A CASE STUDY OF ONION PRODUCTION IN THE TIPAJARA WATERSHED, MIZQUE BOLIVIA

By

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The thesis: "A Case Study of Onion Production in the Tipajara Watershed, Mizque Bolivia" is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN FORESTRY.

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The geologists, the earth's scientists, have given us a beautiful and elaborate picture of the planet's formation and development; they have constructed a time scheme with which they can diagram, as with an overlay, each evolutionary step in the long process. But all that, I maintain, is merely information. It is not knowledge; even less is it understanding. Knowledge and understanding, though based on information as an essential component, require more, namely, feeling, intuition, physical contact—touching, and sympathy, and love. It is possible for a man and woman to know and understand one another, in this complete sense. It is possible to know, though to lesser degree, other living things—birds, animals, plants. It is even possible to know, through love, a place, a certain landscape, a river, canyon, mesa, mountain.

From *Abbey's Road* by Edward Abbey

My Thesis as an Onion
(Variedad Mizqueño)

Once upon a time there was a peasant woman and a very wicked woman she was. And she died and did not leave a single good deed behind. The devils caught her and plunged her into the lake of fire. So her guardian angel stood and wondered what good deed of hers he could remember to tell to God; 'She once pulled up an onion in her garden,' said he, 'and gave it to a beggar woman.' And God answered: 'You take that onion then, hold it out to her in the lake, and let her take hold and be pulled out. And if you can pull her out of the lake, let her come to Paradise, but if the onion breaks, then the woman must stay where she is.' The angel ran to the woman and held out the onion to her. 'Come,' said he, 'catch hold and I'll pull you out.' He began cautiously pulling her out. He had just pulled her right out, when the other sinners in the lake, seeing how she was being drawn out, began catching hold of her so as to be pulled out with her. But she was a very wicked woman and she began kicking them. 'I'm to be pulled out, not you. It's my onion, not yours.' As soon as she said that, the onion broke. And the woman fell into the lake and she is burning there to this day. So the angel wept and went away.

From *The Brothers Karamazov* by Fyodor Dostoevsky

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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I am grateful and fortunate to have had the opportunity to work with my advisor Blair Orr. His constant support and guidance greatly contributed to the quality of this work. Blair's tireless effort to assist Peace Corps students in the field is a direct benefit to those that most require his assistance: poor families in developing countries. He is an inspiration to us all. I would like to thank the members of my graduate committee: Brad Baltensperger, David Flaspohler, and Casey Huckins. I am also thankful for Anne Maclean's help with the GIS and image processing required for this project. Thank you friends and family for supporting and assisting me as I traipse around the world. Special thanks to my mother and father.

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CHAPTER I: INTRODUCTION

In August of 2000, I arrived in the city of Cochabamba, Bolivia to begin my two-year service as a Peace Corps volunteer (PCV). After three months of technical and language training, I was assigned to a small rural village in the Province of Mizque called Tipa Tipa. My job description was vague, but encouraging, as I was sent to help farmers with soil and water conservation.

As a Peace Corps volunteer in rural Bolivia, it was my job to be an agent of change. The more I interacted with local people, however, the more I realized how little I really did know about the farm systems that their livelihoods depend upon. Ultimately, I had to address the fundamental questions of change in development. Why change? Why *should* they change? Perhaps there is no reason to change. Of course I realized that the people were, by and large, poor, but I wasn't quite convinced that *change* would necessarily eliminate this.

In Tipa Tipa, onions were everywhere. They were unavoidable. The people seemed almost obsessed with them. So I began by working long, hard days in the onion fields, learning the ins and outs of production, becoming familiar with the farmers' personalities and their approach to agriculture. I did a little of everything: potato harvests, sowing maize, plowing fields, and, of course, working onions. Of all the hard labor that I did, nothing was more exhausting or more backbreaking than onions. I must have started off with a bias against the thankless task of onion farming from the very beginning.

Yet the more I interacted with local people, the more I realized that their affinity for onions was purely economic. Onion farming did have a past history of success and profitability. The first seed of doubt germinated in June of 2001, when disease began to attack onion crops, and the farmers responded by fumigating with tenacity and despair, at the expense, I might add, of their own health. At the request of several farmers, I brought samples of the diseased plant tissue to the nearby city of Sucre, where Dr. Walter Kaiser, plant pathologist and Peace Corps volunteer, had a laboratory for identifying plant diseases. Dr. Kaiser's response was simple: crop rotation. When I mentioned rotation to the farmers in Tipa Tipa, their response was equally simple: laughter.

And so the process had begun. I was determined to ascertain why the farmers were so attached to onion farming. I was hardly in a position to suggest changing the entire cropping system without first understanding the dynamics of onion production. And still, the specter of change hung over me. I must have believed in change. I must have gone to Bolivia with a whole arsenal of American beliefs and ideals: change is progress and progress is wealth and wealth is good. The farmers, of course, also believed that wealth is good, it just seemed hopelessly unattainable for most of them.

But more than just convincing farmers of the need for change, perhaps I was most interested in convincing myself. So I studied onions. I labored over them, thought about them in the evenings as I ate them with my meals. I even brought my girlfriend a sack of onions as a gift. And yes, as time passed, I became convinced of the need for change. And perhaps in the process I might have convinced a couple of farmers that change might not be a bad idea.

CHAPTER II: STUDY OBJECTIVES

In this study I use several different methodologies to describe the farm system in the Tipajara watershed in the Mizque province of Cochabamba, Bolivia. It was my goal to provide a thorough description of the farm system in the Tipajara watershed. By combining GIS technology and ethnographic information, I explain changes and trends in the farm system through time. This provides the necessary background for understanding a very important component of irrigated agriculture in the area: onion production. I use a statistical model generated from household survey data to analyze the social and economic ramifications of an onion monoculture, and further demonstrate that several virulent crop diseases have seriously compromised the onion farmer's ability to earn money. The possibilities of improved marketing for onions are also discussed. I conclude by providing a list of recommendations for improving farm system productivity and sustainability in the Tipajara watershed.

CHAPTER III: COUNTRY BACKGROUND

GEOGRAPHY

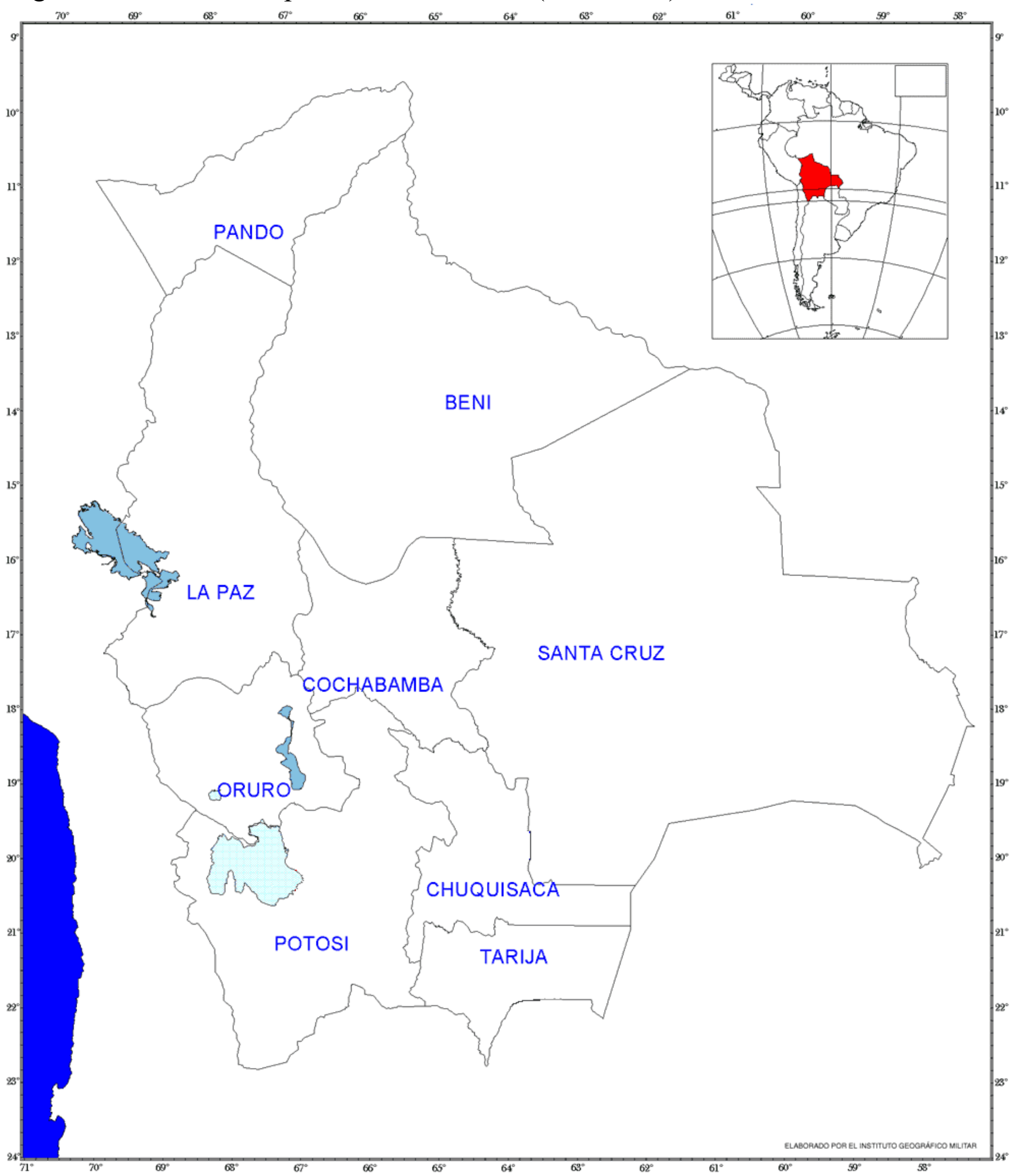
Bolivia is situated in the heart of the Andes mountains, at 17 00 S 65 00 W. It is a country of geographic extremes, with alpine peaks reaching as high as 6,542 meters and lowland tropical rainforest at 100 m. The country has a total land area of 1,098,580 sq. km (CIA 2003). Bolivia is divided into three distinct ecological zones, all of which correspond to extreme changes in elevation. The *altiplano* begins just north of Lake Titicaca and stretches south for 800 km. at an average altitude of 4,000 meters. East of the *altiplano* lies the Cordillera Oriental, a broken stretch of mountainous peaks and valleys from 4,250 m to just 100 m above sea level. Most temperate valleys can be found here, at an average altitude of 2,500 m (Klein 1992). Further east the mountains level off into the seemingly endless green sea of the Amazon basin. Though the Amazon River itself does not flow through Bolivia, the country is host to several major tributaries, the Beni and the Mamore being amongst the largest. Historically, the *altiplano* has supported the largest human populations.

