally each year only to be discarded after each growing season is an estimated land area that exceeds 20 million hectares (50 million acres) This is enough plastic to cover the entire state of Nebraska every year. My literature review on the topic indicates a growing trend of plastic mulch use that in turn shares an upward trend with plasticulture as a whole, as well as the increasing trend of general plastic consumption

for the world, (Humphreys, 2011; Kasirajan & Ngouajio, 2012; Miles, Becker, Kolker, Adams, & Nicholson, 2004; Wittwer, Yu, Sun, & Wang, 1987; Wittwer, 1993).

China is the world's largest consumer of plastic mulch and it accounts for approximately 40% of global plastic mulch consumption (Kasirajan & Ngouajio, 2012). Plastic mulch use provides a number of productive benefits that are described in later chapters. The specific benefit of using plastic mulch as a water conservation strategy in Northern China will be contextualized in Section 2.2. On a global scale the practice of using plastic products has fundamentally changed the face of modern agriculture (i.e. "plasticulture"). Furthermore, the continued use of plastic mulch may influence the socioeconomic status of farming communities worldwide.

Plastic mulch use is a global phenomenon that has increased in its application every year for the past six decades. By 1999, over 12 million hectares of land were being cultivated with plastic mulch globally, and this corresponds to 1 million tons of plastic mulch waste (Miles, Kolker, Reed, & Becker, 2005). The growth in agricultural plastic demand globally contributes to an overall average increase of 10% in world plastic production per year (Scarascia-Mugnozza, 2009). A major consequence of the extensive use of plastic mulch on a global scale is that there are few if any recycling options for farmers. As of 1994, less than 5% of agricultural plastics were recycled (Amidon 1994; Levitan &Barro 2003). The most common method of disposal for plastic mulch (arguably the "dirtiest" and least recyclable), is open burning on the farm. The burning of plastic mulch film releases carcinogenic dioxins 40 times that of

controlled high temperature incineration (Levitan & Barros, 2003). Furthermore, China commonly uses an extremely thin type of polyethylene plastic that is eight hundredths of a millimeter (0.08mm) thick. Installing this plastic with hand tools or machinery requires as much as 30% of the plastic mulch to be buried in the soil to seal the edges of field rows. The buried plastic usually gets shredded through tillage and thus contributes to the phenomenon known in China as the *baise wuran*, the "white pollution" that litters their landscape, endangers livestock, and pollutes rivers and lakes. The detrimental effects of single-use plastic mulch presents a tremendous disposal challenge not only for China, but for agricultural communities throughout the developing and developed world.

A search for existing literature on plastic mulch found hundreds of agronomic journal articles discussing the productive advantages of plastic mulch in various experimental field trials, and one journal article that discusses its water conservation advantages. Not one article was found that discusses the socioeconomic implications of the use of plastic mulch for farming communities at either the local, regional, or global level. Furthermore, no published articles were found that provide insight into how and why farmers continue to extensively use plastic mulch. This study sought to answer these important questions through exploring from farmers' perspectives how and why plastic mulch is used in agricultural communities. It is my belief that until we understand how farmers perceive the use of certain widespread practices that heavily influence our land, water, and energy resources, we cannot begin to formulate

informed policy and technical solutions for improving modern agriculture. Furthermore, in this case I contend the target for innovators should be to design alternative strategies to replace the derived benefits of plastic mulch, while secondarily to remain aware of the undesirable social and environmental costs of plastic mulch use. Individuals who participated in this study more often discussed the positive attributes of plastic mulch, therefore I, too, focus more on the benefits of plastic mulch in my thesis even though the negative implications of its continued use are many and far-reaching.

This research project embraces a multidisciplinary and mixed methods approach (Bernard, 2006) that does not favor any type of information over another. For this reason results presented in Chapter 4 as well as the discussion chapter organize information thematically rather than methodologically. The reader will experience the interweaving of information in this thematic approach as interview excerpts are accompanied by external data, and qualitative data interspersed with quantitative data. This approach is intentional and it is based upon my belief that the triangulation of information is best organized thematically rather than by the method of collection. Information is presented in such a way as to leave no doubt which method was used to collect the information.

The study presented here explores one over-arching question that is further explored by two supporting questions, as follows:

Summary question: What does plastic mulch provide the farming families of Minqin Oasis who are experiencing severe water resource scarcity?

1. Why do farmers continue to use plastic mulch?
2. Does the use of plastic mulch lead to an improvement in the standard of living for farming families?

The first and the second supporting research questions form the objective goal of the first and second sections of the results and discussion chapters; respectively (sections 4.1 and 4.2; 5.1 and 5.2).

This thesis is organized into six chapters. Section 2.1 of the literature review provides an overview of the more relevant historical developments in water resources and agriculture first within Minqin County. Section 2.2 outlines the historical origins of plastic mulch technology, its introduction to China, and its introduction to Minqin County as a modern farming practice. The literature review concludes in section 2.3 with a brief discussion of the theoretical underpinnings of this research project to include the emic perspective, social constructionism, and the Chinese social construction of *xiaokang.* Chapter 3 introduces the research methods, site location, study design, sampling methods, demographics, and a discussion of research bias. The fourth chapter provides results in three sections as they relate to the first and second research question, with the addition of how plastic mulch use continues to shape two recent agricultural water policies. The three sections of Chapter 5 discuss plastic mulch as an adaptive strategy, a more localized understanding of plastic mulch and standard of living, and the implications for plastic mulch water policy reforms.

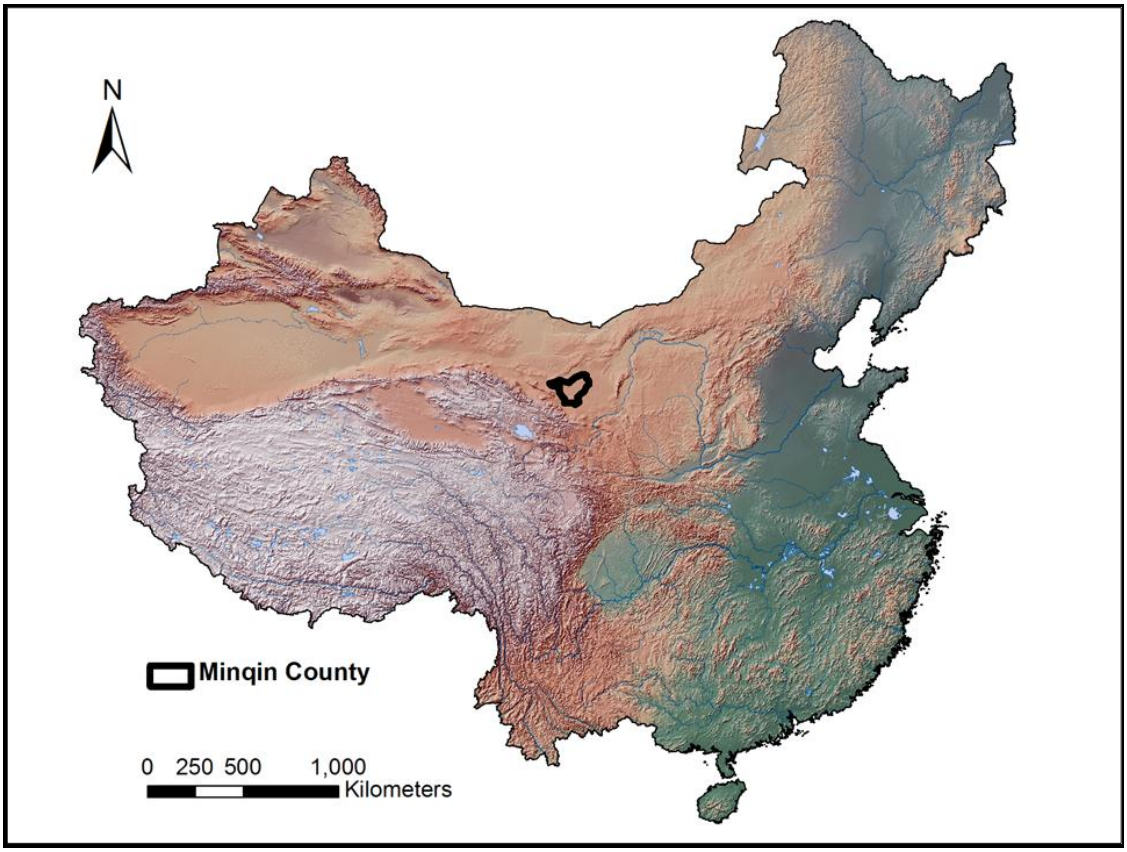
Chapter 6 concludes the thesis by providing a summary of findings, policy recommendations, and suggestions for further research.

2. Literature Review

2.1 A brief modern history of Minqin Oasis

Any resident of Minqin County will tell you their region is truly *queshui*, or water scarce. The greater Shiyang River Basin receives on average of 281 mm of annual rainfall, whereas Minqin Oasis receives an average of 113 mm of annual rainfall (Kang, Su, & Du, 2009). This is an an extremely small amount of precipitation when compared to the potential annual evaporation of over 2600 mm in Minqin Oasis. The renewable surface water of the Shiyang River is generally considered to be the "lifeblood" of Minqin Oasis because it experiences an annual net loss of water through evaporation. Minqin County is situated along the lower reaches of the Shiyang River. This river historically flowed in a northeasterly direction from the Qilian Mountains in the southwest, to its terminal point at Qingtu Lake in the northeast. Minqin County is wedged between the Baidajilin and Tenggeli Deserts (see Figure 2).

Figure 2. Map of China and Minqin County



After the Hongyashan Reservoir was built in 1958, Qingtu Lake dried up (Hermans, Droogers, & Winsemius, 2008). The construction of the Hongyashan Resevoir effectively disconnected the central and lower Shiyang River from the upper watershed (Wuwei District). Today less than 8 % of historical flows from the upper wattershed reach Hongyashan Resevoir (Huo et al., 2007), much less its historical terminal outflow at Qingtu Lake. Today, all that remains of Qingtu Lake is a dry lakebed commemorated by a monument and a visitor interpretive center. The growth

of Wuwei city in the upper watershed, its surrounding industry, and the agricultural communities of the upper Shiyang River have consumed nearly all of the surface water that historically served as the lifeblood to Minqin Oasis (Shi, 2000). The taking of surface water rights by the greater Wuwei District, significant population growth throughout the Shiyang River Basin dchapturing the late 20th century, intensification and expansion of agriculture, and ineffective regulatory policy implimentation at the local level were some of the primary factors that led to the rapid overexploitation of Minqin's groundwater resources.

The dramatic disappearance trees and vegetation over the past 50 years seems to weigh heavily upon the minds of Minqin's residents. One woman recalled, "When I was a child everywhere had trees, but now essentially everything is the Gobi Desert. Before the 60's everywhere had trees." These forests were primarily the silver leaved tree known as the Russian olive (*Elaeagnus angustifolia*). Yang et al. (2007) estimated after the 1950s' there was a loss of 9,000 hectares of the region's Russian olive, and 23,000 total hectares of the Chinese purple willow (*Salix sinopurpurea*) and the "desert cherry," *sha yingtao* (*Nitraria tangutorum*), a shrub that bears edible fruit (see Figure 3).

Figure 3. A young girl eating Minqin Oasis "desert cherries"
Photograph by author. July 2011.

Another study reported the loss of approximately 30,200 hectares of forested land and 70,000 hectares of pasture land in the 1960s (Shi, 2000). It is unknown whether this loss of forested land in Minqin County coincides with the national policy of the 1960's known as the 'Three Great Cuttings,' *san da kanfa* that resulted in an unprecedented loss of forest resources across the nation the nation of China. Regardless of the cause, it appears that some exploitation of Minqin's forests occurred prior to an appreciable decline in the groundwater resources. When the average depth of groundwater exceeds 5 meters, even the most drought-tolerant plants begin to die (Shi, 2000). Data from Shajingzi in Minqin County suggest that sufficient groundwater to support natural

vegetation existed up through the mid 1960's and into the 1970's, however by 1980 the average depth of ground water had met or exceeded 6 meters (Kang et al., 2004), and this effectively eliminated any possibility trees could survive in this area without irrigation.

Following the loss of the historical flows of the Shiyang River, the 1980's brought a host of converging factors that may have influenced the rapid overexploitation of water resources in Minqin County: the Reform and Opening Era, Household Responsibility System (Decollectivization), electrification of villages—the switch from diesel to electric groundwater pumps (Aarnoudse, Bluemling, Wester, & Qu, 2012), and increased intensification of agriculture (Green Revolution).

The market-oriented liberalization of agricultural production during implementation of the Reform and Opening, and particularly the move to decollectivize agriculture under the Household Responsibility System in the early 1980's, is especially relevant to this study. During the Collectivization Period, the sub-village units, *dui* or work teams, and *she* or commune groups, were considered by outsiders to have been disbanded upon the implementation of the Household Responsibility System. This policy allowed peasant farmers to more directly and freely make agricultural production decisions. However, as will be explained further in Chapter 5, these legacy institutions from the Collectivization Period still exist and may still influence decisions made by individual farmers. Furthermore, the legacy sub-village collectivized production units have proven to be important for the

implementation of policy reforms in Minqin County as recently as 2008 (Aarnoudse et al., 2012).

The liberalization of agricultural policies in Minqin County coincided with steep declines in Minqin County's groundwater resources. Over the past decade Minqin's groundwater level exceeded an average depth of 14 meters throughout the county (Kang et al., 2004). Many wells pump from depression cones as deep as 300 meters. While the rate of groundwater decline has in recent years eased, the most recent estimates still indicate an annual rate of decline of about 0.3-0.4 meters (Han, 2011). Today, much of the non-crop vegetation one sees in Minqin Oasis is government reforestation projects along central, high visibility traffic corridors. Additionally, the ability to keep non-crop vegetation alive within the central portion of Minqin Oasis is regarded as "farmland protected" vegetation (Yang, et al., 2007). When land use restrictions and severe circumstances caused farms to be abandoned, a considerable amount of vegetation that was previously supported through irrigation ditches and intentional watering by farmers withered and died as these farmers abandoned their farms. One farmer commented, "People cut down lots of trees because the government would not let them cultivate land. After the well closures the forests were not protected, so all that could be done was to cut them down and use them for firewood." While I was traveling one day in Minqin County it occurred to me that if one wants to find a person, they need only first find a tree and then they will soon find the person who waters the tree. The government realized the truth of this as

well, that is, the added value farming households provide through keeping vegetation alive.

On October 1, 2007 China's national Premier, Wen Jiabao visited Minqin Oasis. His visit was perceived by the relatively remote region to be a strong show of support from the central government for Minqin's environmental and socioeconomic problems. Banners heralding his pledge, "Minqin must not be allowed to become the second Lop Nur" can be found all throughout the county. Following the Premier's visit, Minqin farmers experienced the strictest and most sweeping regulation of water and land resources in recent history. This policy enacted in 2008 and implemented in 2009 is called *Guanjing yatian*, or Well Closure and Land Restriction. This policy resulted in the closure of all but 6,290 of Minqin's 14,200 wells (Song, 2008). One Minqin farmer commented that the closing of wells in his village meant that six wells were reduced to two. These remaining wells in Minqin County were maintained for intensively-monitored agricultural use through having card swipe metering technology installed upon the top of the remaining active wells (see Chapter 4). More specifically, Well Closure and Land Restriction placed a firm cap of 415 m^3 of available irrigation water per Chinese *mu*, and a reduced land allotment to 2.5 *mu* per person in each household[2]. This shift in policy represents a reduction of approximately half the water and land resources allotted to Minqin farmers as was allotted in the past.

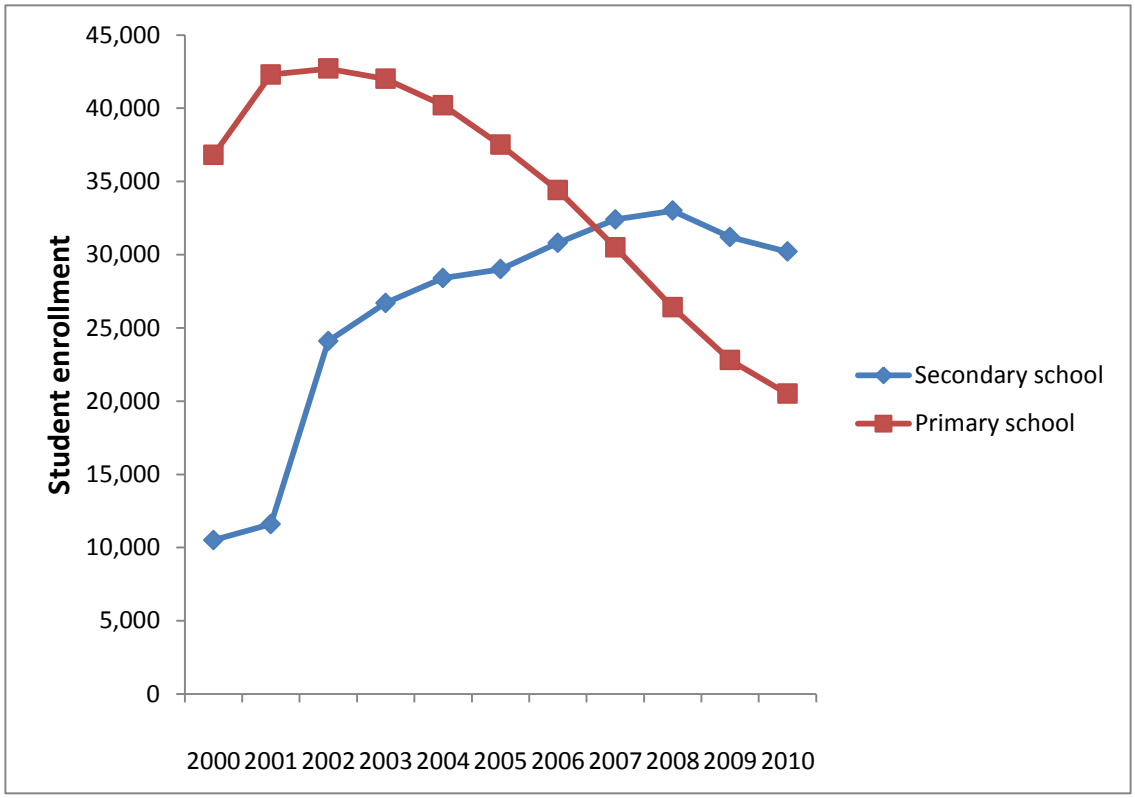
[2] A Chinese *mu* equals 0.667 ha, or approximately one-sixth acre

Prior to the Well Closure and Land Restriction policy, in 1995 the government introduced *Minqin diaoshui gongcheng,* or the Minqin Water Diversion Engineering Project. The project began providing surface water to Minqin in 2001, yet the price of river water remains 10 times the cost of groundwater. Despite the cost, Minqin farmers are being restricted to use the expensive river water for half or more of their irrigation requirements in many of the townships. Many farmers view this provision and diversion of expensive out-of-basin water as still "not having water" in Minqin. It appears that the goal of these policies are unified under the Shiyang River Basin Management Plan in which annual groundwater withdrawal targets for Minqin County of 400 million m^3 in 2000 will be reduced to 170 m^3 million by 2020 (Aarnoudse et al., 2012). The combination of an increasingly serious water scarcity situation in Minqin County and scrutiny from China's Premier appear to be connected to several aggressive agricultural water policies being implemented over the past decade.