Bolivian land is 20 percent arid or desert, 40 percent rain forest, 25 percent pasture and meadow, 2 percent arable, 2 percent inland water, and 11 percent other, a very small percentage of which is irrigated (Hudson and Handratty 1989).

Figure 3.1: Map of South America (CIA 2003)

Bolivia is divided into nine departments: Beni, Chuquisaca, Cochabamba, La Paz, Oruro, Pando, Potosi, Santa Cruz, and Tarija (Figure 3.2). Each department is further divided into provinces.

Figure 3.2: The nine departments of Bolivia (IGM 2002)



POLITICS

Politically, Bolivia is a republic, with the seat of government located in the *altiplano* city of La Paz. The president of the republic holds executive power. He is elected once every four years by a majority popular vote. The number of political parties in Bolivia and the fractious nature of Bolivian politics usually means that no candidate wins a majority vote, in which case alliances between political parties are formed and a vote in the National Congress determines which of the top three candidates becomes president. Legislative power belongs to a bicameral Congress, which consists of a Chamber of Deputies and a Senate (Hudson and Handratty 1989). Though officially a republic since it declared independence from the Spanish crown in 1825, Bolivia has been plagued by military coups, presidential assassinations, and social unrest. The most recent example of which occurred in October of 2003, when the president of Bolivia, Gonzalo Sanchez de Lozada, was forced to flee the country in the wake of massive violent protests and repeated calls for his ouster. Sanchez de Lozada was replaced by vice-president Carlos Mesa, who now presides as head of state (Caceras 2003).

Currently, Bolivia's most pressing political problems stem from the illicit cultivation of coca for the production and export of cocaine. Under strong pressure from the United States to eradicate illegal coca production, the Bolivian government has had enormous difficulties with disruptive peasant populations whose economic means of subsistence have been drastically altered by forced eradication. Sanchez de Lozada argued that it was this segment of the Bolivian population that forced him to resign the presidency (Caceras 2003).

DEMOGRAPHICS

The total population of Bolivia is 8,274,325, with a growth rate of 2.74%. In the past 50 years Bolivians have seen radical changes in the demographic distribution of the population. In 1950, just over 25% of the population was urban, with the rest living in rural areas. Now, 62% of the Bolivian population lives in urban areas (Table 3.1).

Table 3.1 : Census data by gender and area for 1950, 1976, 1992 & 2001

	Population			Percent		
Census and Area	Total	Male	Female	Total	Male	Female
1950 Census	2,704,165	1,326,099	1,378,066	100	100	100
Urban	708,568	N/A	N/A	26.2		
Rural	1,995,597	N/A	N/A	73.8		
1976 Census	4,613,419	2,275,928	2,337,491	100	100	100
Urban	1,906,324	925,379	980,945	41.32	40.66	41.97
Rural	2,707,095	1,350,549	1,356,546	58.68	59.34	58.03
1992 Census	6,420,792	3,171,265	3,249,527	100	100	100
Urban	3,694,846	1,793,445	1,901,401	57.55	56.55	58.51
Rural	2,725,946	1,377,820	1,348,126	42.45	43.45	41.49
2001 Census	8,274,325	4,123,850	4,150,475	100	100	100
Urban	5,165,230	2,517,106	2,648,124	62.42	61.04	63.8
Rural	3,109,095	1,606,744	1,502,351	37.58	38.96	36.2

Source: INE (2001)

A growing population has also caused changes in the population density; in 1950 there were 2.47 people per sq. km., in 2001 there were 7.56 (Table 3.2). Despite its growing population, Bolivia still has the lowest population density of all South American countries (INE 2001).

Table 3.2: Population Density by Department 1992 & 2001 Census

Department	1992 Census		2001 Census	
	Total Population	Persons/Km 2	Total Population	Persons/Km.2
Chuquisaca	453,756	8.81	531,522	10.32
La Paz	1,900,786	14.59	2,350,466	18.04
Cochabamba	1,110,205	19.96	1,455,711	26.17
Oruro	340,114	6.35	391,870	7.31
Potosi	645,889	5.46	709,013	6
Tarija	291,407	7.75	391,226	10.4
Santa Cruz	1,364,389	3.68	2,029,471	5.48
Beni	276,174	1.29	362,521	1.7
Pando	38,072	0.6	52,525	0.82
TOTAL	6,420,792	5.86	8,274,325	7.56

Source: INE (2001)

HISTORY

Though harsh and cold by European standards, the *altiplano* has numerous characteristics that made it suitable for early human settlement and the development of agriculture, which began around 8,000 B.C. Flat, arable land was not in short supply. A host of edible tubers were cultivated and improved over the course of centuries. Plentiful grazing land encouraged the domestication of large herds of llamas and alpacas. Abundant mineral wealth, though under exploited by European standards, was a source of construction material, tools, and luxury goods (Klein 1992).

Despite its great advantages, the *altiplano*, by nature of its extreme elevation, was disaster prone. Hailstorms, frost, and drought limited the range of agricultural products that could be cultivated and in many instances reduced the harvest of important staple crops. The need to secure steady supplies of essential products from the valleys and lowlands, such as fruit, coca, maize, and cotton, led to the development of a complex network of tribal affiliations and migrant highland colonies called *mitimaes*. Each colony was affiliated with a central ethnic community, usually located on the *altiplano*, known as an *ayullu*. Thus kinship and tribal affiliations created a scattered mosaic of colonies and settlements throughout the ecological zones of the Andes. Reciprocal arrangements between populations living in different ecological zones fortified people's diets and diversified their economic possibilities. Reciprocity and verticality, therefore, were strategies of risk management for those communities limited by the unique ecological conditions in which they lived (Godoy 1984, Klein 1992, Larson 1998).

By the early 1400s, the *altiplano* was densely populated by numerous ethnic groups, most notably the Aymara kingdoms that occupied the land area around Lake Titicaca. In the 1460s these groups were conquered by the expanding Incan state. The Aymara were allowed to maintain a certain degree of cultural and political autonomy on the condition that they provide young men as soldiers for the conquering Incan armies (Klein 1992).

The Emperor Tupac Yupanqui (1471-1493) invaded the temperate valleys of Cochabamba and began a drastic restructuring of the valley's previously isolated inhabitants. Several ethnic groups were sent to the eastern frontier to act as a buffer against aggressive lowland tribes, while others were allowed to remain as subjects of the Inca. In this way the Incas introduced the Quechua language to the valleys of Bolivia, resulting in the slow destruction of local languages spoken by the valley tribes (Klein 1992).

The Emperor Huyana Capac (1471-1527) made further changes in order to exploit the fertile maize producing valleys of Cochabamba. He resettled highland tribes to the valleys, creating *mitimaes* loyal to the Empire. Concurrently, he developed a system of forced, rotational labor, known in Quechua as the *mit'a*. Mass migrations of seasonal laborers came from their highland communities to work in state owned maize fields. Cochabamba became the maize belt of the Inca Empire, producing large quantities that were stored in huge stone silos in and around the Cochabamba valley, later to be shipped throughout the empire to make *chicha* (maize beer), or to feed the mass of soldiers in the Incan armies (Larson 1998).

Though less than a century old, the Inca Empire received a shock that resulted in its ultimate collapse: the arrival of the Spanish. In 1529, the King of Spain granted Francisco Pizarro the authority and resources necessary to explore and conquer the regions south of present day Ecuador. Upon Pizarro's arrival, the empire was immersed in a civil war of succession that made it vulnerable to the conquistador's designs. By the end of the 1530s, the Inca Empire had disintegrated, and in the years that followed the Spanish destroyed any remaining pockets of resistance (Crivelli 1911).

Once again the Cochabamba valley experienced radical social and political changes. It retained its role as the maize belt of an empire, but the Spanish system of labor exploitation and colonialism was markedly different than that of the Incas. In order to understand the reorganization of valley populations during the early colonial era, a discussion of Spanish mining efforts in the highlands is essential.

In 1545 the Spanish crown, acting through emissaries in South America, officially established the first mine in the *Cerro Rico* (rich mountain) of Potosi. So rich and abundant were the early deposits that veins of pure silver were extracted from the mountain with little need for processing. Potosi became a boom-town without precedent. From an initial settlement of 170 Spaniards and 3,000 Indians, by 1610 the city's population had grown to 160,000 inhabitants. Even by European standards the city had become a metropolis; Paris had a population of 60,000, London 100,000 (Pacheco et. al. 1997)

A steady output of silver became the primary concern of the early colonial administration. While introduced diseases decimated the already diffuse Indian populations, the need for labor in the silver rich mines of Potosi increased exponentially. In desperate need of a method to exploit Indian labor and extract taxes from a disperse population, Viceroy Francisco Toledo implemented a series of far reaching reforms that would forever alter the structure of Andean society. Under Toledo, the official policy of the colonial regime became "reduction": the forced resettlement of the indigenous *ayullus* into permanent, fixed communities. Though this was a process that took centuries, Toledo laid the foundation for the destruction of the dispersed colonies that occurred within the different ecological tiers of the Andean landscape. In this way the colonial authorities were more easily able to census and tax the reduced communities (Klein 1992, Larson 1998).

Reduction also solved the problem of a securing a steady supply of labor for the resource hungry mines of Potosi. The cost of building and maintaining a working mineshaft was equivalent to the cost of building a cathedral. The Spanish tried a number of tactics to solve the problem of labor shortage, from slavery to wage labor. The final and most successful of these was the introduction of the *mit'a*, a Quechua term used to describe the system of rotational labor used by the Incas in the maize producing valleys of Cochabamba. Under the Spanish system, one-seventh of the male population in each community was required to work one year in the mines; each individual would serve once every six years. Suddenly, the Spanish miners had an annual labor force of 13,500 men. These men became known as *mitayos,* obviously derived from the word *mit'a*. The Spanish mine owners paid the *mitayos* a small wage, which was not even enough for subsistence. The *mitayos* were required to provide their own food, coca, and the cost of transportation. The work in the mines was extremely dangerous, and thousands of men died each year in accidents and from mining related illness (Klein 1992).

The introduction of the *mit'a* caused huge demographic shifts in the valley populations. Suddenly there arose a tension between the Spanish haciendas and the *reducciones*, or the nucleated villages created by Toledo's policy. The new social order created three distinct groups within the indigenous population: *originarios, forasteros,* and *yanaconas*. The *originarios* were those who maintained their ties with their original kin group and were still members of an *ayullu*. In many instances, many different ethnic groups became associated with a single *reduccion,* but all were lumped into the category of *originario* in that particular community. They retained their rights as a member, most notably their rights as land owners, but they were also subject to taxation and forced labor in the mines. *Forasteros* were different from the *originarios* because they were not original members of the community and they maintained no claim to land in the communities where they lived. They were often migrant workers, moving from one village to the next, and sometimes became members of a Spanish *hacienda* to avoid recruitment for the *mit'a*. Those who did so might become members of the *yanacona* class. These were agricultural laborers who were subordinate to a Spanish landlord on *hacienda* lands. The *yanaconas* were generally exempt from serving in the *mit'a*. Because of this highly mobile society, the colonial administration had to balance the demand for a steady labor force in both agriculture and mining (Klein 1992, Larson 1998).

Colonial society in Bolivia was a mosaic of free Indian communities and Spanish *haciendas*, all tied together by a market economy with its central axis in the city of Potosi. It was a society dominated by Spanish landholders, bureaucrats, and mine owners. The entire economy was dependent on the labor of the great mass of Indian peasants that worked the land and the mines. The economy of Upper Peru was subject to cycles of boom and bust as mineral production declined and increased through the years.

In the early 19th century, most of South and Central America was embroiled in a bloody civil war for independence from the Spanish crown. Simon Bolivar led his army of liberation against loyalist Spanish troops and won independence for five South American states: Bolivia, Peru, Ecuador, Colombia, and Venezuela. The revolution consolidated the power of upper classes in these countries, but did little to empower the indigenous population of Bolivia. Indigenous members of the new Bolivian republic were by and large illiterate, and therefore denied the right to vote. The electoral base was composed of the 30,000 to 40,000 elites that continued to dominate Bolivian politics. The Revolution of 1825 did, however, mark the abolition of the dreaded *mit'a* (Klein 1992).

In the 1840's Chilean workers began to colonize the Bolivian coast to extract the rich deposits of guano found there. This was the beginning of a 40-year period of tension and conflicting claims. This ended in 1879, when Bolivia lost the Pacific War, thus losing claim to its only seaport (Klein 1992). To this day Bolivia and Chile maintain a tense relationship. Many Bolivians argue that access to the sea is an economic cure-all that could greatly improve their poverty stricken economy.

In July of 1932, Bolivian President Daniel Salamanca, in response to escalating tensions in the Chaco area east of the Andes, declared war on neighboring Paraguay. Thus began the most disastrous military campaign in Bolivian history. Fighting in the remote Chaco region, the Bolivian army was utterly incapable of providing its troops with adequate supplies. More people were killed by thirst, hunger, and disease than by bullets and mortars. Although the loss of their only seaport in the Pacific War was certainly more damaging to Bolivia's long-term prosperity, the Chaco War was longer, bloodier, and more humiliating than any other conflict in Bolivia's history (Klein 1992, Knudson 1986).

Long after the last bullet had been fired, the Chaco War continued to send a wave of disgust and outrage through the Bolivian population. Literate elites began to question the efficacy of a political system capable of such brutal stupidity. For the first time, the political ideology of the era expressed its misgivings regarding Bolivia's system of land distribution and labor exploitation. The *hacienda* became the rhetorical target of these radical intellectuals, who argued that its abolition and the restitution of Indian lands was the only just course of action (Klein 1992, Knudson 1986).

By the early 1950s several political parties were vying for control of the government. This state of affairs came to a head in 1952, when the Nationalist Revolutionary Movement (MNR), angered because the military refused to let it take power after winning the national elections, distributed arms to the civilian population. In April of 1952 Bolivian civilians, peasants and miners overcame the force of the military, and the centuries old system of land distribution began to unravel (Klein 1992).

From late 1952 through 1953 armed peasant militias began a complete take over of the rural countryside. Landowners were expelled, sometimes killed, and the lands were seized and redistributed among the local population. With the expulsion of the *hacendados*, peasant communities began to form *sindicatos*, which were responsible for organizing the population, distributing arms, and redistributing land (Klein 1992, Lagos 1994). In the years that followed indigenous Bolivians consolidated their land holdings and titles, becoming landowners for the first time since the Spanish Conquest.

The period after the revolution was one in which the United States began to play an increasingly important role in Bolivian politics. Food subsidies arrived in large quantities to mitigate the disruptive effects of the revolution. During the 1970s the government was in the hands of a military dictatorship that received U.S. support because of its anti-communist position. In the early 1980s, democracy again took hold when the military dictatorship relinquished power (Klein 1992).

From 1984 to 1985 Bolivia experienced unprecedented rates of hyperinflation. Structural adjustments during this period curbed inflation rates, but as the threat of inflation diminished, observers and administrators became increasingly aware that the Bolivian economy was in desperate need of alternative export products to fill the vacuum created by the weakened mining economy (Sachs and Morales 1988).

Coca became an important product to fill that vacuum, with disastrous results. As colonization of the tropical Chapare area in Cochabamba increased, the export of illegal cocaine came to the forefront of the political forum. Huge sums of money entered the country through illegal channels. By the late 1980s and early 1990s, the United States was deeply entrenched as the primary provider of aid dollars to eradicate illegal coca production in the Chapare and elsewhere (Klein 1992). Unfortunately, a legal, highly valued product, or better still a suite of such products, has yet to manifest itself, and the Bolivian economy remains stagnant in the face of increasing civil unrest and a general feeling of dissatisfaction.

CHAPTER IV: STUDY AREA BACKGROUND

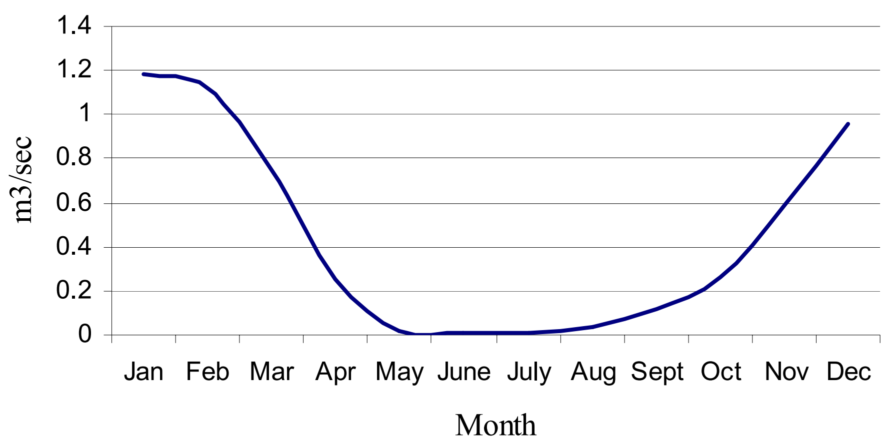
GEOGRAPHY

The Tipajara watershed is a tropical mesothermic valley located in the Province of Mizque. Mizque is located between the following parallels and meridians:

17 degrees 45 minutes and 18 degrees 30 minutes Southern Latitude
66 degrees 15 minutes and 66 degrees 45 minutes Western Longitude