While the population of Minqin County grew approximately 50% from 193,000 in the 1960's to over 305,000 in the past decade (Huo et al., 2007), water scarcity and policies such as Well Closure and Land Restriction have caused more farming families to give up farming and migrate to urban areas for wage labor. From 1998 through 2008 approximately 32,000 people left Minqin County—predominantly from the five most remote and water scarce townships along the Lake District—Shiyang River's lowest reaches (Yang, 2009). The farmer I lived with in the Lake District, Mr. Chen, told me "People aren't having children anymore and my

granddaughter doesn't have any other children to play with." The same evening I visited a boarded up school whose presence made visible the decline in the number of children in Minqin County. This decline is represented by a graph of student enrollment in primary and secondary schools in Minqin County over the past decade (see Figure 4). It may be that we are only beginning to see the effects of regional water and agricultural policies for the farming communities of Minqin Oasis.

Figure 4. Minqin County student enrollment by year



Source: China County Statistics, All China Marketing Research

This section has thus far outlined some of the most significant ecological, environmental, social, and political structures underpinning Minqin's recent history.

Surface water of the Shiyang River is predominantly consumed by upstream users in the Wuwei District. Over the past fifty years, twenty-three water control projects or embankments were constructed along the upper reaches of the Shiyang River (Kang et al., 2004). Only a small fraction of the river's historic surface flows still travel to Minqin County, and these flows are further manipulated by the management of Hongyashan Reservoir. What surface water is allowed to reach Minqin farming communities in the lowest reaches travels along lined canals that restrict the natural recharge of groundwater. The river water provided to Minqin farmers usually comes at a steep price through out-of-basin water diversions—most often sourced from the Yellow River. The water and land allocations regulated by Well Closure and Land Restriction of 2008-2010 have severely curtailed the profitability of farming and this may have added to the number of families who have decided to abandon their farms. What have helped retain some profitability in farming are tremendous shifts in agricultural production from high water use staple crops such as wheat, to comparatively water-conserving and profitable cash crops such as cotton (see Chapter 4.1). More often it is the middle aged and older generation of farmers who remain. These older farmers recall a time when Minqin County was a forested oasis, and the youth still wanted to become farmers. Today, Minqin's future rests directly upon the question of whether it still has the capacity to sustain its livelihood in the face of an increasingly diminishing supply of water resources.

2.2 The historical context for continued plastic mulch use

Few people in the first half of the twentieth century would have predicted that a new invention—plastic film mulch—would become ubiquitous in world agricultural systems by the end of the century. In 1938 a British company developed and improved a method for producing a polyethylene sheet film that could be used for construction of low cost greenhouses (Courter, 1965). Later, in 1956, Dr. Emery Emmert, who is also considered "The Father of Plastic Greenhouses," published an article in *Kentucky Farm and Home Science* titled "Plastic row covering." In 1958 China first began using plastic sheet coverings to warm and protect rice seedbeds from cool and windy weather in the central and southern provinces (Wittwer, 1993). By 1965, use of plastic sheeting had spread to all provinces, autonomous regions and municipalities for promoting earlier crop production. As early as 1965 the use of plastic films for the purpose of early crop maturity had been introduced to all provinces and cities throughout greater China. (Wittwer et al., 1987). The use of plastic films was so significant that it became known as the "third revolution" in Chinese agriculture after chemical fertilizer and new seed varieties (Chen, Li, Wang, & Liu, 2012). Some also referred to this as the "white revolution," denoting the common color of agricultural plastic.

Estimates of China's history of plastic mulch adoption coincide very closely with Minqin farmers' accounts. For instance, in 1986 China became the country with the largest use of plastic mulch in the world and by 1987, approximately half of

Minqin farmers had adopted plastic mulch use on their farms (Chen et al., 2012; S. Wittwer, et al., 1987). Plastic mulch can be said to be an important economic force for China's agricultural sector during the early Reform and Opening era. By 1984-1985 China had become the largest cotton-producing country in the world and the widespread use of plastic mulch for its productive advantages was a key part of this achievement. Not only is cotton cultivation with plastic mulch a critically important means of agricultural production for Minqin County, but for greater China this system increased the yield of cotton an estimated 25-30% (Wittwer, et al., 1987). In the mid-1980's, land in cotton production represented nearly two-thirds of the land China cultivated with the use of plastic mulch. Today Chinese farmers utilize plastic mulch with many crop types, covering approximately seven million hectares (Kasirajan & Ngouajio, 2012), or 5% of China's arable land (Central Intelligence Agency, 2012). While I conducted field work throughout Minqin County I was able to find one elderly woman who farmed 3 *mu* of land for subsistence crops without the use of plastic mulch. This woman was an exception, however, to the 140 other farmers I spoke with who did use plastic mulch. Her exceptional case is most likely a result of her cultivating a small amount of land for subsistence purposes. Traditional flood irrigation techniques have remained the form of irrigation used, regardless of whether plastic mulch is used by farmers. The compatibility of plastic mulch with traditional flood irrigation techniques appears to be an important factor leading to its large scale

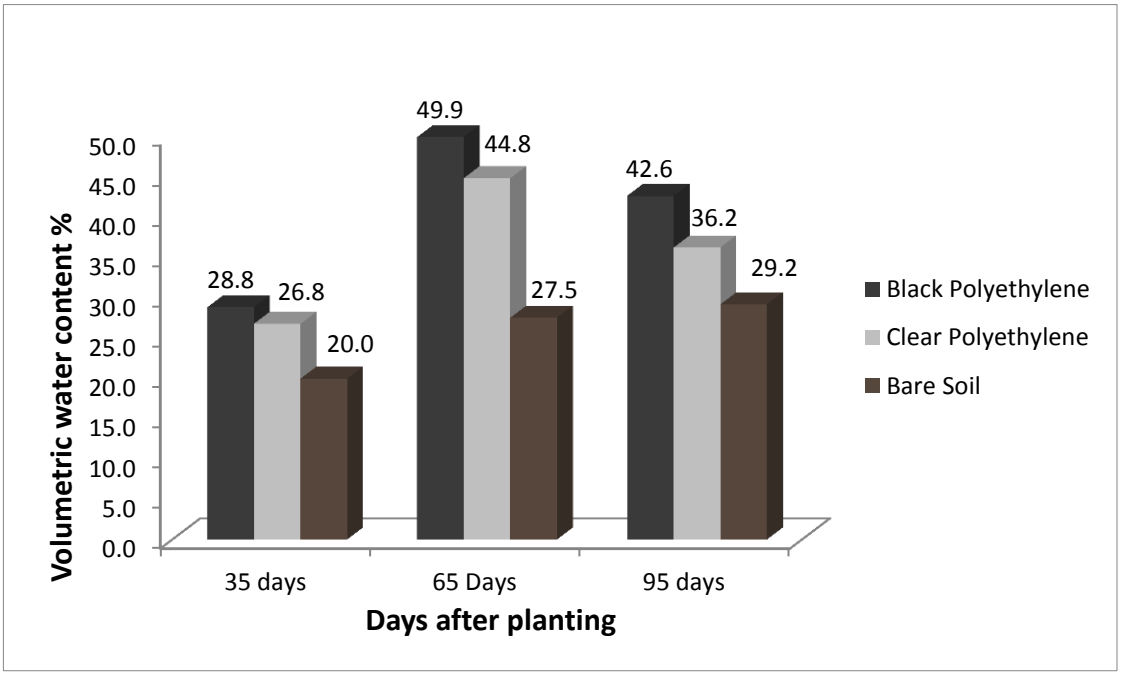
use. With the aid of plastic mulch use, Minqin farmers are irrigating their fields with as little as half the irrigation water required prior to introduction of plastic mulch.

Much of China's plastic mulch use occurs in the arid and semi-arid northern regions of China where insufficient rainfall necessitates irrigation of agricultural land. Furthermore, most of northern China lacks sufficient renewable surface and groundwater resources to sustain its current level of irrigation of arable land. Up to 97% of farmers in northern China still rely upon traditional flood irrigation techniques (Deng, Shan, Zhang, & Turner, 2006). The water shortage in Northern China is one of China's greatest social and environmental challenges in the 21st century. Nearly two-thirds of all arable land is in Northern China, yet this region contains less than 20% of the nation's water resources (Deng et al., 2006). Evidence of this unprecedented water problem is the central government's investment in the South-to-North Water Diversion (SNWD) Project—the largest water diversion in all of history—that when completed will supply 44.8 billion m^3 of water from the Yangtze River at a cost 230-250 billion yuan (Nickum, 2006; Zhang, 2005). Such large investments in waterworks by the Chinese central government highlight the extent to which a reliable supply of water is vital to China's continued economic growth and food security. In contrast to such large national-level investments in infrastructure, others have proposed China pursue small-scale, agronomic water conservation measures to include altered cropping patterns, modification of tillage practices, and the use of plastic mulch (Shen & Wang, 1999). Southern Daily News indicated that people of the Lake District—the

most remote district in Minqin County—had largely transitioned to cultivating water-conserving cash crops. Residents now buy staple grains from the market and have mostly discontinued subsistence farming (Yang, 2009). The notion of structuring a "supply and trade," growing higher value cash crops and importing higher water demand staple crops is a recognized water conservation strategy for Northern China (H. Yang & Zehnder, 2001). This paper will later discuss the probable connection between plastic mulch use and cash cropping in Minqin County. At multiple levels of government, the Chinese have pursued the path of decentralized water conservation policies such as plastic mulch implementation (Shen & Wang, 1999) while at the same time supporting large, centralized projects such as the SNWD to ameliorate the severity of water scarcity in Northern China.

Although the worldwide use of plastic mulch has steadily increased over the past six decades, there has been little research investigating to what extent the use of plastic mulch is for water conservation purposes. Plastic mulch provides a number of benefits that include increased crop production, water conservation, soil warming, weed suppression, seed germination, fertilizer conservation, agrochemical fumigation, inhibition of pests, and rain shedding. The variety of benefits that can be derived from plastic mulch use may contribute to few people viewing it specifically as a "water conservation" technology. Nevertheless, plastic mulch is an effective and proven water conservation technology as demonstrated by experimental field results conducted in Nigeria (Figure 5).

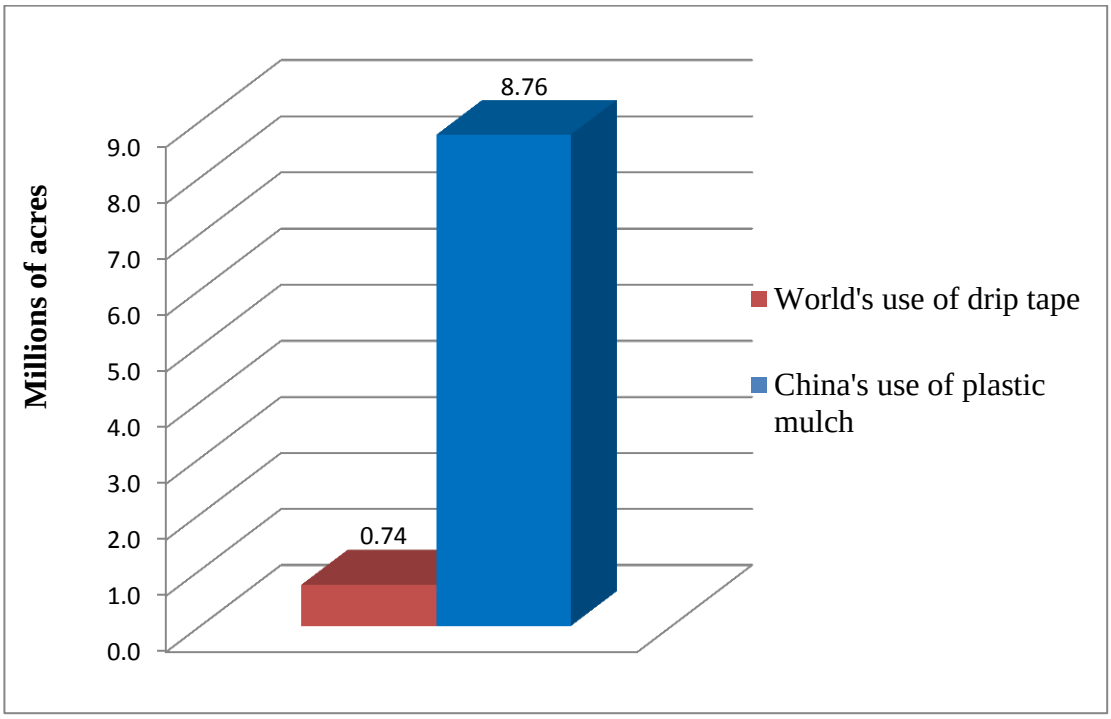
Figure 5. Effect of plastic mulch on soil volumetric water content



Source: adapted from (Anikwe et al., 2007)

A water savings of approximately 20-30% of volumetric soil moisture content may seem comparatively small in comparison to water conserved through drip irrigation. However the fact that plastic mulch use is compatible with traditional flood irrigation practices, its use requires a relatively low initial cost of investment and the lack of need for pressurized piping, are a few of the factors that appear to have led to its large scale adoption in world agricultural systems (Figure 6).

Figure 6. Comparison of land area in China cultivated with plastic mulch versus global land area using drip irrigation (1993)



Source: Adapted from (Wittwer et al., 1987; Wittwer, 1993)

As seen in Figure 6, China alone cultivated over nine times the amount of land area using plastic mulch as the entire world cultivated using drip irrigation. Today China cultivates an estimated seven million hectares (17.3 million acres) of land with plastic mulch (Kasirajan & Ngouajio, 2012).

The purpose of this section has been threefold. First, it is important to understand the general historical context and proliferation of plastic mulch both in China and worldwide. Secondly, it is important to emphasize that while plastic mulch provides a host of desired benefits, its ability to save considerable volumes of

irrigation water firmly establishes it as a “water conservation technology.” As such, plastic mulch can be directly compared to drip irrigation as another, and potentially more relevant, water conservation technology for applied research. Finally, it is important to recognize the extent to which use of plastic mulch has become ubiquitous in world agricultural systems—far surpassing that of drip irrigation. Research on agriculture in the developing world must be informed by a fundamental understanding of the full range of technologies and practices currently being used by farmers. If plastic mulch is being implemented more extensively than drip irrigation, then it is important to investigate the causes for this higher rate of adoption. This study serves as the first social science research project to investigate why farmers use plastic mulch and how use of plastic mulch may influence the socioeconomic development of farming communities.

2.3 Theoretical Foundations

This study sought to reduce a gap in applied social science research for understanding why plastic mulch is used in agricultural communities from the farmer’s perspective. The breadth of plastic mulch research currently available mostly views plastic mulch as a simple technology that can be adequately understood under laboratory and controlled experimental conditions. From a methodological standpoint the design of this type of research excludes farmers as a complex variable for how plastic mulch is used and applied. Based upon the understanding that it is people who

use plastic mulch, I have decided to make the "human variable" the primary focus of this research project to more adequately investigate why plastic mulch continues to be used by farmers when alternative products exist. In contrast to social science research methods, experimental trials have difficulty explaining why the rate of plastic mulch adoption by farmers is so much greater than that of drip irrigation.

This study was conducted at the household level. As explained further in the following chapter, I used participant observation, interviews and surveys to gain access to the perspectives of individual farmers. This methodological approach borrows its theoretical basis from several social scientists of the mid-twentieth century. Kenneth Pike first coined the terms "emic" and "etic" to provide a systematic research strategy for the relationships between language and behavior founded upon structural linguistics (Pike, 1954). Marvin Harris explained, "emic refers to the presence of an actual or potential interactive context in which the ethnographer and informant meet and carry on a discussion about a particular domain," (1976). He later added, "The ethnographer discovers principals that represent and account for the way in which that domain is organized or structured in the mental life of that informant." Plastic mulch is the domain in this study, and as the researcher I interacted with farmers to better understand why they choose to continue the use of plastic mulch. A reflection of how the domain of plastic mulch use is "organized and structured" in the minds of Minqin farmers as expressed through interview responses is illustrated by a theme map in Chapter 4. The emic perspective effectively allows for a more nuanced understanding

of the ways Minqin farmers use adaptive strategies to ameliorate the effects of severe water scarcity. Some of these strategies include plastic mulch use, cash cropping, salt resistant crops, and retaining the structure of work units and communes from the Collectivization Period to pool and use labor more effectively. In agreement with Harris' stance not to privilege the emic or insider's perspective as being an inherently more accurate representation of so-called reality, this project also utilizes outside information and external data that in some instances contradicts the perspectives and cognitive maps of individuals. In this way the study also considers the "etic" perspective.

When I asked farmers about plastic mulch use during interviews their responses in almost every case included the key words *queshui*, and *ganhan*, water scarcity and aridity (or drought). The connection these two terms shared with plastic mulch use was not immediate but rather implied. Water scarcity and the dry conditions appeared to be more important to farmers than questions relating to the use of plastic mulch. It appears the domain that I was researching, plastic mulch, was nested within a larger domain, water scarcity. As it will be discussed further later in this thesis, resources are socially constructed (Robbins, 2004). I discovered early on in this study that plastic mulch and water resources for Minqin farmers are the manifestation of two nested social constructions.

The theory of social constructionism is traced to the seminal work by Berger and Luckermann, *The Social Construction of Reality* (1967). Within the context of the

global problems of increasing population and the concomitant relative decrease in per capita supply of natural resources, one viewpoint is that at some point, as a consumer perceives a decline in natural resources, he or she may decide to consume less. For example, in the face of an energy shortage, a consumer may choose to drive less. This example suggests people may be "endlessly stretching the world's energy supply" through such things as conservation, and in so doing, demonstrates that resources are socially constructed rather than given (Robbins, 2004). This example shares a strong parallel to Minqin Oasis where the "water scarcity" crisis is well-perceived by farmers, and in turn, they appear to be stretching their limited supply of water resources. The importance of *jieshui*, or water conservation, is both a common expression and a commonly cited term on billboards, banners, and printed media.

What is water scarcity? The term "water insecure" has been defined as "when an individual does not have access to safe and affordable water to satisfy his/her needs for drinking, washing or their livelihoods," (Rijsberman, 2004). Despite this definition of water insecurity, there is no commonly-recognized definition of water scarcity. By the Falkenmark indicator (water stress index) which identifies a threshold of 1,700 m^3 per capita of renewable freshwater per year, any region that cannot provide this volume of water to its residents is considered to experience "water stress" (Rijsberman, 2004). When the volume of available water resources falls below 1,000 m^3, the region is "water scarce," and when it falls below 500 m^3 it is deemed to have "absolute scarcity." By many accounts much of Minqin's groundwater is non-renewable

"paleowater" (Edmunds, Ma, Aeschbach-Hertig, Kipfer, & Darbyshire, 2006). Based upon data indicating the total renewable Shiyang River flows to Minqin county have frequently been less than 1×10^7 m^3 during the wet months of the year (Huo et al., 2007), one could easily conclude that by the Falkenmark indicator Minqin County experiences "absolute scarcity." However, the use of macro indices to assess water resources availability does not fully represent water is use in a particular region, or how use of water as a resource is socially constructed. For example, water use in the United States is 2480 m^3 per capita annually, whereas the global average is 1240 m^3 per capita annually (Hoekstra & Chapagain, 2007). In China the average annual per capita use of water is 700 m^3. What may be "water abundance" in the China could be perceived as "water scarcity" in the United States. Thus, perceived "scarcity" of a resource could more closely relate to the accepted methods and extent to which the resource is used in a particular region or locality, rather than the conventional belief that "scarcity" is a simple measurement of a resource's physical status in nature. Moreover, what national and global level statistics also blur is the dramatic difference in water use patterns between urban and rural households. I concur with the conclusions of previous research that there is no commonly accepted definition of water scarcity (Rijsberman, 2004), and instead view the availability or scarcity of water resources as socially constructed at the local level.