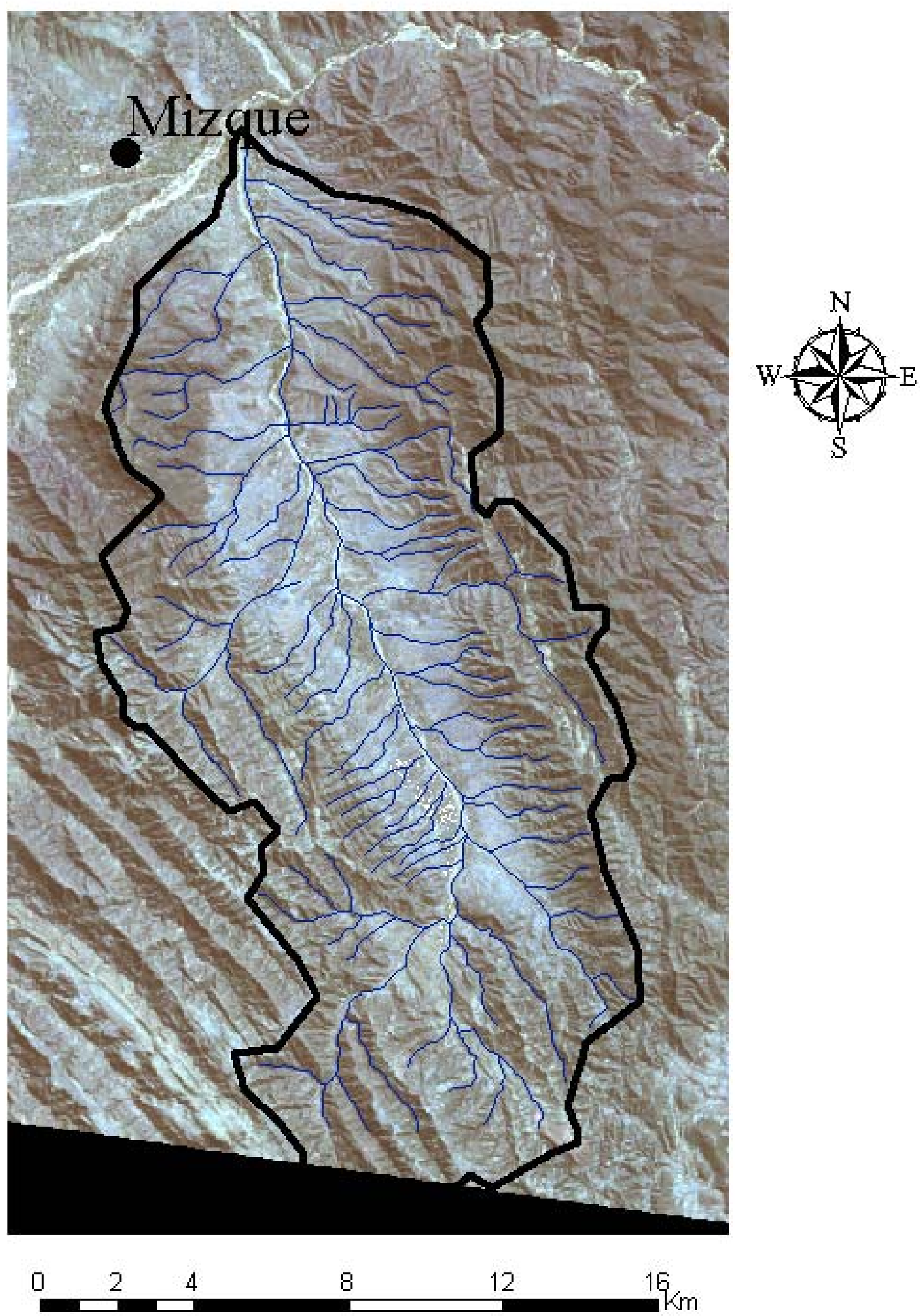
The watershed delineation presented in Figure 4.1 shows that the Tipajara River drains into the Mizque River. At its confluence with the Mizque River, the Tipajara River discharges minimal quantities of water per year (Figure 4.2).

Figure 4.2: Discharge of water, Tipajara river



Source: PDAR 1991

Figure 4.1: Tipajara watershed delineation and drainage



UTM
Spheroid: International 1909
Datum: Provisional South American Datum 1956 (PSAD 56)
Backdrop: Landsat TM Image, July 2002

CLIMATE

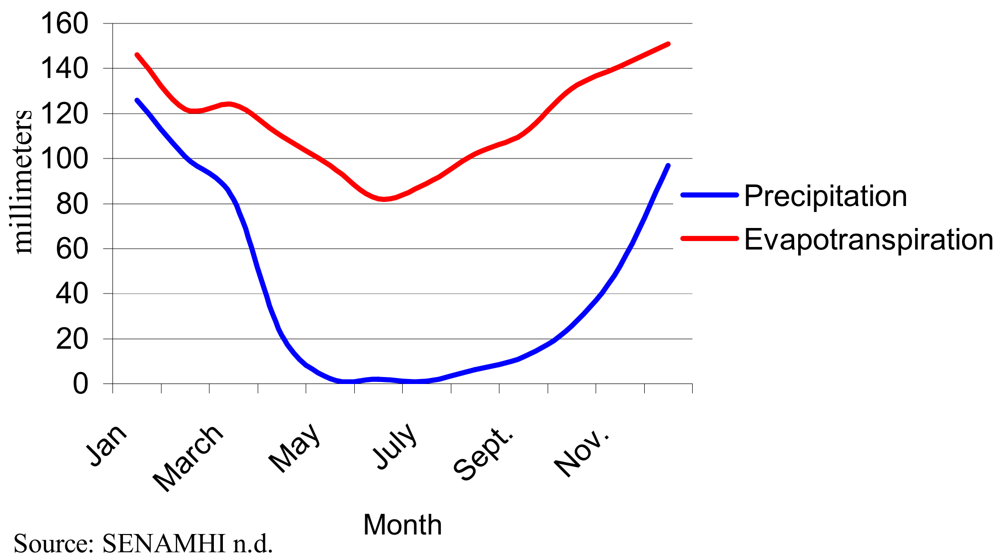
Although the Tiapajara watershed is at tropical latitudes, an average altitude of 2,200 m combined with an arid climate means there are no tropical rainforests to be seen (Figure 4.3).

Figure 4.3: Farm fields and thorny vegetation dominate the valley floors

Being relatively far south from the equator, there is a noticeable but subtle shift in total daylight hours from one season to the next. Summer days are approximately 13.5 hours long, while winter days are approximately 11.5 hours long; this makes for a difference of two hours. Some crops are sensitive to even the slightest change in photoperiod and this must be taken into account when analyzing cropping patterns or vegetative coverage.

Seasonal shifts in climate are most marked by the presence or absence of rain. The Tipajara watershed receives an average rainfall of 529 mm/yr, most of which falls between the months of November and April. Figure 4.4 compares monthly rainfall with potential evapo-transpiration. The averages for rainfall combine data from the weather stations in Aiquile and Mizque from the years 1959 to 2001. As the figure shows, a severe water deficit in the winter months is the single most important factor limiting agricultural productivity in this sector of Cochabamba.

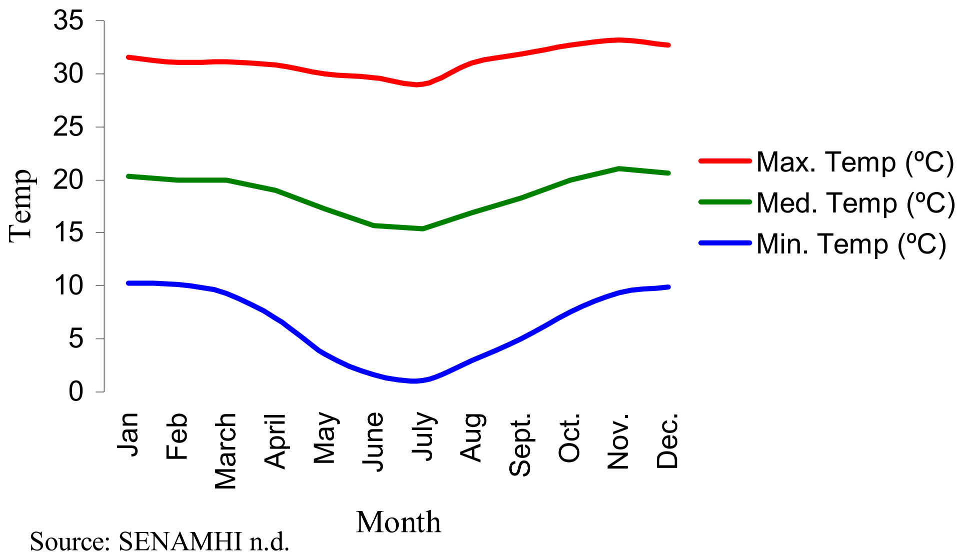
Figure 4.4 : Water Balance, Tipajara Watershed



Source: SENAMHI n.d.

Less distinct but equally as important, the valley's two seasons are marked by a drop in average temperatures. Figure 4.5 represents 30 years of temperature averages (minimum, median, and maximum). The data was collected from the years 1959 to 2001. The most apparent change in average temperatures occurs in the minimum temperature category. During the coldest months of June, July and August nighttime temperatures will sometimes drop below freezing. Median temperatures fluctuate between 15ºC and 21ºC. Summer median temperatures are ideal optimum growing conditions for a number of agricultural crops. There is little seasonal variation in maximum temperatures, which have a yearly average of 31.3ºC. High temperatures are rather moderate and pose little threat to most crops. The local median and high temperatures do present a limitation in that some crops require extreme temperatures for optimum growth.

Figure 4.5: Temperature categories, Tipajara watershed



Source: SENAMHI n.d.

SOILS

The soils in the Tipajara watershed were classified in a study conducted by the *Programa de Ecologia y Medio Ambiente* (PDAR) in 1991. They were classified by order, suborder, group and subgroup. The three dominant orders, in order of percentage of total land area, are entisols, alfisols, and inceptisols (Table 4.1).