The use of plastic mulch appears to reside within the larger social construction of "water scarcity" as perceived by Minqin farming communities. To what extent does

plastic mulch stretch the availability of water resources in Minqin Oasis? I borrow the following description of social constructionism from Gergen: "the process of understanding is not automatically driven by the forces of nature, but is the result of an active, cooperative enterprise of persons in relationship," (1985). Through the emic perspective and through understanding plastic mulch as a domain nested within the larger social construction of water scarcity, I turn to how social constructionism also supports my second primary research question.

To understand how plastic mulch may influence the standard of living in Minqin County, I borrow the Chinese social construction of *xiaokang*, directly translated as "small comfort." This term dates back to the ancient Warring States Period (475-221 BC), yet more recently it was brought back into the political arena by former President Jiang Zemin and also the current president, Hu Jintao (Tilt, 2011). *Xiaokang* is a highly recognizable term to people of varying socioeconomic status throughout all of China. While the term is cultivated in political dialogue from the central party, it is not uncommon to see local townships with painted *xiaokang* slogans (Figure 7).

Figure 7. Slogan in Minqin Oasis that reads, "Conserving water brings *xiaokang.*" Photograph by author. June 2011.

From the perspective of the national political stage, reaching *xiaokang* life was associated with specific and material standards of living. For instance, the 13th National Congress (1987) proposed a three step developmental strategy as follows: 1) the GNP of 1990 to double that of 1980 and to solve the peoples' *wenbao,* or "warm and full" problem, 2) by the end of the twentieth century for the GNP to grow twofold and for the people to reach *xiaokang*, 3) by the middle of the next century for the GNP to reach that of moderately developed countries, and for the citizenry's living conditions to be more affluent and to be more fully modern, (Zhang, Ye, & Li, 2012).

Despite such definite and predominately materially-oriented standard of living targets, there are multiple understandings of *xiaokang* among Chinese citizens. The common perspective of *xiaokang* at the local level coincides with one or a combination of idealized or less idealized senses. According to the Modern Guifan Chinese Dictionary *xiaokang* refers to 1) a Confucian society that is something less ideal than the "*da tong"* [utopia] society, 2) a more contemporary reference to the achievement of a family's economic circumstances and standard of living, and 3) the society's economic circumstances and the nation's level of development (*Xiandai Hanyu Guifan Cidian*, 2004). While *xiaokang* has been more broadly operationalized to include "quality of life" (Tilt, 2011), this study generally accepts use of *xiaokang* in the sense of "standard of living." This standard of living definition is operationalized with the recognition that a number of the participants' perspectives may imply the more idealized and more fully encompassing sense of "quality of life." *Xiaokang* is a social construction unique to Chinese society, and in this study it has been operationalized to compare how the practice of plastic mulch use may influence household income, standard of living or *xiaokang*, and also what else may be needed to achieve *xiaokang.* This final question of "what is needed to reach *xiaokang*" serves to connect (or perhaps reconnect) public perception with the political process of formulating future developmental policy.

As discussed in the first part of this chapter, the national, regional, and local Chinese governmental agencies have formulated and even implemented

developmental policies to ameliorate the severity of water scarcity in Minqin County. This thesis takes a brief look at some of the most significant agricultural water policies in the context to the data collected from this study. My brief policy analysis utilizes the following definition of public policy:

> Policy is about making decisions on behalf of social groups—including the decision not to decide. *Public policy* may be defined as anything governments do or do not do. Thus, if a government decides to do something, that is public policy. If a government decides not to do something, that is also public policy. (Reimer & Bollman, 2010)

The introduction of plastic mulch in Minqin County in the early 1980's was a policy decision on the part of the local and regional Minqin water and agricultural bureaus. With the knowledge its introduction was a government policy, this study foremost takes interest in why Minqin farmers *continue* to use plastic mulch, and secondly to what extent do the most recent Minqin County agricultural water policies reinforce ongoing plastic mulch use.

This section has outlined the relevant theoretical constructs underpinning this study. Firstly the *emic* perspective provides an insider's perspective—that of the farmer—of how plastic mulch is used and why it is continued to be used. Secondly, through the emergence of content saturation it became apparent that plastic mulch use may be a social construction that is nested within a larger social construction, "water resource scarcity." Through the overarching theory of social constructionism, I argue that for Minqin Oasis, water resources are similar to other natural resources in the sense that they are socially constructed—and that concerns over the availability of

water resources permeates the views and perspectives of Minqin farmers. Next, to better understand the extent to which plastic mulch use may be influencing the household economy, I operationalize the social construction of *xiaokang* as "standard of living." Finally, farmer responses to questions about what is needed from their perspective to reach *xiaokang* serve to inform and underscore the value of future agricultural water policy.

3. Methodology

Overview

The field work portion of this research project included pilot interviews, semi-structured interviews, surveys, and participant observation. These methods were used to collect data in Minqin County from June through July of 2011 to explore one over-arching question and two additional supporting questions.

What does plastic mulch provide the farming families of Minqin Oasis who are experiencing severe water resource scarcity?

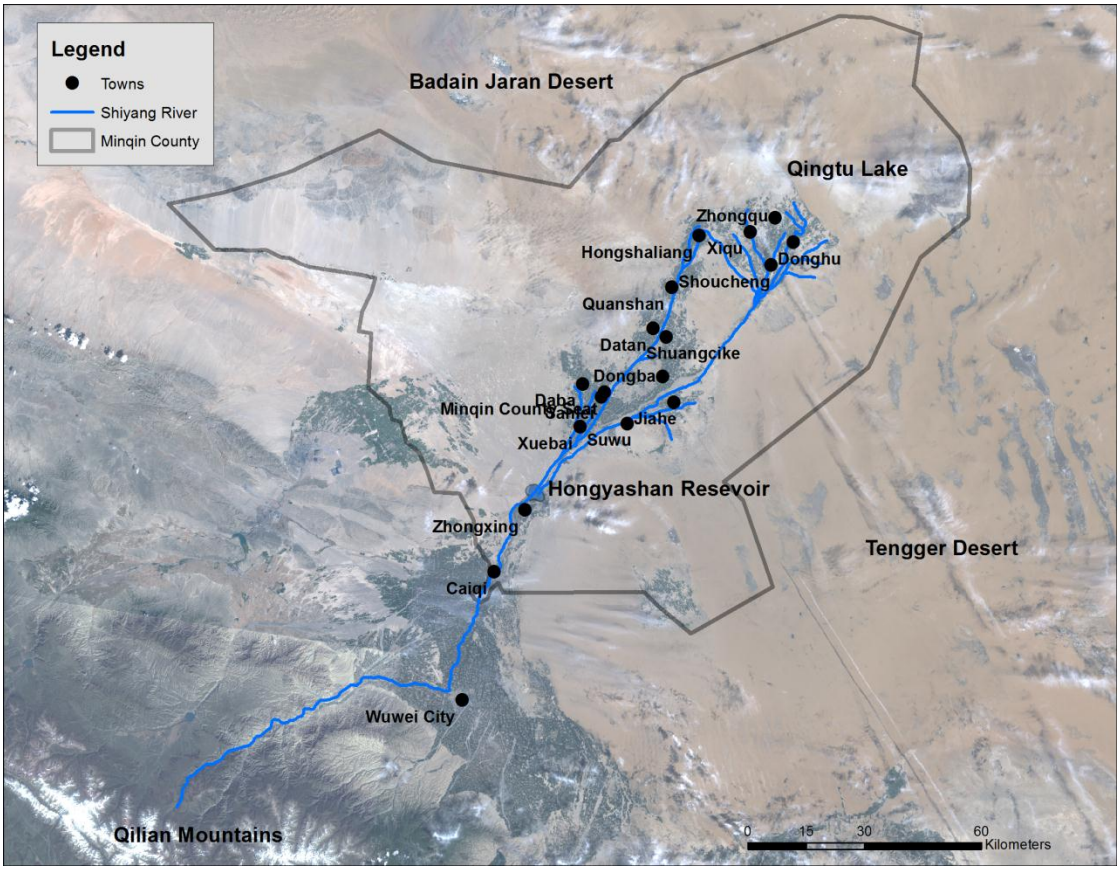
1. Why do farmers continue to use plastic mulch?

2. Does the use of plastic mulch lead to an improvement in the standard of living for farming families?

Field work was organized into three phases. Phase one began with testing the pilot interviews to improve the interview questionnaire. The interview questionnaire was semi-structured, a format in which some questions were open ended to allow participants to provide additional information they judged to be relevant. After all revisions were made based upon the pilot interviews, two interviews were conducted in each of the 15 townships for a total of 30 interviews. The final interview questionnaire is provided in Appendix A. While I was accompanied by two Chinese students, I asked all of the interview questions to ensure uniformity. Owing to a dialect of the region, *Minqin hua,* a local interpreter was used to transcribe all responses into standard (typed) Mandarin Chinese. Detailed reflexive notes were recorded after each

interview. One of the benefits of conducting interviews in the first phase prior to the surveys was to improve the survey questionnaire. Each survey requested the respondent to rate their level of agreement with a provided statement on a five point Likert index (Likert, 1932). The questions involved the following content areas: perception of plastic mulch use, water scarcity and water quality, and the local standard of living (Appendix B). Numbered responses of five levels or greater provide continuous data (Vaske, 2008). These data were later assessed with descriptive statistics. Additional questions were asked that were not on a five point scale. Pilot surveys were conducted to improve the survey questionnaire and also to ensure all team-members were trained and capable of conducting surveys independently and uniformly. After this training and the improvement to the survey questionnaire was completed, the second phase of the project began, consisting of the household survey. Two surveys were conducted by each of the three team members for a total of six surveys in each of the sixteen townships to include *Zhongqu* township, for a total of 96 respondents. A map of Minqin County and the 16 townships is provided in Figure 8.

Figure 8. Map of Minqin County



Imagery source: Landsat 5 Thematic Mapper 2010

Phase three included a five day homestay, during which time I lived with a farming family in *Zhongqu* township. Living with the family provided a more localized and site specific understanding of their lives and this opportunity also provided access to different types of information. Each day I took part in their daily routines, activities, and meals. I would also help with such things as digging irrigation ditches or weeding the fields. I took notes of things I observed and I had many short and extended conversations around questions that arose from things that I observed.

This information was recorded in my field notes on a daily basis and it was later reviewed as part of the data analysis. After returning to the Minqin County seat, I conducted an interview with a plastic recycler and also an interview with the CEO of a plastic reprocessing company. My final interview was with a Wuwei Water Bureau official.

Chinese Agricultural University and the Wuwei City Water Bureau jointly hosted me for the duration of my research. I was also provided lodging and access to resources at the Gansu Province Central Irrigation Research Station in Minqin County near Wuwei City. However, for the majority of my field work I lived and worked from the Minqin County seat (city) located 95 kilometers to the northeast of Wuwei City. It is from the Minqin County seat that I traveled on a daily basis to conduct the interviews, surveys, and to record field notes. During phase two, I located a township that had recently been delisted as a township, *Zhongqu*, and administratively reorganized under *Xiqu* township. Residents of *Zhongqu* confirmed this reorganization was a result of farm abandonment and a recent reduction in overall population. Since a previous survey study included *Zhongqu* township (Lee & Zhang, 2005), I decided to sample its population as a township for this study despite its recent administrative reorganization under *Xiqu* township. For agricultural income, all townships were primarily supported by conventional and commodified agricultural practices, and secondarily by subsistence agriculture. Occasionally animal husbandry was an

additional source of agricultural income. Wage labor was a significant source of income for many families.

Recruitment of participants

Sampling criteria for both interviews and surveys were based upon age, occupation, and willingness to participate. All participants were required to be no less than 18 years old and needed to have some first-hand experience with farming practices. While there was no requirement that participants must have experience using plastic mulch on their farm, all participants both knew what plastic mulch was and all but one farmer indicated it was used on their farm. One of the challenges to sampling the population of Minqin County was the lack of names and addresses of individuals for generation of sampling frames. Furthermore, one village cadre told me to leave his village even after my research approval letter was presented. Lacking a detailed sampling frame, the study utilized opportunistic sampling within each of the townships (Miles & Hubermann, 1994). If a person declined to participate and referred our team to someone else, we declined such referrals and selected another household of our own choosing.

Several younger participants—who were often college students—were typically those who had returned home for the summer to provide labor for their family's farm. These college-educated students were included in the survey to provide at least a few participants who had post-secondary education. These same students were very familiar with farming practices as a result of having worked on farms for

nearly their entire lives. Their inclusion increased both the diversity of age and level of education for the interview and survey sample populations.

The age groups of 18-39, 40-59, and 60 or greater were used to compare the relative ages of the study's participants in a way that conforms to significant periods in history such as the Reform and Opening, Collectivization Period, and Pre-Collectivization (Schmitt, 2011).

Composition of interview and survey populations

As seen in Tables 1 and 2 the majority of participants in both the interviews and surveys came from the middle age category. The study's age profile was representative of those farmers most readily found in the fields and the agricultural communities of Minqin County. A few farmers in the 60 years and older category suggested they were not too familiar with plastic mulch practices, and therefore, having a higher proportion of 40-59 year old farmers is interpreted as appropriate for the purpose of this study. The relationship between age and familiarity with the use of plastic mulch makes sense since survey results indicate that plastic mulch was not adopted in Minqin County until around 1987. The interviews and surveys clearly support the idea that the 18-39 year age category has been leaving farming life behind in search of wage labor. The migration of young people from the region may be why this category has the least number of sampled participants.

Women were generally more reluctant to participate in interviews or survey questionnaires, thus, women comprised approximately one-third of the survey

participants and one fifth of the interview participants (Table 1, Table 2). Often wives would pass the questions on to their husbands. However, in multiple instances, after hearing the introductory questions, wives decided to answer the questions themselves instead of their husbands. When both husband and wife were active in the interview or survey, both ages were recorded, and the primary contributor to the interview was listed first to indicate who served as the primary "participant." Additionally, some husbands who may have been partially engaged in wage labor, when presented with questions they found to be difficult, consulted their wives for the answers to agricultural or household expense questions (i.e. male participants were often surrogates for female participant responses). Other women chose to interview with the aid of their sisters, mothers, daughters, or immediate neighbors. Overall, fewer numbers of women consented to answering questions on their own. Finally, there were a few husbands who ushered their wives out of the room in which questioning was taking place. In some rural Chinese agricultural communities, women are the principal farmers in practice while men tend to serve as livestock herders. Such is not the case for most Minqin farming communities. In Minqin County, animal husbandry overall is relatively minimal, and thus, men and women have a more equal knowledge and responsibility in the cultivation of crops.

Table 1. Composition of interview participants

Variable	Categories	Sample Size (N)	% of Sample
Education	None	1	3.3
	Elementary	9	30.0
	Middle School	11	36.7
	High School	8	26.7
Age	18-39	7	23.3
	40-59	19	63.3
	60+	4	13.3
Sex	Male	24	80.0
	Female	6	20.0
Ethnicity	Han	30	100.0
Family Size	1-3	4	13.3
	4	8	26.7
	5	9	30.0
	6	7	23.3
	7+	2	6.7

Interview sample size is 30

Table 2. Composition of survey respondents

Variable	Categories	Sample Size (N)	% of Sample
Education	None	9	9.4
	Elementary	28	29.2
	Middle School	39	40.6
	High School	15	15.6
	Post-Secondary	5	5.2
Age	18-39	19	19.8
	40-59	65	67.7
	60+	12	12.5
Sex	Male	66	68.8
	Female	33	34.4
Ethnicity	Han	96	100.0
Family Size	1-3	10	10.4
	4	33	33.4
	5	31	32.3
	6	18	18.8
	7+	4	4.2

Survey sample size is 96

Minqin County is populated primarily by ethnic *Han* Chinese. The only ethnic minorities encountered in Minqin County during the duration of the study were an ethnic Mongolian woman who had married into a *Han* family, and an ethnic *Dongxiang* family who owned a noodle restaurant.

Translation and note keeping

Interviews transcripts were translated line-by-line into English so that the original Chinese expression was retained as part of the transcript. All transcripts contained both the original and translated responses that were in turn directly imported

into Nvivo 9 software (QSR International). Each interview transcript was first coded by the individual question. Opening these question nodes within Nvivo 9 allowed a complete review of how all participants answered each question. Additionally, coding by question allowed for further coding into sub-nodes where similar response patterns could be grouped and further evaluated. After coding by question was completed, the responses were then open coded and organized into themes nodes. This method is intended to provide an objective and more holistic perspective of the issues and concerns most often cited as it related to specific social, economic, or environmental topics. During the entire coding process, memos and notes were recorded in an iterative process. This approach to becoming more "grounded" in the data is well established in social science disciplines (Bernard, 2006). The themes surrounding farmers' perceptions of the reasons they use plastic mulch are presented both spatially and relationally through the creation of a theme map. Theme maps have the ability to render complex inter-relationships among themes more understandable and recognizable.

The survey responses were first compiled into Microsoft Excel and then imported in Statistical Package for Social Scientists 19 (SPSS 19). The descriptive statistical analysis capabilities of this software program were utilized to calculate mean response scores to individual scaled questions. The survey's scaled responses were treated as continuous data for the purpose of analysis (Vaske, 2008). String data such as responses to the question, "What crop do you plant less of each year" were

recorded into the dataset as values after all of the crop types mentioned in the sample had been assigned values. After descriptive statistical results were calculated in SPSS, the results were presented in graphical format.

The field journal contained all of the hand written notes from my homestay with the *Zhongqu* family as well as those notes taken throughout the duration of my field work in Minqin County. This journal was reviewed daily while in the field and also throughout the data analysis period. While these notes are not the textual basis for qualitative analysis, the detailed information and observations the notes provided were instrumental in helping me to interpret my data and in answering the research questions. In many instances field notes from participant observation provided the missing piece of information needed to understand a complex relationship. For example, I did not understand how a single card-swipe system implemented at the work unit level (*dui*) for as many as 40 households could account for each individual farmer's water use. While living with Mr. Chen's family, he explained to me that each farmer records in a pen and ink logbook the electricity that is used while the pump is irrigating his plot. Because each field is watered consecutively after the adjacent neighbor's plot is irrigated, any irregularities in the logbook are easily identified, and therefore it is very difficult and rare for an individual farmer to successfully steal water. The hours and electricity recorded in the paper logbook must agree with the digitally controlled water account balance for the entire work unit. This is one of many

examples of how living with a household provided me as the researcher, with access to important and generally more detailed information.

It is difficult if not impossible to determine what responses, if any, may not have been made accessible to the researcher as a result of people declining to participate. It is also difficult to know to what extent the researcher's presence may have influenced responses. Some participants wanted to confirm that our team was not conducting research for the government prior to participating. It also appeared that some individuals did not participate in the study because they felt the perceived risk for participating in research with a foreign researcher may outweigh the perceived benefits. Despite these challenges, Chinese colleagues told me on several occasions that if the farmers in the region had not viewed my visit as a foreigner to their village as something of a "novelty," then they would not have agreed to participate. Some farmers may not have participated because they could simply not afford to take an hour away from their farm labor. In one survey where the farmer was busy, I paralleled the farmer by walking up and down field rows while I read questions and she picked cantaloupes and provided answers. Attempts to interview or survey farmers in the field, however, were generally not successful in obtaining consent to participate. With this said, there is no obvious reason to believe that those who declined to participate belong to any particular group or underrepresented segment of the sampled population. Thus, there is no obvious reason to suspect that this study contained a significant sampling bias.

I did my best to resist allowing my own value judgments concerning the use of plastic mulch to influence the research project. While the use of plastic mulch produces waste, the disposal of which contributes to air, water, and soil pollution, its use also brings with it many advantages related to agricultural productivity and the associated benefits that enhanced agricultural production provide farming communities. When farmers wanted to hear my opinion I reminded them we were only interested in their opinion. When participants made it clear they were trying to provide the "correct" answer or the government's position, we reiterated we were soliciting their perceptions and opinions. I attempted to limit my bias of the topic through choosing a frame that steered away from seeking a valuation of plastic mulch use. This approach instead sought to understand what plastic mulch use offered farming families and communities based upon their own perspectives.

4. Results

This chapter provides the results of interviews, surveys, participant observation, policy analysis, and external data exploring the reasons behind the continued use of plastic mulch and the influence this agricultural practice has upon the household economy and standard of living.

4.1 Farmer perceptions towards continued plastic mulch use

Interview responses from Minqin farmers provide six reoccurring themes. These themes are compiled and described in Table 3.

Table 3. Reasons for plastic mulch use as expressed by farmers

Use Theme	% Expressed	Participants (N)	Description
Theme 1 – Water Conservation	86.7	26	The use of plastic mulch conserves irrigation water and retains soil moisture.
Theme 2 – Productivity and Profitability	53.3	16	Plastic mulch use promotes the growth of healthy crops and dependable yields for farmers.
Theme 3 – Use is an "Imperative"	46.7	14	Crops can only be planted with the use of plastic mulch due to water scarcity, climate conditions, and other reasons, thus making its use a "requirement."
Theme 4 – Germination and Earliness	43.3	13	Plastic mulch use leads to faster germination, soil moisture retention for sprouts, and compressed cropping cycles.
Theme 5 – Semi-arid Climate	26.7	8	With plastic mulch use the arid conditions and high temperatures can be overcome.
Theme 6 – Fertilizer Conservation	20.0	6	Plastic mulch use leads to fertilizer conservation and fertilizer use efficiency.

Interview sample size is 30

The use of plastic mulch for the purpose of *water conservation* was expressed by nearly 90% of interview participants. Polyethylene plastic mulch seals the surface

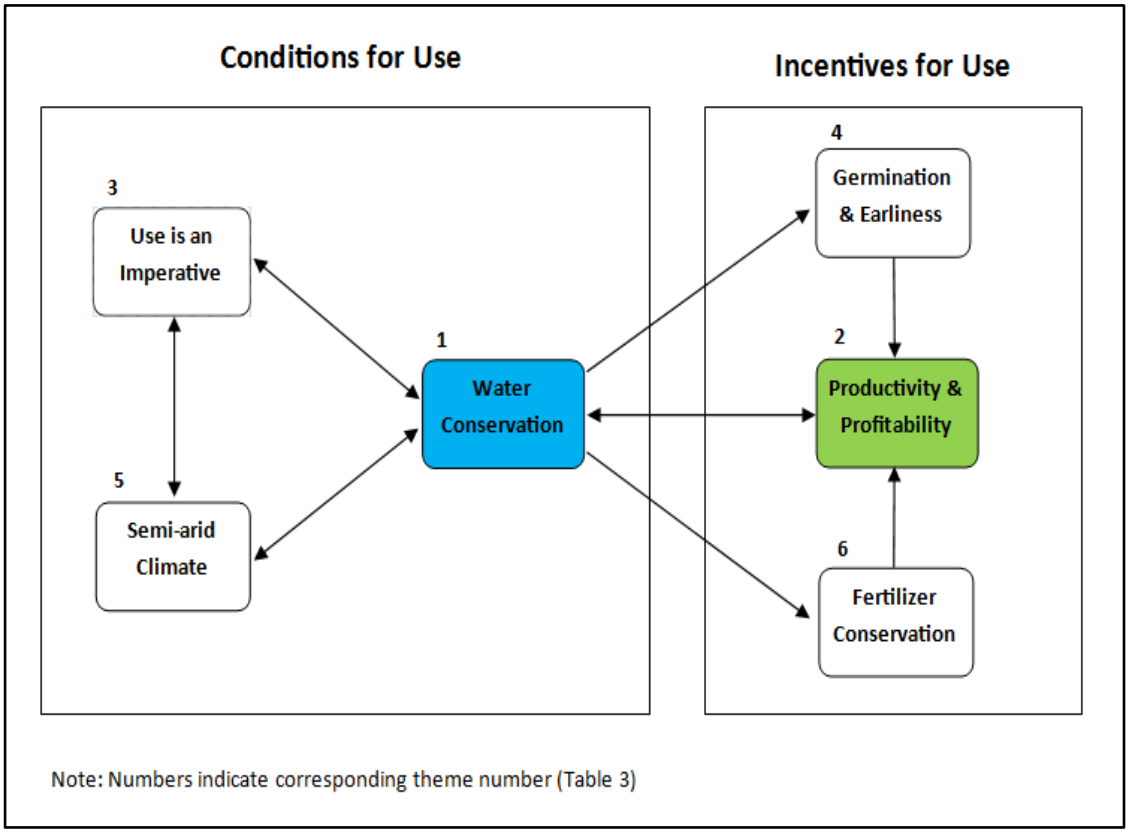
of the soil along the rows of fields. The sealing effect of plastic mulch greatly reduces the amount of soil moisture lost to evaporation. One farmer cited, “The most important reason is for maintaining water content. Today Minqin is very water scarce.” Based upon survey data, Minqin farmers perceived an average water savings of 26% resulting from the use of plastic mulch. Their perception of water savings supports independent experimental results where a 28% water savings was afforded by the use of clear plastic mulch from field trials conducted in Nigeria (Figure 5; Anikwe et al., 2007). In survey responses, farmers reported that they flood irrigate their fields an average of five times throughout a growing season while using plastic mulch. Interview participants explained that if plastic mulch is not used, then the fields must be flood irrigated as often as eight times throughout a growing season. While there is some difference between retaining soil moisture and extending the intervals between irrigation events, this study views them as equivalent based upon the relationship that moisture retained in the crop’s root zone is effectively irrigation water saved. Interview, survey, and independent experimental results all indicate that use of plastic mulch is a significant water conservation technology for farmers.

The second theme, the *productivity and profitability* resulting from use of plastic mulch, was readily expressed by Minqin farmers. Many participants made the connection between water conservation and productive yields. One farmer commented, “It increases production, yields are high. It conserves moisture content [of the soil], retains heat, and [crops] ripen earlier.” As the price of water has consistently increased

since 2000 for Minqin farmers, the decision not to use plastic mulch is both costly and wasteful of water resources with respect to overall agricultural *productivity and profitability*. Theme maps are used in qualitative data analysis to provide a schematic representation of the relationships and interrelationships between the most significant themes in social science research. The theme map presented in Figure 9 illustrates relationships between the six themes farmers expressed for plastic mulch use in Table 3. More specifically, the theme map illustrates how not only the need for *water conservation* provides the conditions for a more productive use of water, but also how plastic mulch use and the derived *water conservation* is further incentivized through the ability of the mulch to provide *fertilizer conservation.* One farmer noted, "It [plastic mulch] can conserve fertilizer, retain moisture, and raise income." In agreement with this farmer's association of the *water conservation* and *fertilizer conservation* advantages of plastic mulch, two independent studies of Minqin's groundwater quality status for nitrogen contamination suggested greater water conservation can be expected to reduce the leaching of fertilizer into aquifers. Namely, *water conservation* through reduced irrigation can lead to *fertilizer conservation* and protection of aquifer water quality (Ju, Liu, & Zhang, 2004; Liu, Su, Yang, & Lv, 2009). Independent research and farmers' statements indicate that use of plastic mulch conserves the use of chemical fertilizer through a reduction in the amount of irrigation water applied, and in turn, the associated leeching effect (Theme 6, Table 3). This

advantage of plastic mulch use would be expected to provide a positive influence upon both the groundwater quantity and quality as compared to non-mulched conditions.

Figure 9. Theme map of responses to questions about the use of plastic mulch



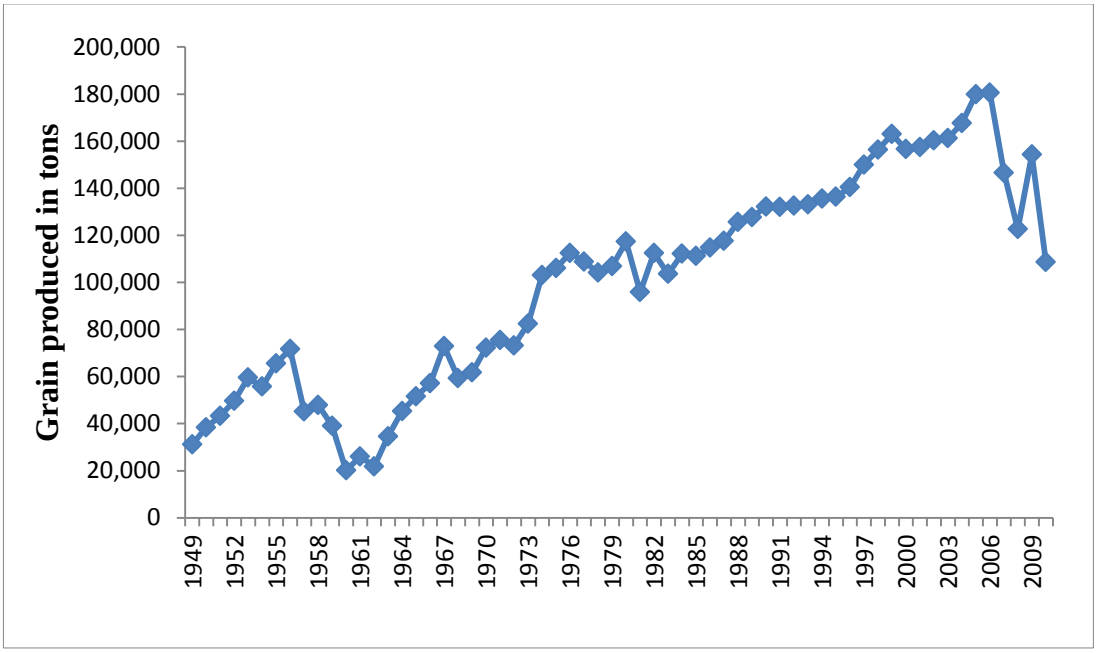
Minqin farmers also use plastic mulch because its *water conservation* properties leads to higher soil moisture and it provides for better seed *germination and earliness*—incentives that in turn provide for greater *productivity and profitability*. One farmer noted, "After applying it [plastic mulch] germination is very good. It conserves water, maintains moisture, and it increases agricultural income." The importance of plastic mulch's ability to provide an enhanced environment for crops

throughout multiple stages of the growing cycle relates to farmers' perception that its *use is an imperative*. Several farmers specifically said it was "impossible," or "not possible" to grow crops without plastic mulch. One farmer explained, "If it's not used the crops will dry up and die. Things will not grow if planted right into the soil." The most readily cited reason for plastic mulch's *use is an imperative* is once again, for *water conservation.* One farmer noted, "Without plastic mulch the crops cannot grow. We use it to maintain [ground]water levels and for retaining moisture." A second condition related to the perspective that plastic mulch *use is an imperative* is the *semi-arid climate* of Minqin Oasis. A farmer explained that plastic mulch must be used, "Otherwise the weather is too arid, the plants will die, and there will be no yield." For the reasons stated above, farmers expressed six related themes surrounding the conditions and the incentives for using plastic mulch in Minqin County.

One of the recent transformational changes occurring in Minqin County appears to relate to the way plastic mulch leads to *water conservation* and *productivity and profitability* (Table 3). Minqin Oasis has for centuries been a collection of wheat farming communities straddling the lower reaches of the Shiyang River. In the region of present day Minqin County, wheat has been both the traditional cultivated crop as well as the primary subsistence crop. However, as surface and groundwater supplies have declined over the past several decades, and especially as the pricing of water increased and water allotments decreased both in 2005 and 2008, the viability of growing wheat as the traditional subsistence crop became seriously jeopardized. In

response, Minqin farmers have significantly reduced their production of wheat in favor of cash crops. According to 1987 and 2000 Thematic Mapper imagery, grains occupied over 80% of the agricultural land in Minqin Oasis. This declined to 70% by 2000 (Xiao-Yu, Du-Ning, Xing-Yuan, Wei, & Dong-Mei, 2006). More recent independent market research data suggests that in only the past four years since 2006, Minqin County grain production has declined to levels last seen prior to the Reform and Opening Era (pre-1980's).

Figure 10. Minqin County grain production by year



Source: (China County Statistics, All China Marketing Research)

One study indicated that the water demand of cash crops may be only half as much as subsistence grain crops (wheat and corn) while providing between 3,000-5000 RMB of increased income per hectare (200-333 RMB/*mu*) (Xiao-Yu et al., 2006).

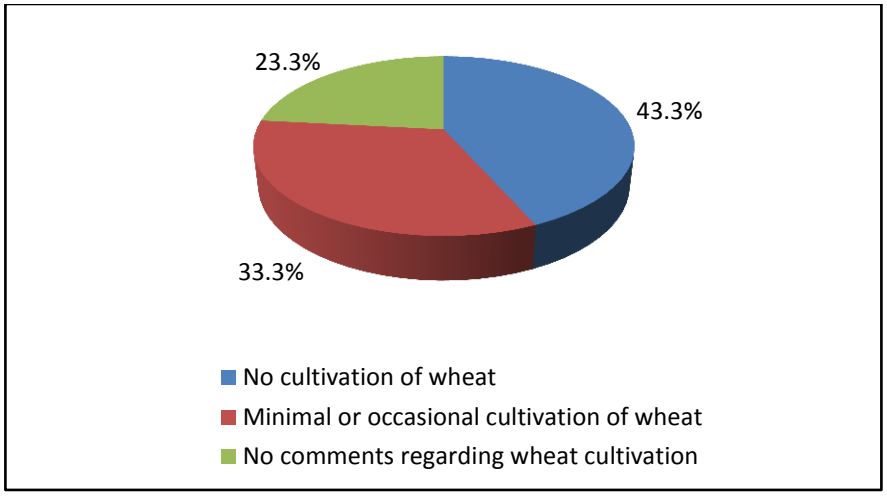
The implications of the decline in wheat production for Minqin farming families can hardly be overstated. In Minqin County, farming families have for centuries relied upon the cultivation of wheat for subsistence. Unlike other regions of China where rice is the staple crop, in much of north and western China wheat remains a primary staple for makings traditional foodstuffs such as noodles, buns, and bread. During my time in Minqin County, I was pleased to have the opportunity to cook the traditional *la mian*, or "pulled noodle" with Mrs. Li (Figure 10 and Figure 11). The *la mian* (and *yamian*, "pressed noodles") are the anticipated meal anywhere within Minqin Oasis—breakfast, lunch, and especially for dinner.

Figure 11. Mrs. Li making *La mian* **Figure 12. *La mian* and two vegetable dishes**

When I asked Mrs. Li about the family's wheat supply she decided to take me to see their grain storage room. Inside the darkly lit room was a waist high pile of wheat in large plastic sacks. Ms. Li explained that the family last grew wheat three years ago

and they have since subsisted from this supply of wheat. A neighbor of Mrs. Li was a friendly middle-aged man who showed me around the courtyard of his house. When I asked if he cultivated wheat he explained "We don't. We last grew wheat three years ago. We don't plan to grow wheat again. You can't earn much money from wheat—we just buy it now." These conversations with Mrs. Li and her neighbor, both of whom have recently reduced or eliminated their cultivation of wheat, are consistent with the results of my interviews (Figure 13).

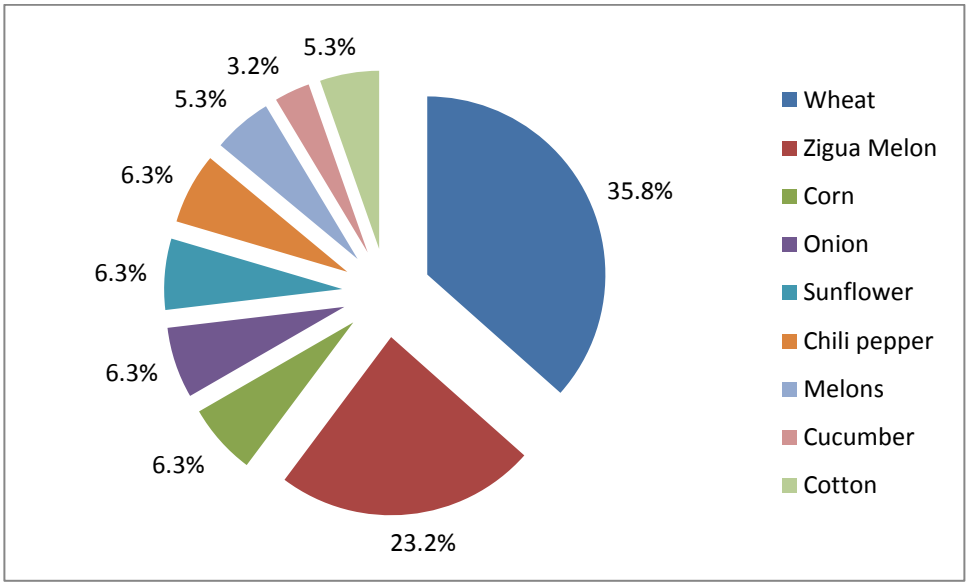
Figure 13. Percent of farmers reporting limited wheat cultivation



Interview sample size is 30

Figure 12 suggests that over three quarters of Minqin farmers cultivate a minimal amount of wheat or they choose to not cultivate wheat entirely. Based upon interview responses indicating this is a shift in agricultural production from past practices, the survey asked farmers which crop they plant less of each year (Figure 14).

Figure 14. Which crops do you plant less of each year?



Survey samples size is 96

Over one-third of the survey respondents identified wheat as the crop they plant less of each year. Interview responses provide a more detailed understanding of why farmers have been cultivating cash crops in favor of wheat (Table 4). The only other notable crop that has been planted less each year is *zigua*, or "seed melon." This fruit is related to the watermelon and it produces large dark black seeds that are eaten for snacks in a similar way to sunflower seeds. Even though plastic mulch can be used with melons, farmers indicated that *zigua* has not been a profitable cash crop in recent years, and thus they have decided to cultivate it sparingly. Unlike the *zigua* melon, wheat is unique in that it is a traditional staple crop that is not being cultivated for very specific reasons. The reasons farmers cited as leading to reduced or no cultivation of wheat are compiled in Table 4.