Table 4.1: USDA soil orders and groups for the Tipajara watershed

Order	Suborder	Group	Subgroup	Phase
Entisols	Orthents	Ustorthents	Typic Ustorthents	
			Lithic Ustorthents	
Inceptisols	Ochrepts	Ustochrepts	Aridic Ustochrepts	Calceric
Alfisols	Ustalfs	Haplustalfs	Aridic Haplustalfs	Calceric

Adapted from PDAR 1991

Table 4.2: Characteristics and distribution of dominant subgroups in the Tipajara watershed

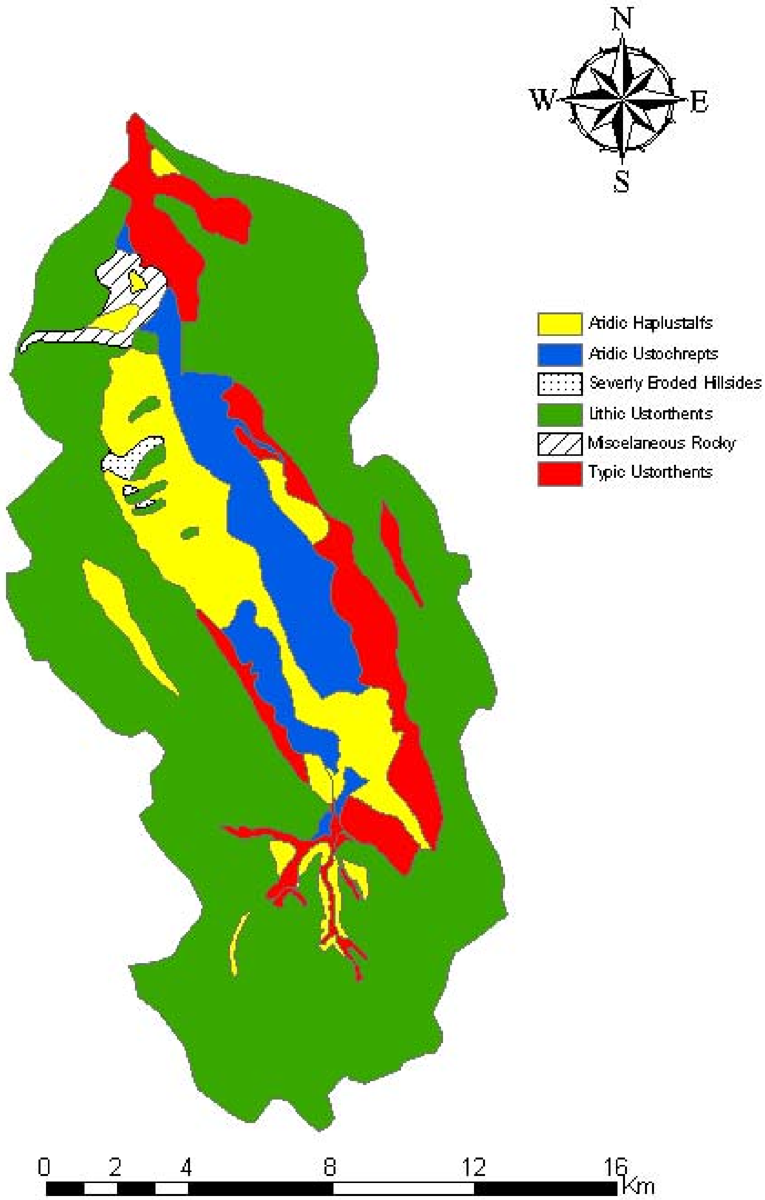
Subgroup of Dominant Soils	Physiographic Features	Hectares	%
Aridic Haplustalfs*	Plains with gentle to moderate slopes. Prairies at the foot of mountains. High terraces.	4,043	16.5
Aridic Ustochrepts*	Prairies at the foot of mountains. High terraces. Low terraces	1,992	8.1
Eriales	Eroding Hillsides	94	0.4
Lithic Ustorthents	Mountains with steep slopes.	11,442	46.7
	Mountains with moderate slopes.		
	Hills at the foot of mountains.		
Miscellenous Rocky	Escarpment of plains	3,850	15.7
Typic Ustorthents*	Mountains with moderate slopes.	2,746	11.2
	Hills at the foot of mountains.		
	Low terraces		
	River Bed	320	1.4

Adapted from PDAR 1991
*primary soils for onion production

Figure 4.6 shows a map for the different soil subgroups in the Tipajara watershed.

A detailed summary of the physical and chemical characteristics of these soils can be found in Appendix I.

Figure 4.6 : Soil series by subgroup in the Tipajara watershed

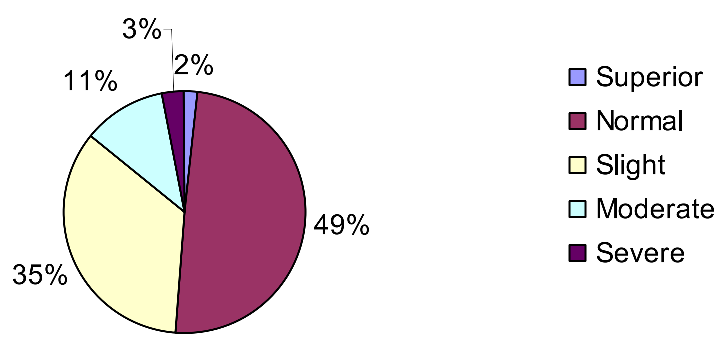


UTM
Spheroid: International 1909
Datum: PSAD 56
Source data: PDAR 1991

FAMILY NUTRITION

Most families primarily consume foods rich in carbohydrates. Rice, maize and potatoes are the staples of the vast majority. These are often eaten in soups, sometimes mixed with different vegetables grown locally. Fresh meat is uncommon, perhaps consumed on average once a week. Eggs are a primary source of protein, though dried jerky is a common component of soups. During the months of March, April, and May, fruit is often picked from trees scattered in the fields. Families tend to consume carbohydrates at the expense of other important foods. Most notably there is a glaring lack of protein and dairy in the local diet, but fruit and vegetables are also consumed sporadically. Figure 4.7 illustrates the generally poor level of nutrition experienced by most children under 5 in the community of Tipa Tipa. Free check-ups at the local health center are only available for children under 5 years and pregnant mothers; this explains why the data only cover this age group.

Figure 4.7 : Nutritional state of children under 5 years, Tipa Tipa
Based on local classification



Source: Distrito X de Salud Mizque (SNISII)

It is quite possible that levels of malnutrition are much higher in other communities that are more water limited, as these communities are unable to grow vegetables or fruit trees.

HISTORY

The Pre-Incaic valleys of Mizque were most probably occupied by agriculturalist tribes that also relied on hunting and gathering as a means of subsistence. Various rock paintings have been found in the area depicting different zoomorphic and anthropomorphic figures (Figure 4.8).

Figure 4.8: Pre-Columbian zoomorphic figures near the town of Mizque
Photo courtesy Brad David Kennedy

A common theme in many of these paintings is hunting, suggesting that wildlife and forests provided important products to early human settlements in the area.

Around 1480 the Inca sent a *mitimae* colony of Aymara speaking Chuy people to settle the Mizque valley. The group was sent to defend the eastern frontier from aggressive Guarani speaking tribes, known as the Chiriguano (Gade 1999). Many fortifications were built along the eastern frontier to defend the empire from Chiriguano incursions; the most famous of which can be seen at Incallajta several kilometers from the town of Pocona (Swaney 2001).

Forty years after the Conquest, Viceroy Francisco Toledo founded the *reducción* of San Sebastian de los Chuyes, known by the local inhabitants as Mizque, with the expressed intent of creating a nucleated village that would prevent further Chiriguano incursions. Spaniards found the location attractive and migrated there for several reasons. Flat, fertile soils, a warm climate and abundant water from the Mizque River created favorable conditions for agriculture. The climate permitted a diet of wheat bread and wine from fermented grapes, reminiscent of the Mediterranean foods that the Spanish preferred. Forest resources and fish were also in great supply (Gade 1999).

The location was also economically advantageous. The mining metropolis of Potosi, surrounded as it was by poor soils and cold, dry conditions, relied primarily on imports from the *altiplano*, valleys, and *yungas* for its supply of agricultural products. Mizque was well situated between Cochabamba, Sucre, and Potosi, which made it a primary destination along this important trading route and an important producer in its own right (Gade 1999). Figure 4.9 shows a colonial bridge on the road between Cochabamba and Mizque.

Figure 4.9: *El Puente de los Libertadores*, called so because Simon Bolivar passed across this bridge on his travels to the cities of Sucre and Potosi
Photo courtesy Brad David Kennedy

By the 18th century Mizque had a population of 22,000 and was well established as one of the most important towns in Upper Peru. The Catholic Church had a strong presence in Mizque. With several religious orders and a cathedral, the pleasant town of Mizque acted as the *defacto* seat of the diocese for several bishops that preferred it to the much hotter climate of Santa Cruz de la Sierra (Figure 4.10). Mizque also had a hospital, only one of seven in all of Upper Peru (Gade 1999).