Table 4. Factors influencing minimal wheat cultivation

Use Theme	% Expressed	Participants (N)	Description
Theme 1 - Wheat is For Subsistence Farming	63.3	19	If wheat is cultivated at all, it is grown for subsistence because wheat yields and profits are low.
Theme 2 - Plastic Mulch Cannot Be Used With Wheat	33.3	10	With the exception of wheat, all other crops are cultivated using plastic mulch.
Theme 3 - Wheat's High Water Demands	30.0	9	Cultivating wheat without plastic mulch is not practical for Minqin

Interview sample size is 30

A closer look at the factors influencing the decrease in wheat cultivation (Table 4) reveals a shared theme with the earlier question of why farmers continue to use plastic mulch. Namely, the third theme of Table 3, *use is an imperative*, is very similar to the first theme of Table 4, *wheat is for subsistence farming*. This suggests that the cultivation of cash crops and the use of plastic mulch are effectively coupled. In other words, if a Minqin farmer is not using plastic mulch in a given field, then one can predict the farmer is cultivating a subsistence crop. A famer explains how wheat is viewed at the local level when he says, “Grains are planted for us to eat. We haven’t planted [grains] these past few years. Before, 80-90% we kept for ourselves to eat. Now we keep 100% for ourselves to eat.” The perception of wheat remaining a “subsistence crop” appears to have been influenced by government policy. A recent Minqin County government water conservation policy disincentivizes the use of water

for high water demanding crops (Minqin County People's Government, 2011). In any case, there is little reason to doubt today that the perceived necessity of plastic mulch use is anything but a socially-constructed imperative for Minqin farmers. In effect, the imperative of plastic mulch use sharpens the divide between cash versus subsistence crops, and the corresponding water-conserving versus water-demanding crops; respectively.

The second theme explaining why the cultivation of wheat is in decline relates once again to the use of plastic mulch; *plastic mulch cannot be used with wheat*. A farmer commented to me, "Besides wheat, all crops use mulch—90% do. There is no way for wheat to use it." Interestingly, in the 1980's the government conducted pilot projects in Gansu Province for developing a multi-purpose seeder that could be used with plastic mulch to cultivate spring wheat (Shi, 2000). This was an important government objective because at that time spring wheat was the dominant crop type for the region. While this seeder was originally invented and tested in Gansu province, the equipment failed to become cost-effective for farmers, and thus failed to deliver the desired water savings for which it was intended. Without a practical alternative to reducing the high water demand of wheat, Minqin farmers increasingly turned to growing cash crops.

Independent of the theme that *plastic mulch cannot be used with wheat*, the third theme is simply that *wheat's water demands are too high*. One farmer explained, "Every day there is no rain and the upper reaches do not have water. Every person is

allotted 400 m^3 of water. We must buy grains, and the cultivated fields use a lot of water. We plant a lot of water-conserving crops." The most extensive discussion of water-conserving crop types for the Shiyang River Basin compare the water demand of spring wheat for an entire growing season in Minqin Oasis to the water demand of other crops. The water demand of spring wheat is 572 mm, compared to 300 mm for cotton, 318 mm for melons, and 510 mm for flax for the entire growing season (Kang, Su, & Du, 2009). The three themes that explain the reasons why farmers are choosing to substantially reduce their traditional cultivation of wheat appear to hinge upon water conservation, plastic mulch use, and wheat's high water demands. Plastic mulch appears to play a significant role in influencing Minqin farmers' production decisions.

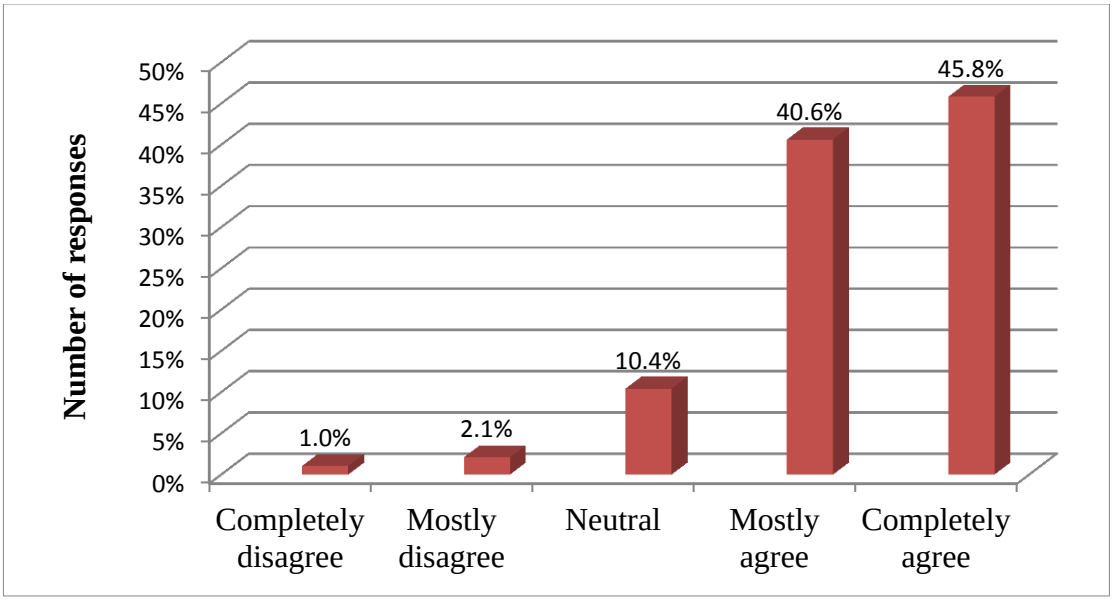
In summary farmers indicate they continue to use plastic mulch for a specific set of perceived conditions and incentives. The primary condition for plastic mulch's continued use appears to be water scarcity (*water conservation*), whereas the primary incentive relates to *productivity and profitability*. The steep decline in wheat cultivation and the widespread acceptance of plastic mulch use in response to water resource scarcity can be viewed as the context defining the modern era of plasticulture for the farming communities of Minqin Oasis.

4.2 Plastic mulch use and standard of living

The second theme expressed by Minqin farmers for why they use plastic mulch was *productivity and profitability* (Table 3). Survey results indicate on average farmers in Minqin began using plastic mulch in 1987. What does over two decades of

plastic mulch use mean for the socioeconomic development of Minqin County farming families? In what ways might the use of plastic mulch influence the household level economy and also the standard of living? The survey asked respondents to indicate their agreement with the statement in Figure 15.

Figure 15. "Plastic mulch has raised agricultural profit"



Survey samples size is 96

The descriptive statistics provided in Figure 15 shows that nearly 90% expressed an either moderate or strong levels of agreement with the statement suggesting that use of plastic mulch increases farmers' profits. The mean response to this statement on a 1 to 5 scale was 4.28. The next important question is to understand how much the use of plastic mulch is actually "increasing" household incomes, and then to what extent this may influence the standard of living. In support of the above survey results, interviews asked farmers if plastic mulch had an influence upon their household income. If they

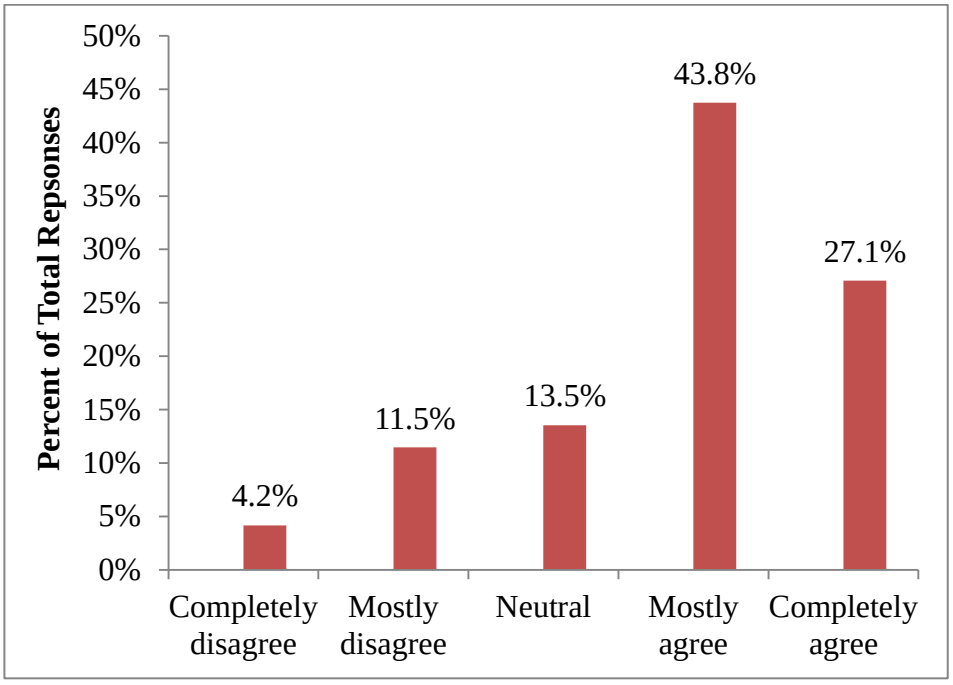
indicated plastic mulch increased their income, they were then asked by what percent they felt plastic mulch increased income. Interview participants indicated plastic mulch influenced their profits to increase by an average of 40.1% (22 of 30 total participants indicated both an increase and also estimated the percentage of increase). Even though this sizable percentage does not factor in those farmers who did not indicate an increase, it is worth noting that no farmers indicated plastic mulch use caused their incomes to decline.

This study did not assume an increase in income necessarily corresponds to an increase in the standard of living. Instead, participants were asked to indicate what household goods they purchased after they began using plastic mulch. The type and frequency of items listed by the fifteen participants are as follows: television (8), appliances (6), refrigerator (6), general household goods (4), washing machine (4), motorcycle (4), furniture (3), three-wheeled vehicle (3), clothes (2), electric bike (2), foodstuffs (2), bicycle, car, cell phone, cooking utensils, computer, house, induction oven, landline phone, rice, rice cooker, wash basins, and wheat. While 15 participants indicated the above listed items, seven participants did not see a change in their level of consumption after using plastic mulch. Some of the listed items are sizable investments and purchases that were "first time" purchases. There were also many types of agricultural machinery and equipment listed with the household goods by participants. For instance I sensed a degree of pride when I asked one farmer if he took out a loan to buy the large red tractor that stood over two meters high. The farmer

responded with a faint smile, “No, I purchased it with cash.” Other farmers said they had purchased “a lot of things,” and when asked further, the list of items usually included some type of household appliance or a three wheeled motorized cart.

As discussed in previous chapters, *xiaokang* is a sociopolitical construction that most Chinese people understand, yet they tend to have some difficulty defining exactly what the term means. Nevertheless, it was useful to ask Minqin farmers if by their perception the use of plastic mulch helped them move towards *xiaokang*.

Figure 16. "Plastic mulch helps farmers move towards *xiaokang*."

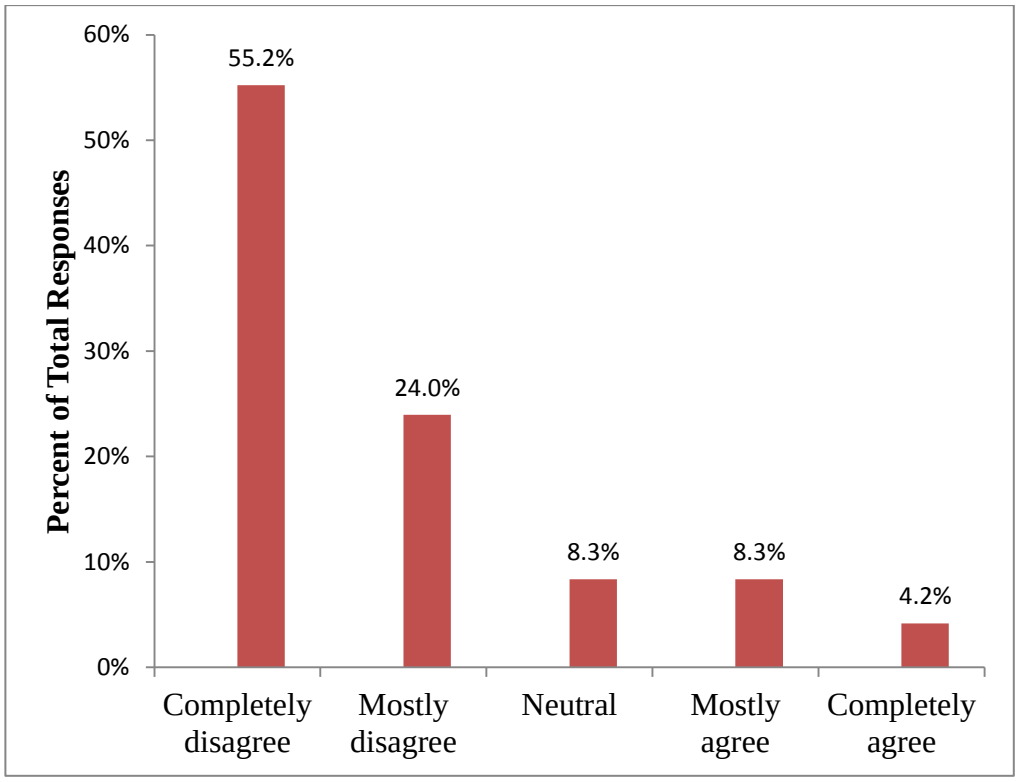


Survey samples size is 96

In contrast to Figure 15 that illustrates a 4.28 average response for the ability of plastic mulch to increase profits, Figure 16 indicates a less convincing average response with a mean of 3.78 and only 27% of respondents completely agreeing with

the statement that plastic mulch helps farmers move towards *xiaokang*. Many farmers commented about how their houses are badly in need of repair, the costs of farming operations were rising, and also the missed opportunities to capture the corresponding increases in what are historically high commodity prices. Through the use of a statement and scaled response structure, Minqin farmers were asked if they had reached *xiaokang* (Figure 17).

Figure 17. "I feel my standard of living has reached xiaokang."



Survey samples size is 96

The results indicate over 77% of Minqin farmers moderately to strongly disagree with the statement that they have reached *xiaokang*, and the mean response

for the sample was 1.82. One participant succinctly depicted the quality of life in Minqin as having approached *wen bao* (warm and full) but not having reached *xiaokang* (small comfort) when she said, "We have not reached *xiaokang*. If we have enough to eat, that is good." This statement agrees with the survey responses provided in Figure 17 and it broadly relates the local sentiment of Minqin farmers that their standard of living has not reached *xiaokang*.

It seems reasonable then to ask if plastic mulch has been used for over two decades in Minqin County (on average since 1987), and if its use has generally led to an increase in income over time, what other conditions explain why Minqin farmers have not realized a higher standard of living? One farmer viewed the increased revenue from plastic mulch as generally being spent on the rising water price rather than being spent on household goods. This farmer explained, "there is no change in [household goods consumption]. The money that is earned [from plastic mulch] goes to pay for [high priced] water." In addition to the derived economic benefit of plastic mulch being at least partially negated through rising water prices, farmers also see the status of *water resources* as the first indicator of their future standard of living (Theme 1, Table 5). In other words, if the role of plastic mulch is to be related to Minqin farmers' standard of living, one must first understand to what extent plastic mulch may influence the status of water resources for Minqin County.

Table 5. What does your future standard of living depend upon?

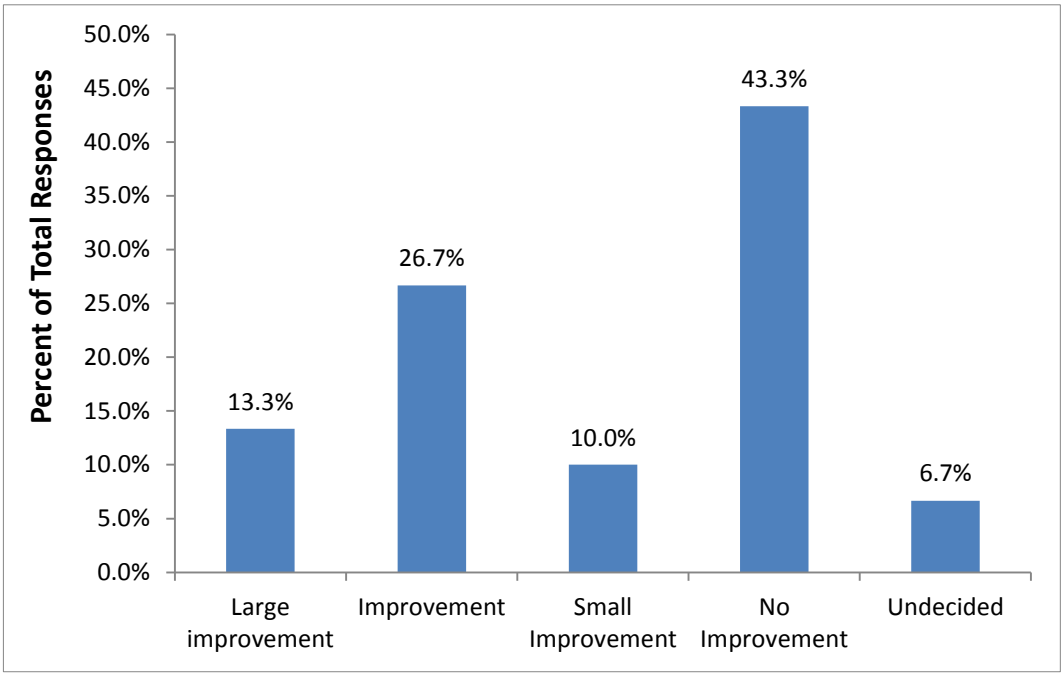
Use Theme	% Expressed	Participants (N)	Description
Theme 1 – Water Resources	40.0	12	The future standard of living will depend upon the accessibility and affordability of water resources.
Theme 2 – Society's Development	23.3	7	Society's continued development will translate into improvement in the standard of living at the local level.
Theme 3 – Market Crops and Pricing	20.0	6	The future standard of living will be influenced by the stabilization and improvement in market crop prices.
Theme 4 – Government Policy	20.0	6	Local and national policies that pertain to water, science, and technology will influence the future standard of living.

Interview sample size is 30

The importance of water resources for the future of Minqin farmers cannot be overstated. One farmer explained, "There is no water for planting. While there is an industry for water there is no money to pay the water bill." This statement echoes the first theme of Table 5 in that water must not only be made *accessible* (through such things as out of basin transfers), but also be made *affordable*. Another farmer commented, "Only through resolving the water problem can we actually raise [the

standard of living]. The problem is that the government isn't giving us water, and it doesn't let us use groundwater. In a sense there is no water, but if you pay a high price you can get water." Many farmers seemed perplexed by their rather acute awareness that groundwater still remained below their feet yet its continued extraction was being significantly restricted by agricultural water policies. Furthermore, farmers were similarly disturbed that river water was being provided through out-of-basin transfers, yet it was priced too high to be considered affordable. When asked to define *xiaokang* one farmer responded, "Water is scarce here. I wish every day I could shower." What all these statements from farmers have in common is that access and affordability of water is paramount for the future standard of living for Minqin farming communities. With a deeper sense of water's significance for Minqin's future standard of living, the question remains; how does plastic mulch influence the status of water resources for the region? In Figure 18 the role plastic mulch may play in influencing the status of water resources for Minqin Oasis is investigated more directly.

Figure 18. Do you think plastic mulch can improve Minqin's water situation?



Interview sample size is 30

The survey results in Figure 18 appear to provide some explanation for why Minqin farmers are not convinced plastic mulch use helps them move towards *xiaokang* (Figure 17). Since Table 5 indicates Minqin farmers see their future standard of living depending foremost upon the status of water resources, and since Figure 18 indicates that only 40% of farmers view plastic mulch as possessing the ability to substantially improve the water resources picture for Minqin, it appears plastic mulch may not play an active role in improving the future standard of living for farmers. In general there are two competing perspectives of how much plastic mulch may be able to influence water resources. A few farmers believe that plastic mulch use can improve the status of water resources for Minqin County. One such farmer noted,

"Yes, it [mulch] can improve it, because we don't irrigate with much water. Originally we irrigated with a lot of water. Now using half the water to irrigate is okay." While the tone of this farmer's optimism is certain, the majority of farmers actually contend that plastic mulch cannot truly change the trajectory of water resources decline in Minqin County. One farmer commented, "That's impossible. [Mulch] can only save water." Another farmer of similar perspective stated, "It [mulch] cannot change the water resources conditions, it can only resolve the matters of the most urgent importance. Minqin must divert water from other places and this can increase the ground's water content." Ultimately most farmers tend to agree plastic mulch use can ameliorate the severity of Minqin's water resource scarcity, but it cannot actually improve the overall status of water resources for the region. These results suggest that other factors besides plastic mulch use are more significant in influencing the long term status of water resources and in turn, the future standard of living for Minqin's farming communities.

4.3 Plastic mulch and two recent water policies

Government agricultural water policies may have the greatest influence on the overall long term status of Minqin's water resources. Interestingly, the most significant and recent water policies for Minqin Oasis appear to be based upon the anticipated continued practices of plastic mulch use and cash cropping in the region.

The apparent coupling of cash cropping and plastic mulch use in Minqin County may have their origins in previous government water policies (Minqin County People's Government, 2011; Shi, 2000). The prior agricultural water policies that promoted plastic mulch and cash cropping continue to shape the two most recent and important water policies for the region. Minqin County and the Wuwei Water Bureau began construction of *Minqin diaoshui gongcheng,* Minqin Water Diversion Engineering Project in 1995, and *guanjing yatian,* Well Closure and Land Restriction, a policy that was fully implemented 2009. The water diversion project was completed and began to provide Yellow River water to Minqin Oasis as early as March of 2001 (Song, 2009). Taken together, these policies aim to reduce Minqin's water crisis through providing surface water diverted from out-of-basin while directly managing groundwater water use and water pricing through the use of a magnetic card swipe system (Figure 19). Further investigation of these policies suggests they were actually predicated on and made possible through the expectation that Minqin farmers will continue their use of plastic mulch and cultivation of cash crops. This is because the highly prohibitive cost and water allocation quotas associated with the Minqin Water Diversion Engineering Project and the Well Closure and Land Restriction preclude cultivating anything but relatively high-value cash crops through the use of plastic mulch.

A review of recent government water policy (Minqin County People's Government, 2011), an interview with a top level Wuwei Water Bureau official, and interviews with farmers provide a consistent understanding of the water pricing

changes that are influencing Minqin County farmers and their household economy. The current price of Yellow River surface water is 0.225 *yuan* per cubic meter. Considering that over 85% of Minqin farmers do not have the pressurized piping required for drip irrigation, the continued use of comparatively large volumes of water through flood irrigation makes the cost of this surface water seem unaffordable for some farmers. In fact, the price of diverted Yellow River water is a 10 fold increase over the current price of groundwater. One farmer joked that the only place in China with higher water prices is Hong Kong. Other farmers raised their voice and spoke angrily about how high the water price has become and also voiced concern regarding the extent to which water is being regulated.

How these agricultural water policies are implemented at the local level became clearer to me during the time I resided in *Zhongqu* Township. A farmer explained to me that in 2008, just prior to implementation of Well Closure and Land Restriction, using water was simply a matter of how much water the farmer could afford. Upon implementation of Well Closure and Land Restriction in 2007-2010, the new water allotment was based upon the reduced land allotment of 2.5 *mu* per person. Today this means most townships in Minqin receive 415 m^3 of water annually per *mu* of allotted land area. For farmers of *Zhongqu* Township, the implementation of the two recent water policies involves the annual scheduling and coordination of two water delivery systems as follows: three allocations of diverted river water irrigation events inset with two groundwater pumping irrigation events, for a total of five

inundations for the growing cycle. Villagers are informed of the schedule for when the river water will be delivered (a result of the Minqin Water Engineering Diversion Project). The villagers accordingly align their irrigation ditches and prepare their fields prior to a government technician arriving to open the canal gate. The technician then returns periodically to measure the flow rate and then after three days the gate is closed until next the scheduled river water delivery. Unlike the provision of river water where a government technician was involved, groundwater pumping is automatically regulated through a computerized card swipe water allocation system pictured in Figure 19.

Figure 19. The automatic card-swipe water allocation system

Photograph by author. July 2011.

The magnetic card swipe system is the first of its kind to allow a government to digitally set a water allocation quota for remote areas where it is generally difficult to monitor and enforce such a quota. Each team leader is given responsibility to be the care taker of the magnetic card that controls the well head and electric pump. While the pump runs, a log is kept of which farmer is using the water, as each adjacent field is watered sequentially. In this way the unit leader records the hours and minutes of pump time to determine if each farmer is within his allotted water quota as well as the

total water that has been used and what remains on the magnetic card for the entire work unit. If the unit leader does not carefully manage the water for his incorporated neighbors and kinsmen, then the work unit will exceed their collective water quota and the pump will not turn on the next time the card is swiped.

Regardless of whether the farmer uses surface or groundwater, the irrigation water is deducted from the government established quota of 415 m^3. What may be more important to note than the quota of 415 m^3 of water per *mu* is actually the government's structured schedule of five total irrigation events per growing season. Furthermore, the studies survey results generally agree that an average of five flood irrigation events are happening throughout Minqin County. In *Zhongqu* each diverted surface water delivery was spaced by four weeks. Inset between the three surface water deliveries are two groundwater irrigation events. As such, crops must survive in the arid climate for 10-14 days between irrigation events. Based upon interviews, farmers indicated that subsistence crops such as wheat that are not planted with plastic mulch require six to eight irrigation events during the course of a growing season. For this reason it appears the government's water policies as implemented that provide for five irrigation events a growing season require Minqin farmers to use a coupled plastic mulch and cash cropping system. Many farmers agree that the most common cash crops cultivated today (such as sunflower, cotton and fennel) can be grown with as few as three to five irrigation inundations per season if plastic mulch is used. In effect, the integrated implementation of the Minqin Water Diversion Engineering Project and

Well Closure and Land Restriction and the corresponding scheduling and timing of five irrigation inundations indirectly require the continued use of plastic mulch for the cultivation of water-conserving crops. It will be agricultural water policies such as these that will determine to what extent the status of water resources in Minqin may be improved, and in turn, if the standard of living for its farming communities may also be improved in the years to come.

5. Discussion

5.1 Plastic mulch use as an adaptive strategy to water scarcity

When I look retrospectively upon my time in Minqin County I find it very interesting that out of over 300 farmers I spoke with in formal and informal situations, I encountered just one farmer who did not use plastic mulch. This woman was in her 60's and she cultivated 3 *mu* of land for subsistence purposes. Interviews with plastic mulch collectors and reprocessors also indicated that the county uses an unprecedented amount of plastic mulch. Why does Minqin County such use a large volume of plastic mulch? Based upon the literature review and information from interviews and surveys, the nearly ubiquitous use of plastic mulch by farmers in Minqin County may relate to the water conservation benefits it provides to this "water scarce" region. Ninety percent of farmers indicated that they use plastic mulch to conserve water. Despite what appears to be a strong link between plastic mulch and water conservation in this study, nearly all literature reviewed fails to discuss plastic mulch as a water saving tool in agriculture unless it is being used in conjunction with drip irrigation. From survey data only 14% of Minqin farmer's use drip irrigation while nearly 100% use plastic mulch. This rate of drip irrigation use is actually very high as compared with the rest of China where the national average is less than 3% (Deng et al., 2006). As China cultivates nearly 10 times as much land through the use of plastic mulch as the entire world cultivates in drip irrigation (Figure 6), it appears that applied research

may have thus far seriously underestimated the water conservation properties of plastic mulch as a stand-alone practice.

The results presented in Chapter 4 provided a localized and more nuanced understanding of why plastic mulch has become a constructed "imperative" for Minqin farmers. More than any other reason, Minqin farmers expressed that they use plastic mulch for water conservation because Minqin Oasis is "water scarce." There are other *conditions* for use such as the arid climate as well as the general sense of it being "impossible" not to use plastic mulch. At the same time, there are several incentives that lead to the use of plastic mulch including increased productivity and profitability as well as the related benefits of better germination of seeds, safeguarding of sprouts, conservation of fertilizer, increased harvests, and reduction in the use of increasingly costly irrigation water (Figure 9). With this perception of the conditions and incentives for plastic mulch use in mind, it is less surprising Minqin County has a nearly 100% adoption rate of plastic mulch use. Yet what makes this "imperative" a social construction? There was however one farmer who said to me, "We could [choose] not to use plastic mulch. It would require us to use twice as much water." The fact that among the sample population there was only this one farmer who even mentioned the possibility of not using plastic mulch indicates that most Minqin farmers do not even consider or question their use of plastic mulch—use of plastic mulch is an imperative.

It appears the imperative of plastic mulch use as perceived by Minqin farmers is nested within a larger domain—the social construction of "water resource scarcity." For good reason, desert oasis communities uniquely construct the importance of water—one might say the appearance of water serves as a geographical landmark. For example, 10 of the 16 township names in Minqin County are related to water. These names are directly translated as the following: Three Thunder, East Dike, Spring Mountain, West Canal, East Lake, Large Dike, Jia River, Large Shoal, Red Sand Canal, and Central Canal. Furthermore, prior research suggests that resources are socially constructed beyond that which is merely "objective," or natural (Robbins, 2004). Water means different things to different people from around the world. Broadly speaking, the way water resources are used varies quite dramatically between urban and rural, developed and developing countries. A striking anecdotal piece of information shared with me by one farmer was that the three people in his immediate family and his 20 sheep consume one 500 liter cistern of water every five days for all their needs. This conservative level of water use is absolutely unimaginable for someone of a developing country. For me it was an impressive lesson about just how much—or perhaps how little water people actually *need* in order to live. Much of their water savings came from not using drinking water to flush human waste. They also appeared to "wash up" with a moist towel daily rather than immerse themselves by showering. These observations cause me to wonder how a collection of oasis communities could have developed daily water use practices that are so frugal that

they would make “water conservation” practices used in other places appear wasteful. Indeed, when “water scarcity” is firmly constructed, it can bring about a number of adaptive strategies within communities to ameliorate the severity of water scarcity.

Use of plastic mulch appears to be one important adaptive strategy that allows farming communities to stretch the supply of diminishing groundwater resources of Minqin Oasis. Plastic mulch use is not, however, the only adaptive strategy, nor is it always independent of other strategies utilized by Minqin farmers. Some of the other adaptive strategies include a shift in agricultural production from subsistence crops with relatively high water demands to the increased commodification and cultivation of water conserving cash crops, selection of salt-resistant crops, the continued utilization of legacy commune work teams for more efficient pooling of labor, greenhouse crop cultivation, and animal husbandry. For the purpose of this study I have chosen only to discuss those strategies that relate most closely to plastic mulch agriculture.

Perhaps the simplest way to illustrate a number of related adaptive strategies is through contrasting the shift in agriculture production between two crop types. Chapter 4 indicated a dynamic shift in the subsistence based crop production of wheat to cash crops such as cotton, sunflower, fennel, and melons. The contrast between wheat and cotton provides the best representation of the advantages gained when wheat is no longer cultivated as the traditional staple crop. It appears that water savings is one of major drivers leading to this shift in production. Information

provided by farmers as well as external data (Kang et al., 2009; Xiao-Yu et al., 2006) indicate the volume of water saved through cash cropping may be as much as half the volume of previous irrigation water use. A considerable component of the water savings derived from cultivating cash crops relates to their compatibility with plastic mulch, whereas there is no feasible way for wheat to be cultivated with plastic mulch. For these reasons, plastic mulch use and cash cropping are effectively coupled practices for Minqin farmers. However the selection of cotton as a cash crop extends beyond its compatibility with plastic mulch use. If planted side-by-side with wheat, cotton would still conserve irrigation water for farmers in Minqin County, given their current irrigation practices. Furthermore, due to the natural salinization process of soils in arid and semi-arid regions where irrigated agriculture occurs, cotton is a crop type that can still produce profitable harvests even in soils that have already become relatively saline. For this reason, the choice of growing cotton in Minqin Oasis' increasingly saline soil conditions is an adaptive strategy unto itself (Aarnoudse et al., 2012). The selection of cotton over wheat as a crop type is an adaptive strategy to diminish the effects of declining irrigation water quantity, quality, and even soil quality.

The selection of cotton as a cash crop also appears to be in response to market forces. The strategy to cultivate cotton is also influenced by both previous and current government agricultural water policy. At the advent of the Household Responsibility System in the early 1980's, for the first time individual households needed to collect

income from the open market to pay for public services that were no longer provided by the government. This created a policy incentive to increase commodification of agriculture. As of 2010 the state-owned Qinfeng Cotton Factory in Minqin County produces an annual revenue of over 200 million *yuan* in finished chemical, fiber, dye and printed cotton products (Factory, 2010). The shift in production from subsistence to commodification in Chinese agricultural is a continuing reported trend in recent studies (Galipeau, 2012; Schmitt, 2011; Tilt, 2008). And yet there is something unique about the commodification of agricultural practices in Minqin County. Unlike prior studies where the shift to cash cropping is in transition or a hybridized cropping system of subsistence and commodification, in Minqin County nearly 80% of farmers indicate that they have either ceased to produce wheat, or grow very limited amounts of wheat (Figure 13). Why is Minqin so different with respect to the extreme extent to which it has almost exclusively transitioned to commodity agriculture? It is worth mentioning that Minqin farmers are taking these risks even though today Chinese farmers still lack crop insurance and other basic guarantees when producing products for the market. Furthermore, Minqin farmers largely have elected to seek the benefits of cash crops in exchange for giving up the cultivation of their historical and culturally significant staple crop of wheat. In turn, Minqin farming families rely on the open market to buy wheat to retain this important element of their food culture.

The discontinuation of wheat cultivation may not be entirely unique to Minqin County (Table 4, Theme 1). Prior research suggests that grain crops that consume or

"waste" water have been discontinued from cultivation in other areas of Northern China (Yang & Zehnder, 2001). Moreover, if a crop is not compatible with the "imperative" of using plastic mulch, it cannot be grown at all. As explained in Chapter 4 (Figure 13), it appears to be the rather dramatic consensus decision of nearly 80% of Minqin's farmers to no longer cultivate wheat. The practice of buying grains from outside Minqin County translates into "virtual water" being imported into the region through the embedded water required to grow wheat. Virtual water imports in response to declining groundwater tables throughout the Northern China Plain is an adaptive strategy suggested by prior research (Yang & Zehnder, 2001).

An additional adaptive strategy related to the use of plastic mulch by Minqin farmers to ameliorate the severity of water resources and sustain livelihoods is pooling labor within legacy commune work units. At several points, this paper has discussed China's transition in the early 1980's from the Collectivization Period to the Household Responsibility System. What is interesting is that the legacy work teams or *dui* of the Collectivization Period, *(*and the *she*, or work groups) have been adapted to implement local water policies (Aarnoudse et al., 2012). On the surface, it is not apparent how collections of 10 or so households working together some 30 years after Decollectivization holds any relationship to plastic mulch. While living with Mr. Chen's family I observed their morning routine of waking up before six in the morning to begin digging irrigation ditches before it became too hot to work. What amazed me is how much soil—sometimes in piles approaching two meters high—was

being moved by hand both in and out of the same sections of ditches throughout the growing season. The reason this high expense of labor is used repeatedly is because like other townships, *Zhongqu* must use two irrigation systems to water their crops.

The days of simply pumping water into a single system of irrigation ditches have passed. As mentioned briefly in Chapter 4, *Zhongqu* irrigates three times from State provided river water. Inset within these three river water deliveries are two groundwater pumping irrigation events. Unfortunately the river water irrigation ditches are as much as two meters below the level of the groundwater ditches. For the groundwater ditches to pass over every point they intersect the river water ditches, an incredible amount of labor must be invested to fill sections of the ditches with soil so as to use the government directed hybrid irrigation system (Figure 20). It appears that the long term goal of the government may be to eventually phase out groundwater pumping entirely.

Figure 20. Zhongqu farmers sharing labor to fill a river irrigation ditch with soil
Photograph by author. July 2010.

For this reason Minqin farmers have utilized their legacy work units for pooling labor to more effectively move soil in or out of the river irrigation ditches every two weeks throughout the growing season. What this means for an individual farmer is that if plastic mulch is not used with his or her fields, it would require irrigation nearly twice as often as the fields of his adjacent neighbors. Conversely, if the work unit for some reason did not use plastic mulch but one farmer elected to use plastic mulch, the farmer's family would be expected to contribute labor, but would not need water aligned to his fields except once in every other irrigation event—a sharp decline in his return for pooled labor. In other words the shared (hybridized)

irrigation system for the work unit requires that all fields in the work unit need water in a synchronized fashion. This more nuanced understanding of irrigation systems at the local level demonstrates that the decision to use or not use plastic mulch does not truly rest upon the individual farmer. This is not the first study to find legacy work units from the Collectivization Period being used to implement water policy reforms in rural China (Aarnoudse et al., 2012). The finding that farmers may strongly consider and conform to their neighbors' decisions when choosing to use or not use plastic mulch because of a shared irrigation system suggests the decision whether to use plastic mulch use can be a highly influenced by social components of the local agricultural production system.

5.2 Plastic mulch and standard of living in Minqin County

The second research question of this paper seeks to understand in what ways plastic mulch has influenced standard of living for farmers in Minqin County. As previously discussed, plastic mulch has played a significant role in the shift from cultivation of subsistence crops to cultivation of cash crops, in that cash cropping and plastic mulch use appear to be coupled. This indicates that use of plastic mulch significantly influences Minqin County's local economy. This thesis has engaged the question of the various influences on standard of living through the social construction of *xiaokang*. This construction is cultivated by central party leadership to involve definite socioeconomic "targets," but in the end what "*xiaokang"* means depends upon

how an individual farmer interprets its meaning. It is very interesting that farmers were generally quick to respond that they had not reached *xiaokang* and yet they were considerably slower in defining the term's meaning. It is my belief that standard of living and *xiaokang* (as there is some difference between the two) ought to be defined by everyday people in society. *Xiaokang* provided a relatively fixed construction and corresponding point of reference from which to understand the influence of plastic mulch use upon standard of living.

Nearly 90% of Minqin farmers mostly or completely agree with the statement plastic mulch increases their agricultural profit (Figure 15). Furthermore interview participants who indicated increased profit from using plastic mulch also indicated that on average it increased their income by approximately 40%. To further investigate how increased profit from plastic mulch may be influencing their households, participants were asked to list all household items they may have purchased as a result of using plastic mulch. While many of the purchases listed were agricultural equipment and machinery, a sizeable number and variety of household goods were also associated with increased profit from use of plastic mulch. The changes in purchasing power noted in the household goods assessment cannot be attributed solely to changes in agricultural practices, however, because the introduction of plastic mulch in to Minqin County coincided with the liberalization and economic growth of the Reform and Opening that was also impleented in the 1980's. Even so, the sequence and way in which the questions were asked, and the way in which the

participants responded to the questions still causes me to believe that many of the household goods they listed were in fact by their perception a result of increased profits made available to their families through plastic mulch use. Some household goods listed by farmers such as appliances and motorcycles are of considerably high value for Minqin County, which is one of the poorest counties in China.