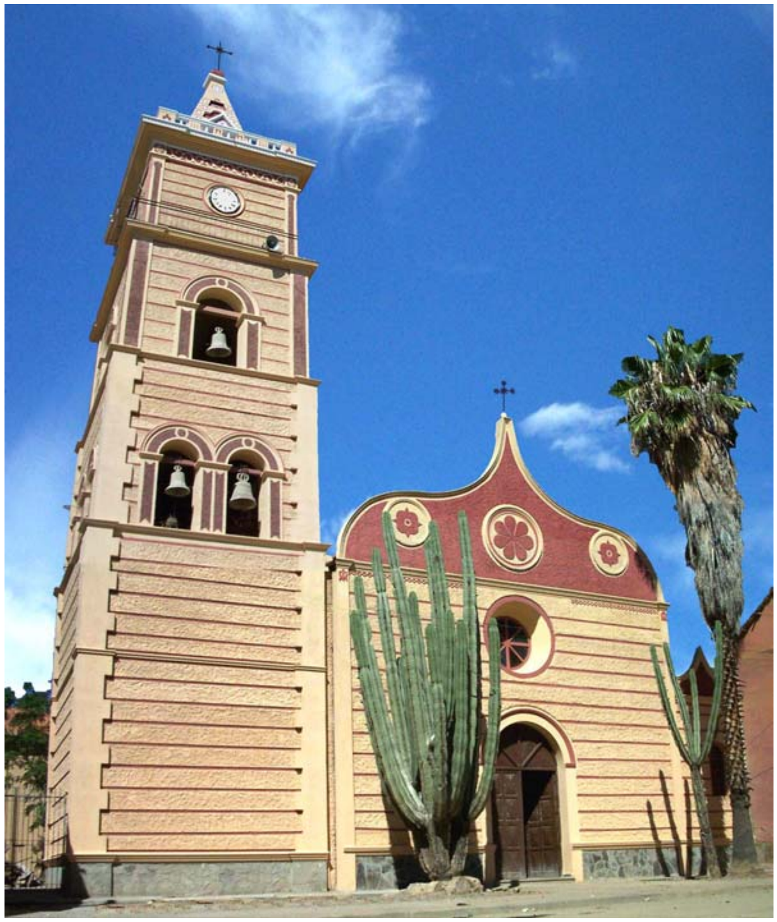


Figure 4.10: The newly restored Cathedral in Mizque
Photo courtesy Brad David Kennedy

The *hacienda* was the primary producer of agricultural goods. The *haciendas* of Mizque relied heavily on *yanacona* laborers, who were often descendants of the highland Indians that fled their communities in an attempt to escape from the *mit'a.* Wine producing *haciendas* relied primarily on African slaves to perform most of the tasks on the vineyard. Some *haciendas* were so large that they had access to both highland areas (>3000 m) and valley lands. The highest areas were used to graze cattle, sheep, and horses, while lower, unirrigated slopes were used to cultivate wheat, maize, quinoa, barley, pulses, and potatoes. Irrigated lands in the valley bottoms were used to produce native crops, like sweet potato, *ahipa*, maize, and *yacon* , and introduced crops like sugar cane, cotton, tobacco, and grapes. Many different fruits also became commonly cultivated in irrigated parcels: avocado, cherimoya, pacay, banana, orange, fig, apple, quince, and peach (Gade 1999).

Mizque's economy was linked to the greater economy of Upper Peru through its abundant natural resources. Enormous quantities of wine were exported to the insatiable markets of Potosi. Declines in the mining economy in the early 18th century decreased the demand for wine, and grapes were superceded in importance by local varieties of chili pepper. Mizque was also a supplier of honey, wheat, horses, wax, and cotton. Timber was also sent to Potosi for use in making mining equipment. Cedro (*Cedrela spp.*), a local forest tree, was exported as a prime cabinetry wood (Gade 1999).

This era of prosperity did not last. In the early 18th century Mizque began a long and steady decline. In 1710 the town of Mizque was ravaged by an epidemic of fevers that eliminated half of its population. By 1771 the Chuy Indians, descendents of the original *mitimae* colony, had been almost completely wiped out by malaria. All segments of the population experienced this decline: from the Spanish *vecinos* to the indigenous *originarios, forasteros,* and *yanaconas*. The decline in the native population resulted in the subsequent collapse of the *hacienda* economy, as labor became scarce and existing laborers were often too sick to work at full capacity. The only group that seemed to flourish were the people of African ancestry, who made up 30 percent of the population in the valleys of Mizque by the year 1787 (Gade 1999).

Malaria was the causal agent responsible for Mizque's demographic collapse. At this time, people were not well equipped to deal with malaria and its horrible consequences. They were unaware that the mosquito was the primary vector of the disease; they were equally oblivious to the fact that Mizque, with its warm climate and its floodplains and stagnant puddles, was the perfect breeding ground for this fatal pest. The result was disastrous (Gade 1999).

Unable to avoid infection by remaining in the Mizque valley, most people developed different strategies to minimize the risk of contracting malaria. Some Spanish landowners fled to the upland areas of their *haciendas*, while others abandoned the area and moved to the nearby city of Cochabamba. Traveling merchants learned to bring their llama trains through Mizque during the dry season, when the risk of malaria infection was relatively low. Resistance to the disease played an important part in determining the composition of the population. Africans seemed to have the most genetic resistance to the disease, most likely because of exposure in their native continent, followed by the Spanish, who were also exposed to malaria on the Iberian Peninsula. The indigenous population seemed to suffer the most, and this partly explains why most *mizqueños* are now *mestizos* (Gade 1999). Interestingly, the African population has totally disappeared from present-day Mizque.

The early 20th century showed no improvement in the centuries long malaria crisis that gripped the region. Between 1908 and 1940, 40 percent of the deaths that occurred in the area were attributed to malaria. From 1922 to 1929, 70 percent of all deaths were attributed to the disease. Yet advances in science and medicine were to change this. Modern science had identified the mosquito as the vector of malaria, and in the three years between 1929 and 1932, a massive effort was made to eliminate standing water from Mizque. Homes were fumigated and whitewashed, and quinine was made available to those individuals that tested positive for malaria. A nation wide epidemic in the early 1940s drew further attention to the problem, and Mizque was fumigated with DDT while new synthetic drugs were distributed to the unhealthy population. These tactics finally yielded a measurable result: by 1951 not a single person in the town of Mizque tested positive for malaria (Gade 1999).

The valleys of Mizque underwent major changes in the years that followed the centuries long battle with malaria. Coincidentally, malaria was brought under control at the same time that the Agrarian Reform was getting underway. The *haciendas* were destroyed and their lands were divided amongst the landless sharecroppers. Between 1950 and 1976 Mizque experienced a 32 percent increase in population; many of the newcomers came from the Cochabamba valley in search of unoccupied agricultural land. The eradication of malaria also caused a drastic reduction in infant mortality. By the 1980s, 50 percent of the population was under 20 years old. Irrigation expanded to cover 70 percent of the valley floors, and the years between 1955 and 1967 saw a doubling in agricultural productivity. Improved infrastructure, such as roads, electricity, water, and sewage also improved living conditions and once again connected Mizque with the broader Bolivian economy. In short, the eradication of malaria spurred the development of the Mizque valleys (Gade 1999)

CHAPTER V: METHODS AND DATA

PROJECT BACKGROUND

The data collection for this study was undertaken as part of an integrated farm systems management project that I executed in collaboration with the community of Tipa Tipa and the Bolivian non-governmental organization (NGO) PLAN. After a year and a half of fieldwork with my community counterpart, we both believed that alternative forms of production were necessary if local farmers were to have any hope of achieving sustainable production and a steady income over the long term. My assumption that onion production was unstable, based on field observations, led me to design and present a written grant proposal to PLAN. In the process of writing the proposal, it was agreed that the project budget would include money for the hire of two field technicians. Their job was to work in collaboration with the Peace Corps volunteer to design and implement a cost-benefit analysis and a general farm systems analysis for the Tipajara watershed. The data would then be used as a basis for understanding the current state of agricultural production and to identify constraints to future increases in productivity. After completing the data collection, I presented PLAN with a general summary of the cost-benefit data and the demographic data collected for the Tipajara watershed. PLAN will use the data to design future projects in agriculture, forestry, health, and family nutrition. In addition, it was agreed that I would use the data to prepare my thesis.

STUDY METHODOLOGY

Though much of the data presented in this thesis is based on a quantitative model that I developed through survey questionnaires, there is a great deal of information included that was gathered through participant observation. Essentially, a participant observer is a researcher who is completely immersed in the community and culture being studied. Though Peace Corps and participant observation are two distinct phenomena, they are certainly complementary, as Peace Corps provides the researcher with the perfect opportunity to participate in all aspects of community life. All of the data presented in this thesis, whether quantitative or qualitative, rests on the firm foundation that I laid in the early months of my Peace Corps service as a participant observer. Participant observation requires knowledge of the local language, an awareness of the cultural forces at work in people's daily lives, and the trust of local people that inevitably builds as the observer becomes a fixture in the community, which allows people to go about their activities in a normal fashion (Bernard 2002, Nichols 2000).

I used key informants quite extensively as a means of understanding changes in the farm system over time (Bernard 2002). Key informants provided me with important information on the following topics: local history, changing cropping patterns, family lineages, and incidence of disease through time.

Many researchers with experience in the developing world have emphasized the importance of pilot testing as a means of avoiding irreparable errors in the main data collection phase of a research survey (Devereux and Hoddinott 1993). Nichols (2000) defines a pilot survey, or a pre-test, as "a small survey, in advance of the main fieldwork, to test the form, sampling procedures and fieldwork management procedures" of the study being conducted. The pre-test for this study was done in September of 2001, when fellow PCV Kitri Falxa and I designed the survey forms and interviewed 25 farmers in Tipa Tipa to calculate the cost of production and net income for the onion production cycle of 2001. This experience allowed me to design, and later refine, the survey forms that were used in the main survey, to understand the potential pitfalls certain questions may have, and to develop a statistical sampling methodology.

I was also given the opportunity to further refine the survey form when, in August of 2002, I attended a workshop in the city of Cochabamba with several farmers from Tipa Tipa and the two field technicians who would do the interviews for the study. In this workshop, as a group activity, we calculated the real costs of production with the four local farmers. During the activity, the farmers were able to point out several hidden production costs that I had overlooked in the initial survey design.

I had to confront several important considerations and limitations when I was designing the study. To make the population size manageable, and in consideration of the mountainous geography of the Mizque Province, we agreed to limit the study to the geographic area of the Tipajara watershed. Considering the profound ecological differences due to extreme changes in elevation over relatively short distances, watersheds are a logical unit of measure for any natural resource management program in the rural valleys of Bolivia.

Since PLAN was financing the data collection process, they required that the data be collected only from communities in which PLAN was currently working. Due to the nature of PLAN's fiscal structure, they are very strict about working in communities that have gone through the lengthy process of formally affiliating themselves with the NGO. Based on these two criteria, we were able to make a preliminary list of the communities to be included in the study. They are:

Loro Mayu
Montecillos
Rumi Cancha
San Pedro Alto
San Pedro Bajo
Taboada
Tipa Jara Grande
Tipa Jara Chico
Tipa Tipa

Rumi Cancha, San Pedro Alto, and Tipajara Chico were eliminated from the list because these three communities have less irrigation water and only cultivate onions on a small, non-commercial scale. It should be noted here that Khuru Mayu is the only significant onion producing community in the Tipajara watershed that is not on the list. It is therefore unlikely that this sampling methodology introduced any significant bias into the study. It was not possible to include Khuru Mayu in the study because they had no affiliation with PLAN.