With the understanding that income is different from *xiaokang*, the extent to which the use of plastic mulch may help farmers move towards *xiaokang* produced detectable differences in survey responses. The mean of responses (averaged on a five point scale) to the question that asked to what extent plastic mulch increases profit was 4.28 (Figure 15), whereas the mean of responses to the question asking if plastic mulch helps farmers move towards *xiaokang* was 3.78 (Figure 16). This sizable decrease in the mean within the same sample population to two different yet related questions yields two implications. First, as discussed in Chapter 2, *xiaokang* is a specific construct in Chinese society that means standard of living as well as elements of quality of life; it is material wealth but also something more as well. For this reason it is expected that survey responses would indicate *xiaokang* as something more than increased income. Second, it appears that at least some of the income gained from the use of plastic mulch may be lost in other areas of agricultural production, and therefore not contribute to an improvement in standard of living. When asked if after plastic mulch use more household goods were purchased one farmer replied, “No change. The money that is earned mostly goes to pay for water.” This statement

implies that recent changes in water pricing have effectively offset the increased profitability resulting from plastic mulch agriculture. This reference to local water policy reforms will be discussed further in the next section. Only three interview participants did not view plastic mulch helping them reach *xiaokang*. One additional farmer corroborated the sentiment of water scarcity being paramount to all other considerations when he said, "if the water problem can be resolved, our lives will be improved."

The views of those in the minority opinion who that plastic mulch does not help farmers move towards *xiaokang* suggest that the water scarcity problem is too large for plastic mulch to make much of a positive difference. The *availability of affordable water* for agriculture appears to be the most immediate obstacle to both increasing the profitability of agriculture and to reaching *xiaokang*.

Owing to a weak indication that plastic mulch can move households towards reaching *xiaokang,* and in recognition of the farmers' consensus that the "water problem" (theme 1, Table 5) presents the greatest obstacle for Minqin farmers reaching *xiaokang*¸ respondents were asked to what extent plastic mulch may improve water resources. Only 40% of farmers agreed that plastic mulch can improve Minqin's water resource situation (Figure 18). While use of plastic mulch is principally an adaptive strategy used to mitigate water scarcity, its ability to actually improve the standard of living is limited to the extent to which it can actually improve the status of water resources in Minqin County. Furthermore, even though plastic mulch use does

conserve as much as half the irrigation water that may otherwise be used, it can only assuage the severity of water resource scarcity and modestly improve household income. Plastic mulch use does not appear to result in a significant improvement in the standard of living for Minqin farmers. What would change the influence of plastic mulch upon standard of living in Minqin County would be greater access to affordable water. As discussed in the following section, Minqin farmers view their standards of living as relatively unchanging at the present time because of recently implemented restrictive water and land use policies of the local and regional government.

5.3 Plastic mulch influencing recent agricultural water policy

In response to the continued decline of the groundwater table in Minqin County the Wuwei and Minqin Water Bureaus have implemented two water policies over the past decade. These policies, the Minqin Water Diversion Engineering Project and Well Closure and Land Restriction, have had the combined effect of diverting out-of-basin surface water to the Shiyang River's lower reaches in Minqin County, while also restricting the water use at each individual wellhead. The ultimate goal of these policies appears to be to significantly curtail all groundwater pumping for agricultural purposes in Minqin County (Aarnoudse et al., 2012). Living with Mr. Chen's family in *Zhongqu* Township provided me with an important opportunity to observe the implementation of agricultural water policies, the effects of their implementation at the local level, and also how they related to plastic mulch use.

Presently in Minqin County the average water allocation per *mu* is 415 m^3. Within this water allocation, for *Zhongqu* Township, three of the five field inundations are provided by surface water diversions from the Yellow River or Hongyashan Reservoir. While this slightly higher proportion of irrigation water sourced from surface water is a change from years past, it also presents new problems. Chapter 2 explained that the definition of "water insecurity" is when an individual does not have access to safe and *affordable* water to satisfy his/her needs," (emphasis added) (Rijsberman, 2004). The important part of this definition as it relates to water supplied from the Yellow River is that many Minqin farmers felt it was not affordable. While farmers such as Mr. Chen are not directly forced to open their fields to accept and buy Yellow River at a price 10 times the price of groundwater, the magnetic swipe card system does not have sufficient credit to provide him his full allotment of 415 m^3 per *mu* of water for the growing season. One farmer stated, "We've got to buy high-priced water." Fields simply cannot wait four weeks between surface water irrigation events in the local climate. Another farmer commented, "We're now diverting Yellow River water. The cost is really too high. We can't afford to use it." For this reason the implementation of Minqin Water Diversion Engineering Project and Well Closure and Land Restriction (to include the card swipe system) at the sub-village level effectively sets a high price for diverted river water as well as structuring how and when a Minqin farmer waters his or her fields.

What these policies have to do with plastic mulch is that the sequencing of five total irrigation events throughout the county (5.3 average) and the firm cap of 415 m^3 of water per *mu* per season requires use of plastic mulch and cash cropping. Traditional grains such as wheat require as much as 6-8 field inundations and usually more than 415 m^3 of water per season. The previous section discussed how an individual farmer must consider the collective decision of his or her work unit for plastic mulch use because of the pooled labor required for implementation of the hybridized ground and surface water irrigation system. The water quotas and implementation of the Minqin Water Diversion Engineering Project and Well Closure and Land Restriction also significantly influence a farmer's decision whether or not to use plastic mulch and whether or not to plant cash crops. In the end, it appears that the individual farmer may have little agency in deciding whether or not to use plastic mulch. This is somewhat of a strange conclusion to draw now some nearly 30 years after implementation of the Household Responsibility System that ostensibly gave farmers considerable personal freedom to make decisions about their farming practices. Furthermore when I asked a water bureau official about the policy of plastic mulch use he denied it was a policy. The official said, "Originally yes [it was a policy], but now farmers choose to use plastic mulch on their own." The results of this study however suggest that farmers have little agency in decided whether or not to use plastic mulch as a result of shared irrigation systems and recent water conservation policies. The

recently implemented and highly restrictive agricultural water policies appear to further entrench farmers' perception of plastic mulch use as an "imperative."

As explained in section 5.2, the shift from a predominantly groundwater sourced irrigation system to one based on a river water (primarily from the Yellow River) has come at the cost of increased labor at the sub-village level. The adaptive strategy to pool labor within village work units allows for this transition in irrigation water supply systems to be implemented over a time span of multiple years. To what extent might the large additional expenditure of labor required to implement a two-source irrigation system lead farmers to conclude it is no longer worth farming?

When I was out helping to dig ditches in preparation for the next irrigation period, I talked with a handful of the young adults who had returned from school in Lanzhou to help with farm labor (such as dig ditches) over the summer while their classes were not in session. They all agreed they wanted to get a "good" job in the city after they graduated. In the short term, what will happen to the amount of available labor for farms when these children graduate from school and no longer return during the summers? What happens as the labor pool decreases in numbers and increases in age? What is the broad outlook for the farming communities in Minqin County? Even this looming concern for farmers was associated with the sense of water scarcity in Minqin Oasis. When I asked one farmer if the water situation was serious he said, "It's extremely serious, our children's generation have gone out to seek wage labor. What kind of life exists for the next generation is a real problem." The theme of Minqin

County's youth leaving the region in search of higher education and wage labor was a prevalent theme in interview and survey data, and this theme was further supported by external data that indicates a declining trend in school enrollment for the county (Figure 4). What this broader perspective of Minqin County's environmental, social, and economic problems suggests is that the combination of water scarcity in the region and recent water policies have been highly restrictive, to the extent that they have diminished hope for the future of Minqin's farming communities. Minqin's farming communities have employed a number of adaptive strategies in response to government policy, as well as in response to the perception and construction of water scarcity in Minqin Oasis. Plastic mulch use is one easily identifiable adaptive strategy for the agricultural production system of Minqin County. The continued use of plastic mulch is reinforced by recent, highly-restrictive government agricultural water policies as well as by the need for pooled labor and shared irrigation systems at the sub-village level. Furthermore, the two sweeping water policies implemented over the past decade in Minqin County may not have been feasible to implement had not plastic mulch use and cash cropping already been widely popularized throughout Minqin County.

6. Conclusion

This research emphasizes the need for a more active dialogue with the world's farmers, based upon the premise that they commonly hold a marginalized status in society, yet their actions are tremendously important in land management and resource stewardship. The low socioeconomic status of many of the world's farmers most often results from such things as the lack of education, wealth, access to infrastructure, and also to the simple reality that most rural agriculturalist are women. The voices of farmers are extremely underrepresented in development of agricultural policy, and yet they are the principal stewards of the Earth's land and water resources. As such, they will have a truly profound and lasting effect upon the future health of the biosphere. For these reasons, this study attempted to better understand farmers' decision-making processes regarding a highly prolific global agricultural practice—the use plastic film mulch.

This study used a mixed methods approach to include several types of quantitative and qualitative information that were organized thematically in such a way as to strengthen the reliability of the research findings. Review of the literature prior to this study found only one published journal article that quantified the water savings afforded by the use of plastic mulch, and none that explored why farmers choose to use plastic mulch. In response to this gap in applied research, it is my hope that this study will help provide insights into the perspectives of one group of farmers on why they choose to use plastic mulch at the local level. In Minqin County, plastic

mulch is used foremost for water conservation. This is an interesting conclusion considering that the current discourse of water conservation technologies in agriculture does not recognize plastic film mulch as a stand-alone "water conservation technology," despite its apparent large-scale application as such in the developing world.

Summary of findings

The first question this study sought to answer was the following: why do farmers continue to use plastic mulch? An overwhelming percentage of the sample population identified plastic mulch use as a water conservation strategy (86.7%). The use of plastic mulch to conserve irrigation water was closely linked to the theme of *productivity and profitability*. This theme was further supported through several related themes that can be thought of as the conditions and incentives for plastic mulch use. These lesser known themes of why plastic mulch is used include such advantages as "germination and earliness" and "fertilizer conservation." Moreover, farmers commented on how in their community the use of plastic mulch allows young sprouts to germinate faster while also being more resistant to drying out between irrigation events. When hearing these types of statements from farmers, it occurred to me how important small things such as sprouts can be, yet to an outsider studying the topic on a regional or global scale, these important subtleties can easily be overlooked.

The shift from the traditional cultivation of wheat to the cultivation of cotton and other cash crops that use less water provides a window into what plastic mulch

provides the farmers of Minqin County. Grain production in the region has now plummeted to levels last seen prior to the Reform and Opening period. This finding was uncovered from farmer interviews and survey data, news reports, and external data. The decision by most farmers to no longer cultivate wheat—a crop that has served as the subsistence crop in Minqin County for centuries—is a dynamic shift in local agricultural production.

On a household level, this shift means that farmers must grow cash crops for the market so that they can afford to buy wheat for their families. On a county-wide scale, the apparent coupling of plastic mulch use with cash cropping allows Minqin farming communities to use as little as half the irrigation water used in the past. This finding is supported by farmer interviews and survey data, as well as external data from field experiments conducted in Minqin County (Kang et al., 2009). Survey data from farmers in this study, and field experiment data from an independent study (Anikwe, et al., 2007), agree that when the crop type is held constant, the use of plastic mulch alone yields a water savings of approximately 25-30%.

At the county level, this study contends that the incompatibility of growing wheat by using plastic mulch heavily influences farmers' decisions to discontinue cultivation of this traditional staple crop in favor of high value cash crops. The finding that cash cropping conserves water while increasing profit is consistent with previous research published on the Shiyang River Basin (Xiao-Yu et al., 2006). Furthermore, this shift to exchange high-value cash crops for staple crops that require more

irrigation—the trade for embedded, out-of-basin *virtual water*—is a recognized water scarcity mitigation strategy for Northern China, (Yang & Zehnder, 2001).

My efforts to understand why farmers continue to use plastic mulch was heavily influenced by my time spent talking with farmers and from living with a family in Minqin County. What "water" is depends on where you stand in the world. The ability of Mr. Chen's family to use 100 liters of water per day for their five family members and twenty sheep was eye-opening, to say the least. It appeared that the frugality this family applied to their household water use extended to how they used plastic mulch to conserve water in their agricultural fields. What could unify this holistic approach to conserving water except a social construction of "water scarcity?" Indeed, using plastic mulch requires a considerable amount of extra labor to install as well as remove from the fields. Using plastic mulch is *not* convenient. Many farmers specifically said the removal of plastic mulch makes a lot of extra work for them, and that working with the material is a "hassle." For this reason, the perception of water scarcity in Minqin County heavily influences farmers' decisions to use plastic mulch—even though its application and removal is anything but convenient. Despite the challenges to using plastic mulch, its ubiquitous use by Minqin farmer appears to relate to how farmers view its use to be an "imperative" (i.e. socially constructed).

As resource scarcity is constructed within a social context, adaptive strategies will emerge that can be expected to extend the supply of the resource in question. Such appears to be the case for Minqin County. The adaptive strategies most relevant

to this study were the use of plastic mulch, the ongoing shift to cash cropping, and pooled labor within village sub-units. The reality that all of these strategies are at least partially influenced by the local government does not make them any less of an adaptive strategy. Furthermore, the most recent agricultural water policies have imposed severe restrictions on water and land use, and they have further reinforced existing water conservation strategies.

The second question this study sought to answer was based upon farmers' perceptions, does the use of plastic mulch lead to an improvement in the standard of living? The findings yield a mixed result. The access to affordable irrigation water appears to be the ultimate limitation preventing increased income from plastic mulch having the ability to improve standard of living. Survey results indicate 90% of the sampled population expressed a moderate or strong agreement with the statement "plastic mulch has raised agricultural profit." This set of responses does not, however, indicate whether the increase in income from plastic mulch is sufficient to actually raise the standard of living. Of the interview participants who were able to estimate how much of increase in income plastic mulch provided, the increase was an average of 40.1% (22 of 30 total participants). At face value this increase appears to be substantial. A household goods inventory was conducted with each survey respondent to understand from their perspective, if certain household goods were made affordable as a result of increased income from plastic mulch. Fifteen respondents indicated a number of goods were purchased as a result of plastic mulch derived income ranging

from low-value to high-value products, seven indicated no change in purchases, and eight were undecided. While the majority of farmers (80.9%) indicated moderate to strong agreement with the statement that "plastic mulch helps farmers move towards xiaokang," the mean response value however was only 3.78 on a five point scale. These somewhat mixed results indicate that another factor other than plastic mulch may more heavily influence Minqin farmers' standard of living. Since more farmers indicated their future standard of living depends on water resources (40% of the total sample), participants were then asked if they thought plastic mulch can improve the water resource situation. Only 40% viewed plastic mulch as having the ability to actually improve the status of water resources for Minqin County. From these results, it appears that while plastic mulch does increase agricultural profits to a modest degree, it cannot overcome the primary limitation for the improvement in standard of living—water scarcity. Based upon farmers' accounts, plastic mulch may have provided a larger increase in income in the 1990's when water resource extraction was relatively unregulated.

Policy recommendations

The Well Closure and Land Restriction policy aims to place firm caps on how much water (and by extension, how much land) an individual farmer may use. As of 2011, the average water allotment in the Lake District was 415 m^3 and the county-wide per capita land allocation was officially 2.5 *mu*. To implement these restrictions where past allocation measures were unsuccessful, automatic card swiping machines

were installed on all remaining active wellheads. On the surface this policy appears to limit the individual farmer's water use practices. However, in actuality farmers do not have their own swipe cards, nor do they have their own water accounts. To feasibly implement Well Closure and Land Restriction, the legacy sub-village work units from the Collectivization Period were used to place the work unit leader in charge of sub-dividing each household's water bill in lieu of providing individual farmers with their own swipe cards and water accounts. This difference in the intent behind the policy to hold each farmer responsible, versus the way in which the policy was actually implemented presents problems.

First, the majority of the farmers I interviewed and surveyed could not tell me the price of water although every farmer said it was too expensive. It seems a bit ironic that an automatic magnetic card swipe system is revolutionary its ability to precisely account for water, and yet its users have little understanding of the water price or billing. The confusion and lack of transparency surrounding the price of water contributes to a great amount of frustration and even anger on the part of farmers, and as such, this mismatch of policy intent and implementation is counterproductive.

Second, the local government's *Implementation Notice Regarding Construction of a Model Water Conservation Society* (2011) provides a tier-based incentive structure in which if a farmer uses less than 80% or 90% of the allotted volume of water, the unit price of water is reduced accordingly. If more than the allotment is used there is a corresponding penalty that is assessed. Despite this well-

intention policy mechanism, this policy cannot actually provide such incentives and disincentives to individual farmers because most farmers do not actually know the price of water, nor do they account for their own water bill. For policy incentives and disincentives to work as they are currently written, individual farmers must know the price and the volume of the water they use.

The second policy recommendation is a much more challenging problem. Over the past decade the government moved swiftly to divert out-of-basin water through the implimentation of the Minqin Water Diversion Engineering Project. This project did not resolve the root problem which is that Minqin County, as the lower reaches of the Shiyang River, no longer receives but a few percent of its historical flows from the Shiyang River. The diverted surface water, primarily from the Yellow River, is provided at a steep price, especially for the income levels of Minqin farmers. Several farmers commented that having unaffordable water is really not having water at all. This agrees with Rijsberman defintion of water insecurity, that water must not only be available, but be affordable as well (2004).

The second problem with the governement's desire to increase the use of surface water in Minqin County is that surface water is not provided in sufficient quantity to be used as the exclusive source of irrigation water. This requires farmers to use two independent irrigation systems in an alternating sequence. This entails moving tremendous amounts of soil multiple times throughout the growing season in order to irrigate the crops. The labor required to use both sources of irrigation water is a real

concern, because the aging farming population of Minqin County may increasingly choose to give up farming. Moreover, the added labor costs do nothing to encourage the youth to stay behind and continue farming. This study revealed that one of Minqin farmers' greatest fears is that the youth all eventually leave the county for wage labor and no one will remain behind to continue their way of life. It is recommended that higher income residents of the upper reaches of the Shiyang River should shoulder a greater percentage of the incurred costs of out-of-basin water transfers until a sufficient proportion of the historical Shiyang River flows can be restored to Minqin County. This would potentially elimnate the added labor of a two-source irrigation system.

Suggestions for further research

This study emphasized the urgent need for more social science research to understand why farmers around the world continue to increasingly adopt certain modern agricultural practices and not others (e.g. plastic mulch versus drip irrigation). Such studies would have significant implications for the sustainability of water resources to meet the demand of a continually increasing global population.

Secondly, only one existing natural science journal article attempts to quantify the water savings derived from plastic mulch use (Anikwe et al., 2007). As previously discussed, China alone cultivated over nine times the land area in plastic mulch than the land area the entire world cultivated with drip irrigation (Figure 6). A broader discourse that quantifies water savings of plastic mulch in multiple regions of the

world, with multiple crop types is critical to understanding the effects of global plastic mulch use upon the future supply of water resources. The lack of literature published on plastic mulch use as a "water conservation technology" would be understandable if its global application were less extensive, or if so many regions of Asia and Africa were not so badly in need of improved agricultural water use efficiency. In short, current research cannot explain how the prolific use of plastic mulch is currently influencing the status of water resources on any spatial or temporal scale, nor can it predict how plastic mulch may influence the status of water resources in the future.