After deciding which communities were to be included in the study, I required a sampling frame to determine the number of onion farmers in each community (Bernard 2002). Every community in this sector of Bolivia is organized into *sindicatos*, which are the equivalent of village governments. Though not every community member is affiliated with the *sindicato*, I estimate that approximately

95% of households are affiliated and listed in the registry. Unmarried males with no children are less likely to be affiliated than any other demographic group. The hired field technicians visited each village during a community meeting to explain the nature of the study and to ask permission to conduct the study. Once the community granted permission to conduct the study, the field technicians were allowed access to the *sindicato* registry, which has all the names of affiliated household heads. At this point, the community of Tipajara Grande indicated that they did not want to participate in the study, and this community was subsequently eliminated from the list.

Once a full list of all affiliated members was obtained for each community, I divided each household into two categories: onion producers and non-onion producers. This was done through verbal verification with a member from each community. To summarize, the population from which I took the sample was determined by the following characteristics: all onion-producing households in the Tipajara watershed affiliated with the *sindicato* in communities associated with PLAN. After I acquired the sampling frame, I used the following equation to determine the sample size:

$$\frac{x^2 NP\,(1-P)}{C^2\,(N-1) + x^2\,P(1-P)}$$

Where x^2 is the chi square value for 1 degree of freedom at a desired probability level. N is the population of onion farmers in the five communities and C is the confidence interval, which I set at 5%. P is the population parameter of a variable, which in this case I set to 0.5 (Bernard 2002). Once the total sample size was calculated, I used the proportional allocation method to determine the number of households to be included from each community. In this procedure the proportion of the sample that was selected from each community was equal to the proportion of all households within that community (Freese 1984). The calculation had the following results:

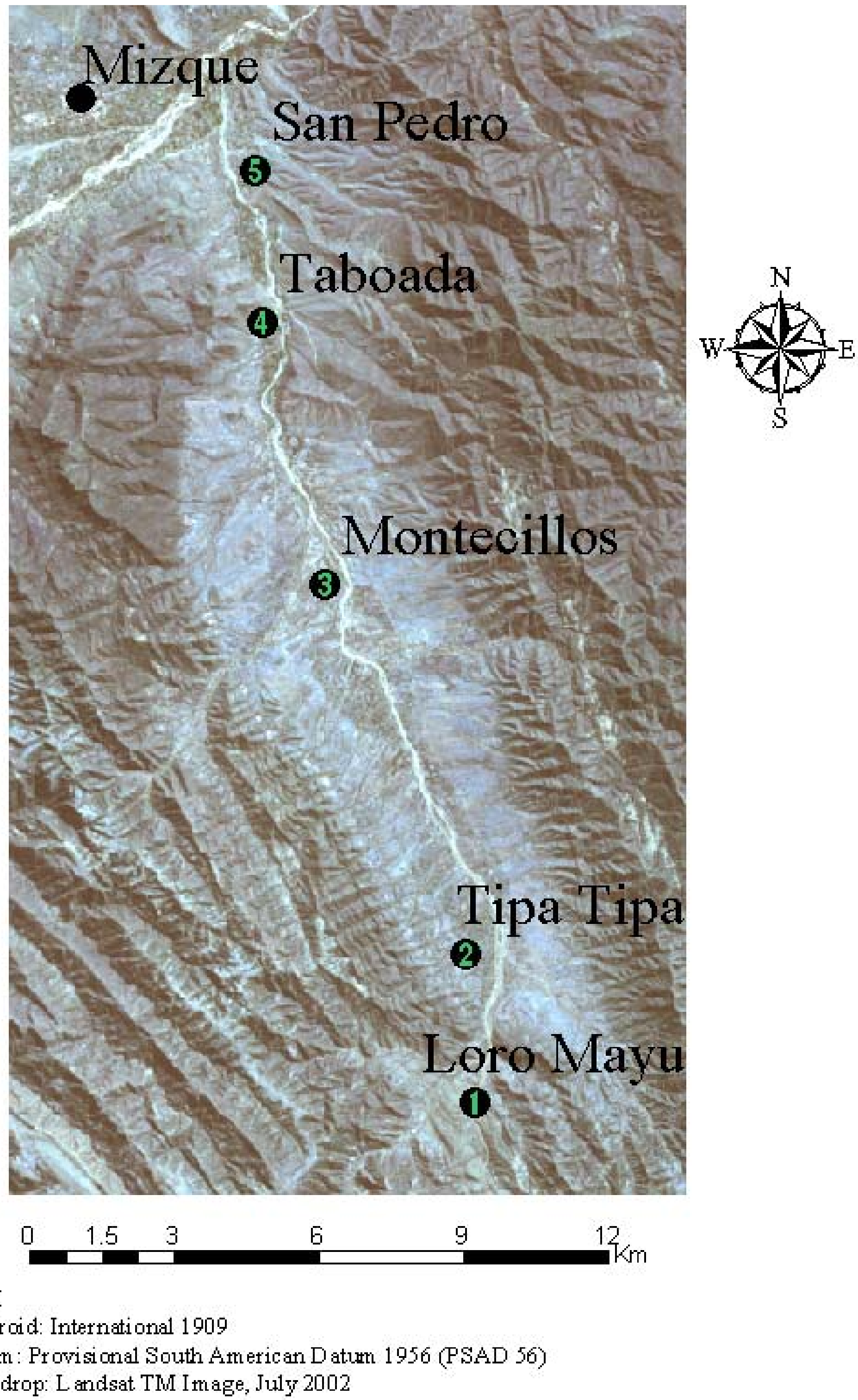
Table 5.1: Sample size by community

Community #*	Community Name	# of onion producers	# in sample
1	Loro Mayu	20	10
2	Tipa Tipa	100	55
3	Montecillos	69	32
4	Taboada	73	40
5	San Pedro Bajo	60	32
Total		322	169

*The numbers assigned to each community will be used instead of names

Working through the calculation, one quickly realizes that the total number in the sample at a 5% confidence interval should be 175. These 6 households were eliminated from the survey at the very end because they had proven extremely difficult to find, and the field technicians were tired of the enormous amounts of footwork required to find each farmer. The sampling method was a simple random sample. I assigned a number to each household; I then used a random number generator in MS Excel to select each household to be interviewed (Bernard 2002).

Figure 5.1: Study communities by number



The two field workers responsible for the data collection, Toribio Maygua and Mario Huanca, were undergraduate students hired from the University of San Xavier de Chuquisaca. Hiring field workers to conduct interviews provided several advantages. The first and most obvious was the increase in manpower needed to complete the interviews in a reasonable amount of time. *Técnicos,* as described by Boa et. al. (2001), also provide other advantages. Their ability to communicate effectively with both scientists and local farmers is an important bridge between the two cultures, and in this particular case their mastery of both Quechua and Spanish proved an invaluable skill when dealing with semi-literate, often times monolingual, Quechua families.

Bernard (2002) explains that using multiple interviewers has several distinct disadvantages, as well. For example, each interviewer may introduce bias into the study. This is especially the case when the survey involves complex or embarrassing social issues and/or open-ended questions. I minimized the potential for interviewer bias in a number of ways. First, the questionnaire used only forced choice questions, which generally avoided sensitive or embarrassing potential responses. Furthermore, I trained the interviewers in tandem to ensure that their method of asking the questions was both uniform and unambiguous. I was able to anticipate potential misunderstandings because of the survey pre-test performed the year before. The interviewers were each required to do several mock interviews to ensure that they asked the questions in a uniform and consistent manner (Nichols 2000). This practice was followed by several trips to the field where I monitored the field workers to verify that they were asking the questions in the appropriate manner. Once the field technicians reached a satisfactory level of skill in conducting interviews, they were required to observe one another at regular intervals to guarantee that their method of interviewing remained consistent throughout the interview process. All participants were informed in their native language of Quechua that their participation was voluntary, and at any time they could choose to terminate the interview. This research was conducted following Human Subject Research guidelines and was approved by the Michigan Technological University Institutional Review Board.

It must be noted that we were forced to change the names in the random list a number of times. However, these changes were only made when absolutely necessary. Some families on the list had moved within the past year. Some families refused to participate, and other families did not cultivate any onions for the 2002 cropping cycle. Whenever this happened, the family was eliminated from the list and another family was randomly selected from the original sampling frame. It took approximately 4 months to complete all 169 surveys

During the data entry process, I tried to filter out biased or illogical responses within the survey data. In any instance where the information on the data sheets looked unusual (e.g. extremely high or low numbers) or in some cases was illegible, I consulted with the field technicians to confirm the information. There were several instances when I personally consulted with the interviewed farmer just to make sure his response was correct. In an overwhelming majority of the cases, from my experience and the experience of the field technicians, the farmers did their best to provide honest responses to the best of their knowledge.

I also had the opportunity to use a geographic information system (GIS) to generate the maps that are used in this thesis. I used GIS to determine ground cover from satellite images, to create tenure maps based on aerial photos, and to show changes in land use, land cover, and infrastructure over time (Burrough and McDonnell 1998, Chang 2002). The primary GIS packages that I used were ARC View, ARC Map, ERDAS Imagine, and ILWIS.