Despite the obvious way in which the impervious properties of polyethylene plastic film mulch seals the surface of the soil and reduces evaporation (a central stage of the hydrological cycle), no existing water resource models distinguish use of plastic mulch as an agricultural practice that will alter timing and amount of water used, or influence fertilizer application and leaching. Additionally, I found no published research that has attempted to comprehensively investigate how plastic mulch not only retains irrigation water, but also how it may significantly influence several aspects of the hydrological cycle. The use of plastic mulch in agriculturally dominated river basins would be expected to increase the following aspects of the hydrological cycle: the impervious surface effect (much like paved urban areas), the volume and velocity of rainfall shed to furrows, the rate of agricultural erosion and transport of agrochemicals to aquatic environments (Rice et al., 2001), and finally, the responsiveness or flashiness of a river basin to storm events. Furthermore, increased

rates of erosion and runoff in agricultural fields could be expected to alter and decrease the rate of groundwater recharge. Of possibly greater immediate consequence is that no research has investigated the potential relationship between use of plastic mulch in basins dominated by agriculture and the potential impact on flooding events. This is particularly relevant in places such as China where 40% of the world's plastic mulch is used concurrent with the monsoon rain season.

Final thoughts

It is my hope that this project has brought greater clarity to issues surrounding the use of plastic mulch. The use of plastic mulch plays a role in providing a relatively low-cost water conservation technique to agricultural communities that lack safe and affordable access to water to satisfy their needs for drinking, washing and their agricultural use. This description of "water security" speaks to agricultural communities worldwide. While the challenge of water insecurity for Minqin farming communities is great, their determination to provide a more promising future for their children is equally great. Plastic mulch use is one of several adaptive strategies used by the farmers of Minqin County to conserve the use of water. Additionally, plastic mulch use appears to provide Minqin farmers with increased income, yet this increased income is largely offset by rising water prices and other government restrictions. Within the context of increasingly strict natural resource regulation, plastic mulch is an important mitigation strategy used by farmers to ameliorate the

severity of water scarcity until water policy reforms deliver affordable renewable water resources to the agricultural communities of Minqin County.

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APPENDICES

Appendix A – Interview Questionnaire

A. 个人信息

1. 年龄： Age
2. 性别： Sex
3. 民族： Ethnicity
4. 会说其他的语言： Can speak other languages:
5. 你住在民勤县多长时间？How long have you lived in Minqin County?
6. 您的职业： Your occupation?
7. 家庭有几口人： How many people in the household?
   孩子是多大： How old are the children?
   孩子的性别： Sex of the children:
8. 您是户主吗？ Are you the head of the household?
9. 所有的土地总面积(亩): Total area of all land (*mu*):
10. 种地总面积（中文单位：亩）： Total area of cultivated land (Chinese unit: *mu*):
11. 教育情况：Education Situation:

a) 上过学吗？[是/否] Have you been to school?
b) 会认字吗？[是/否] Can you read?
c) 你上了几年学？How many years have you been to school?
d) 孩子的学校离家多少公里： How many kilometers is the children's school from home?

12. 收入: Income:

a) 家庭每年所有的补贴是多少钱？How much is the total annual household subsidy?
b) 家庭每年农业的收入是多少钱？How much is the annual household agricultural income?
c) 家庭每年打工的收入是多少？How much is the annual household income from wage labor?

B. 生态和水相关风险的感知 Ecological and Water Related Risk Perception

1. 您觉得民勤县的生态环境怎么样，有没有变化，请讲一下？What do you think of Minqin County's ecological environment? Have there been any changes? Please explain.
2. 你对生态环境比较关心哪些方面？Which aspects of the ecological environment are you concerned with?
3. 请讲一下过去 5 年您的家庭用水质和水源情况。Please discuss the situation of your family's use of water resources and water quality during the last 5 years.

过去 15 年：During the last 15 years:

4. 你们乡村有遇到水的问题吗？Has your village experienced water problems? 严不严重？ Severe or not severe?
5. 这个情况什么时候开始的，还是一直就有？When did this situation begin, or has it always existed?
   [如果发生变化了的话] 是什么原因造成了这个情况？*[If there have been changes]* What caused this situation?
6. 您觉得现在的水资源情况是变好了还是变差了，为什么？Do you think the current water resources situation has improved or become worse, why?
7. 你认为如何改善现在的水情况，请讲一下你的看法？How do you think the water situation can be improved? Please discuss your view.

C. 塑料薄膜使用的感知 Perception of Plastic Mulch Use

1. 您当初怎么想到要用塑料薄膜的? At the time, how did it occur to you to use plastic mulch?
   怎么知道用（谁给你看）？ How did you know how to use it (who showed you)?
   从什么时候开始用？When did you start using it?
   为什么还在用？Why are [you] still using it?
2. 您觉得塑料薄膜对民勤总的生态环境影响是好的、坏的还是一般的？Do you think the effects of plastic mulch on Minqin's overall ecological environment are good, bad, or so-so?
3. 民勤农民为什么要用塑料薄膜？Why do Minqin farmers use plastic mulch?
4. 您觉得塑料薄膜能改善民勤的水资源情况吗 （大/少）？Do you think plastic mulch can improve Minqin's water resources situation (big/small)?
5. 使用塑料薄膜后，您家的农业用水量跟以前比是多了、少了还是没变化 (%)? After using plastic mulch, is the amount of agricultural water your family uses more than before, less, or is there no change (%)?
6. 用塑料薄膜谁得到了好处？ Who benefits from the use of plastic mulch?

D. 塑料薄膜使用*[适用的话]* The Application of Plastic Mulch *[if used]*

1. 每年您有多少亩地用塑料薄膜(亩)? Annually, how much area do you have that uses plastic much (*mu*)?
2. 每亩地一般要用多少公斤塑料薄膜？ How many kilograms of plastic mulch are usually used on each *mu*? 价格？Price?
3. 什么庄稼要用塑料薄膜？（用多少次？）Which crops use plastic mulch? (Used how many times?)

4. 您用塑料薄膜以后，用农药更多，少，还是没变化？After you use plastic mulch, [do you] use more agrochemicals, less, or is there no change?
5. 用白膜的好处是什么？What are the benefits of using clear mulch?
   用黑膜的好处是什么？What are the benefits of using black mulch?
   你喜欢用哪一种？Which kind do you prefer?
6. 平均来说，每年您地里用的塑料薄膜量是更多了还是更少了？On average, annually, do you use more or less plastic mulch on your land?
7. 农民怎么处理用过的塑料薄膜？（收了%）How do farmers dispose of plastic mulch?
8. 您希望有别的处理方法吗？Do you wish there were other disposal methods?
9. 用塑料薄膜种的庄稼您是更喜欢卖掉还是自己吃？Do you prefer to sell or consume crops that are planted using plastic mulch?
   [如果] 您的庄稼怎么卖掉？[If] How do you sell your crops?
10. 您最少留多少粮食给自己吃（百分之）？At a minimum, how much grain do you leave to eat for yourselves (%)?

E. 水的使用和分配 Water Use and Allotment

1. 您农业用的水百分之多少是来自地下水?What percentage of the water you use for agriculture is from groundwater?
2. 每一亩用多少水？ How much water does each *mu* use?
3. 分配的水量够吗？ Is the amount of water allotted enough?
   为什么？Why?
4. 每一方水是多少钱？ 和以前相比，对您家来说贵还是便宜了吗？
   河水：
   井水：
   How much does each cubic meter of water cost? Compared to before, according to your family, more or less expensive?
   River water:
   Well water:
5. 水是怎么管理的。。。是什么限制了人们不能想用多少就用多少？
   How is water managed…what limits people from using however much they want to use?

F. 本地生活水平和农业 Local Standard of Living and Agricultural

1. 你怎么认识“小康社会”？What is your understanding of “*Xiao Kang Society*?”
2. 您的生活水平达到小康了吗？Has your standard of living reached *Xiao Kang*?
3. 今后的话，您觉得您的生活水平会随时间改变吗？
   为什么？

In the future, do you think your standard of living will change with time? [Why?]

会提高还是降低？Will it improve or decline?

4. 您的生活水平比民勤县平均水平高还是低？Is your standard of living hirer or lower than the average level in Minqin County?

   你们乡村呢？Your village?

5. 塑料薄膜对农民收入的影响怎么样？

   大概是百分之多少？

   What effect does plastic mulch have on farmers' income?

   About what percentage is it?

6. 用塑料薄膜后，您买的家里用的产品更多，少，还是没变化？

   说一下哪些产品？

   After using plastic mulch, have you bought more household products, less, or is there no change?

   Tell which products?

7. 您在食物上的花费大概是家庭收入百分之多少？What percentage of your household income are your food expenses?

8. 您以前办过农业贷款吗？ 您当时借了多少钱？ 在哪个银行贷了款？ Have you taken out an agricultural loan? How much did you borrow at the time? At which bank did you borrow?

G. 其余事项 Remaining Items

对于本地的农业实践、水的使用还是生态环境方面的问题，您还有要跟我说的吗？

Do you have anything else to tell me about local agricultural practices, water use, or environmental issues?

Appendix B – Survey Questionnaire

A. 总信息 General Information

13. 年龄：_____Age
14. 性别：_____Sex
15. 民族：_____Ethnicity
16. 会说其他的的语言：_____Can speak other languages
17. 你住在民勤县多长时间？_____How long have you lived in Minqin?
18. 您的职业：_____Your occupation
19. 您的家庭有几口人：_____How many people in your household?

a) 孩子 1 是多大： _____How old is child 1
b) 孩子 1 的性别：_____Sex of child 1
c) 孩子 2 是多大： _____How old is child 2
d) 孩子 2 的性别：_____Sex of child 2
e) 孩子 3 是多大： _____How old is child 3
f) 孩子 3 的性别：_____Sex of child 3

20. 您是户主吗？_____Are you the head of household?
21. 所有的土地总面积 (亩): _____ Total area of all land (*mu*)
22. 种地总面积（中文单位：亩）：_____Total area of cultivated land (Chinese unit: *mu*)
23. 教育情况：
    Educational Situation

e) 能认识字吗？ _____Can you read?
f) 上过学吗？_____Have you attended school?
g) 你上了几年学？_____How many years of school did you attend?
h) 孩子的小学离家多少公里？_____How far is the child's [primary] school from home?

24. 收入:
    Income

d) 家庭每年所有的补贴是多少钱？_____What is the annual household total subsidy?
e) 家庭每年农业的纯收入是多少钱？_____What is the annual household agricultural net income?
f) 家庭每年打工的收入是多少？_____What is the annual household income from wage labor?

B. 塑料薄膜使用的感知 Perceptions of plastic mulch use

以下有些句子，只需要您用 12345 来判断我说的话[提醒下列都是将来的]:（表示）

1=完全不同意， 2=大部分不同意， 3=中立， 4=大部分同意， 5=完全同意

There are some sentences below. You only need to use 12345 to judge what I say

1=completely disagree, 2=mostly disagree, 3=neutral, 4=mostly agree, 5=completely agree

第一部分： First Part

1. 使用塑料薄膜主要的好处是环保的。_____
   The main benefit of using plastic mulch is environmental protection.
2. 使用塑料薄膜后，减少了地下水的使用量。_____
   Using plastic mulch has decreased the amount of groundwater used.
3. 塑料薄膜主要原因是为了节水。_____
   The main reason for plastic mulch is water conservation.
4. 使用塑料薄膜是在为子孙后代着想。_____The use of plastic mulch considers the next generation.
5. 塑料薄膜污染了环境。_____Plastic mulch pollutes the environment.
6. 燃烧塑料薄膜关系到人们的健康。_____Burning plastic mulch affects people's health.
7. 塑料薄膜废弃物的处理需要更多的方法。_____More methods are needed for the disposal of plastic mulch waste.
8. 塑料薄膜对民勤总的生态环境影响是好的。_____The effect of plastic mulch on the overall ecological environment is good.
9. 薄膜对土地是有害的。_____Mulch is harmful to the land.
10. 烧掉塑料薄膜对大气不好。_____Burning plastic mulch is bad for the environment.
11. 按固定的水分配，塑料薄膜可以让我种多一点庄稼。_____Given the fixed water allotment, plastic mulch can allow me to plant more crops.
12. 您用塑料薄膜以后，用的化肥更少了。_____After you use plastic mulch, you use less fertilizer.
13. 您用塑料薄膜以后，用的除草剂更少了。_____After you use plastic mulch, you use less herbicide.
14. 用塑料薄膜能抗旱。_____Using plastic mulch can fight drought.
15. 用塑料薄膜能抗沙漠化。_____Using plastic mulch can fight desertification.
16. 塑料薄膜有利于绿化。_____Plastic mulch is good for greenification.

第二部分： Second Part

1. 使用塑料薄膜主要的好处是经济的。_____The main benefit of using plastic mulch is economic.
2. 塑料薄膜主要是为了增加产量。_____Plastic mulch is mainly for increasing yield.
3. 塑料薄膜提高了农业利润。_____Plastic mulch has raised agricultural profit.
4. 塑料薄膜延长了作物的生长时间。_____Plastic mulch has extended crops' growing period.
5. 塑料薄膜的价格很便宜。_____Plastic mulch's price is very inexpensive.
6. 塑料薄膜废弃物危害牲畜。_____Plastic mulch waste harms livestock.
7. 塑料薄膜需要的劳动力少。_____Plastic mulch does not require much labor.
8. 塑料薄膜能起到保湿的作用。_____Plastic mulch can be used to retain moisture.

C. 水的使用 [评估] Water use [Evaluate]

1. 一亩地每年能分配多少方水? _____How many cubic meters of water are allotted annually for one *mu*?
2. 分配的水百分之多少用掉？_____ What percentage of allotted water is used?
3. 每一方水是多少钱？ 地下水：_____河水：_____ How much money is one *fang* of water? Groundwater_____ River Water_____
4. 每一亩每一次浇多少水? _____How much water is used to irrigate one *mu* one time?
5. 每年每一亩要几次浇水？_____Every year how many times is each *mu* irrigated?
6. 农业用的水百分之多少是来自地下水？_____What percentage of agricultural water comes from groundwater?
7. 使用塑料薄膜后，您的农田用水量跟以前比是多了、少了还是没变化 (%)？_____After using plastic mulch, the water used on your farm compared to before is more, less, or no change (%)?

D. 风险的感知 Risk Perception

以下有些句子，只需要您用 12345 来判断我说的话:（表示）
1=完全不同意，2=大部分不同意，3=中立，4=大部分同意，5=完全同意
There are some sentences below. You only need to use 12345 to judge what I say (indicate)
1=completely disagree, 2=mostly disagree, 3=neutral, 4=mostly agree, 5=completely agree

1. 地下水变得不适合饮用。_____Groundwater has become unsuitable for drinking.
2. 地下水变得不适合浇水。_____Groundwater has become unsuitable for irrigation.
3. 农业用水供应变得不足。_____The supply of agricultural water has become insufficient.
4. 水价变得买不起。_____The price of water has become unaffordable.
5. 水质变差，导致越来越多的人得病。_____Water quality has become poor, which has led to more and more people becoming sick.
6. 缺水导致更多的年轻人出去打工。_____Water scarcity has led to more young people leaving for wage labor.
7. 水位会降低，抽不到水。_____The water level will drop, and we won't be able to draw water.
8. 水资源变得太少，供应不了总人口。_____Water resources have become too scarce, and can't supply the total population.
9. 干旱越来越常见。_____Drought is increasingly common.
10. 沙尘暴会越来越多。_____Sandstorms will be more and more.
11. 本地区温度会越来越高。_____This region's temperature will be higher and higher.
12. 农药会渗透下去污染地下水。_____Agrochemicals will seep down and pollute the groundwater.
13. 草地会越来越少。_____Grasslands will become smaller and smaller.
14. 树木会全死了。_____All trees will die.
15. 沙漠化会越来越多。_____Desertification will be more and more.
16. 将来地下水位不会回升。_____In the future, the groundwater level will not rise.
17. 将来水分配的太少，不能满足庄稼的需求。_____In the future, water allotment will be too little; [the water allotment] won't be able to meet the needs of the crops.
18. 将来政府不让我们种地。_____In the future, the government will not let us farm.

E. 本地生活水平 Local Standard of Living

以下有些句子，只需要您用 12345 来判断我说的话[提醒下列都是将来的]:（表示）1=完全不同意， 2=大部分不同意， 3=中立， 4=大部分同意， 5=完全同意

There are some sentences below. You only need to use 12345 to judge what I say (indicate)

1=completely disagree, 2=mostly disagree, 3=neutral, 4=mostly agree, 5=completely agree

1. 我觉得我的生活水平达到小康了。_____I think my standard of living has reached *Xiao Kang*.
2. 我的生活水平比整个民勤县平均水平高。_____My standard of living is higher than the average level of all of Minqin County.
3. 塑料薄膜对农民收入的影响增加了。_____Plastic mulch's effect on farmers' income has increased.
4. 塑料薄膜帮助农民改善了生活。_____Plastic mulch has helped farmers improve their lives.
5. 塑料薄膜帮助农民奔小康。_____Plastic mulch helps farmers reach *Xiao Kang*.

本地生活水平［评估］Local Standard of Living [Evaluate]

1. 为了您家庭奔小康，您需要什么[不要钱的答案]？_____In order for your family to reach *Xiao Kang*, what do you need [don't want the answer of money]?
2. 您家庭在食物上的花费大概是家庭总收入的百分之多少？_____What percentage of total income is your family's food expenses?

其它 (评估)：Other (Evaluate):

1. 您地里从哪一年开始使用塑料薄膜的？_____What year did your land start using plastic mulch?
2. 您的土地用滴灌吗？Does your land use drop irrigation?
3. 您的土地总面积里有百分之多少滴灌？What percentage of the total area of your land is using drip irrigation?
4. 十年以前，您的土地总面积里有百分之多少滴灌？Ten years ago, what percentage of the total area of your land was using drip irrigation?
5. 您所有的水费大概是家庭总收入的百分之多少？_____What percentage of your total income are your water expenses?
6. 您种的哪个庄稼一年不如一年？_____Which crops do you plant less and less of each year?
7. 你的农田回收塑料薄膜吗？_____Does your farm recycle plastic mulch?
8. 薄膜百分之多少回收？_____What percentage of mulch is recycled?
9. 按关井压田，你更关心水的分配_____(1) 还是土地的分配_____(2)？ In light of Well Closure and Land Restriction, are you more concerned with water allotment _____ (1) or land allotment_____ (2)?

F. 塑料薄膜使用 Plastic Mulch Use

[塑料薄膜使用意向]：请用数字表明您是否会用塑料薄膜：
1=绝不会，2=不太可能会，3=不确定，4=可能会，5=打算用。
[Plastic Mulch Use Intention]: Please use numbers to indicate whether [you] will use plastic mulch:
1=Absolutely Not, 2=Not Likely, 3=Unsure, 4=Might, 5=Plan to Use

如果有一种能分解的薄膜和现在使用的薄膜的作用和价格是一样的话， 你会买吗？_____If there were a type of mulch that could degrade, that had an identical use and price to mulch currently used, would you buy it?

[新产品意向] 评估 [New Product Intention] Evaluate

1. 现在塑料薄膜的价格是多少（1 公斤）？_____What is the current price of plastic mulch (1kg)?

2. 可以分解的薄膜的价格最多贵多少钱是可以接受的？_____What is the most expensive price that you could accept for degradable mulch?