UNIVARIATE STATISTICS

This is a brief summary of the data set for the household survey conducted in the Tipajara watershed in the 2002 cropping season. Table 5.2 summarizes the physical inputs used for onions production. Table 5.3 summarizes these values in economic terms, and Table 5.4 summarizes the economic indicators of production. At the time of the study, USD $1 was equivalent to Bs. 7.45. These are the most relevant and logical variables for analyzing onion production in the Tipajara watershed. Differences in community are not shown in these summaries, but will be addressed using more rigorous statistical tests in the results and discussion chapter. Table 5.5 shows some of the basic demographic characteristics of the study population by community. Table 5.6 is a census of the average number of animals for each family by community. Generally, those families and/or communities with more animals have less irrigation.

Table 5.2: Physical Inputs for Onion Production in the Tipajara watershed

Variable	N	Mean	Std Dev	Minimum	Maximum
Male Labor (Days/Ha)	169	171	88	16	648
Female Labor (Days/Ha)	169	95	48	6	256
Tractor (Hours/Ha)	169	4	7	0	60
Oxen (Days/Ha)	169	19	14	0	80
Manure (Trucks/Ha)	169	1	1	0	8
Manure (Bags/Ha)	169	13	32	0	240
N (Kg/Ha)	169	91	67	0	437
P (Kg/Ha)	169	76	68	0	442
K (Kg/Ha)	169	2	9	0	77

Table 5.3: Economic Inputs for Onion Production in the Tipajara Watershed

Variable	N	Mean	Std Dev	Minimum	Maximum
Parcel Size (Ha)	169	0.69	0.78	0.13	8.00
Male Labor (Bs/Ha)	169	3392.00	1738.00	320.00	12160.00
Female Labor (Bs/Ha)	169	1135.00	619.90	60.00	3600.00
Tractor (Bs/Ha)	169	277.05	353.45	0.00	1400.00
Oxen (Bs/Ha)	169	384.78	298.68	0.00	1680.00
Manure (Bs/Ha)	168	1358.00	2183.00	0.00	20000.00
Fertilizer (Bs/Ha)	169	735.69	526.64	0.00	3350.00
Fumigation (Bs/Ha)	169	1604.00	1316.00	0.00	8000.00
Seed (Bs/Ha)	169	1242.00	684.58	70.00	3600.00
Fumigation Frequency (Times/Week)	159	1.32	0.59	0.25	4.00

Table 5.4: Economic Indicators for Onion Production in the Tipajara Watershed

Variable	N	Mean	Std Dev	Minimum	Maximum
Yield (Tn/Ha)	169	18.35	12.51	0.00	68.64
Selling Price (Bs/Bag)	169	57.13	19.31	0.00	140.00
Gross Income (Bs/Ha)	169	8988.00	7337.00	-240.00	36560.00
Cost of Production (Bs/Ha)	169	10381.00	6007.00	916.00	50896.00
Net Income (Bs/Ha)	169	-1393.00	7733.00	-42896.00	20400.00

Table 5.5: Demographic Averages per Household in the Tipajara Watershed

	Community 1	Community 2	Community 3	Community 4	Community 5	Tipajara Watershed
Family Size (Persons/Household)	8	6	7	6	6	6
Total Arable Land (Ha/Household)	3.1	2	2.9	1.8	1.9	2.2
Catholic (%)	100	68	82	92	88	81
Evangelist (%)	0	32	15	8	13	17
Father's Age	49	40	44	43	41	42
Father's Education (Grade Level)	4	5	3	5	5	5
Mother's Age	47	37	44	43	39	41
Mother's Education (Grade Level)	3	4	3	4	3	3

Table 5.6: Mean Number of Animals per Household in the Tipajara Watershed

	Community 1	Community 2	Community 3	Community 4	Community 5	Tipajara Watershed
Chickens	8	2	6	4	5	4
Cows	8	3	4	2	3	3
Donkeys	2	0	0	0	0	0
Goats	26	2	10	6	6	7
Pigs	1	1	2	1	2	1
Sheep	15	5	11	1	3	6
Total	59	13	34	14	19	21

MULTIVARIATE STATISTICAL METHODS

Once the data had been entered and properly summarized, I used Statistical Analysis Software (SAS) to perform a number of statistical tests. First, I analyzed the data using a Pearson test for correlation, which allowed me to decide what further statistical tests were required. The Pearson test showed that there were many relationships between the variables for onion production. Demographic variables revealed fewer relationships; those relationships that did exist had higher P-values and were therefore weaker. The Pearson test demonstrated that the data were excellent for creating a multivariate regression model (Hill, Griffiths, and Judge 1997). I then used SAS multivariate regression technique to generate two multivariate regression models: one for yield and another for net income.

I also used an ANOVA test of significance to test differences across these categorical distinctions: community, parcel size, and winners/losers. An ANOVA test of significance only shows that a difference exists. When more than two categories exist for each variable, the ANOVA does not indicate where the differences exist between categories. I therefore selected all those tests that were statistically significant for further analysis. I then used Tukey's *w*-procedure, which allowed me to ascertain which differences within each category were significant and which were not (Steel and Torrie 1960).

CHAPTER VI: RESULTS AND DISCUSSION FOR TENURE AND LAND USE

Changes in land use and land tenure in the years that followed the eradication of malaria drastically changed the structure of society and the nature of agricultural production in the Tipajara watershed. Linked as it is to the greater towns of Mizque to the North and Aiquile to the South, the Tipajara watershed experienced the same changes that the Mizque valley did in the years following 1952. During my time as a Peace Corps volunteer, I took a particular interest in this transformation and how it shaped changes in agriculture. This chapter documents the intensification process during this period, and it provides important information for understanding the reality and the consequences of a cash crop monoculture for the farmers in the Tipajara watershed.

PRE-REFORM SOCIETY

Throughout its history, the Tipajara watershed has been an agricultural valley that links the two larger towns of Aiquile to the South and Mizque to the North. Evidence of pre-Colombian peoples is not scarce: from stone fortifications on mountaintops to shards of pottery in farm fields to pre-Incan rock paintings depicting hunting scenes. The people that live in the area have no memory of these distinct cultures, nor are their histories preserved through oral tradition.

Ethnographer Georges Rouma (1933) gives an account of the culture of the Quechua Indians living in the *hacienda* of Novillero in the era before the Agrarian Reform. Novillero is approximately 30 km. from the Tipajara watershed. Some of the customs and traditions he describes have long since disappeared, others remain in the more isolated communities, and others are still a part of the daily life of the Quechua speaking *campesinos* in the area.

Rouma describes a culture that was still very much self-sufficient in providing most of the needs for the daily household. Clothing was generally produced from sheep's wool, which was produced on-farm. Women were responsible for shearing the sheep and turning the wool into yarn, which was then used to weave ponchos, pants, sweaters, and even hats. Men were responsible for building the home, the base made of stones, the walls of adobe bricks, and the roof from mud and sticks. The household also produced a number of useful domestic products: ceramics, knives, picks, and sandals. A variety of plants and trees were used for wood, medicine, and food (Rouma 1933).

The farm system was based primarily on the production of cereals. Maize was a staple crop produced and consumed on-site. Surplus might be sold to the city, but the majority of the surplus was stored in a silo made from the hard branches of the *chacatea* shrub (*Dondonea viscosa)* (Figure 6.1).

Figure 6.1: Called a *pirhua* in Quechua, these silos have detachable roofs to allow for easy access to the stored maize
Photo courtesy Jimmy Knowles

Wheat was another commonly produced grain, especially on hillsides. A key informant, who had lived in the Tipajara watershed for approximately 80 years, said that chickpeas were a widely cultivated crop when he was a young man. Certainly potatoes were an important part of the farm system and the daily diet.

Coca (*Erythroxylum coca*) was consumed on a daily basis by the local population. Rouma (1933) estimates that each male above the age of 15 consumed around 60 grams of coca per day; women consumed 30 grams per day. This is probably very close to the amount that is consumed today, though the consumption of coca by women is observed infrequently. As one key informant recalled, llama trains full of coca would pass through the Tipajara watershed until the late 1950s, perhaps well into the 1960s.

Rouma (1933) also describes the most prominent festivals that occur during the year. To this day the largest festivals of the year are *Todos Santos* and *Carnaval*. During these festivals large quantities of *chicha*, a drink made from fermented maize, are produced and consumed over the course of several days. Traditional musical instruments like the *charango* (a small guitar) and *zampoñas* (pan pipes) are also played during these festivals (Figure 6.2).

Figure 6.2: A traditional band in Tipa Tipa

Pre-Colombian forms of worship were a part of everyday life. As Rouma (1933) explains: "…respect for *Pachamama* (Mother Earth), the ancient Incan deity, is still extremely alive. The Indians never take a portion of coca, a cup of *chicha* or alcohol without first giving some to the soil, in homage to *Pachamama*. When they build a house or before they begin a big job, they dig a pit and bury coca, salt, *chicha*, pepper. These are offerings to *Pachamama*." Though the intensity of these customs has been dulled somewhat by modernization, families still make these offerings to *Pachamama*.

One key informant was particularly useful in providing a great deal of information about Tipa Tipa in the era prior to and during the Agrarian Reform. From here forward, I will refer to him as Don Pedro. Don Pedro was born in 1941. He lived through the Reform as a young boy, and was always eager to explain times past. I would visit him often, and his stories became very much a part of my field notes as I tried to reconstruct the local history. He was the son of a sharecropper who lived on the *hacienda* of Josefina Betancur and her son Don Alberto Torrico. Though not required to work and live on the *hacienda*, most sharecroppers did so because all of the best lands were owned by the *patrones* (Klein 1992). Josefina and Alberto were the *patrones* of the area known as Tipa Tipa, called so for the presence of two oversized Tipa trees (*Tipuana tipu*) located within the boundaries of the community.

Don Pedro's parents were known as *colonos*, the pre-reform word for sharecroppers; in colonial times sharecroppers were labeled *yanaconas*. Don Pedro's parents were illiterate and were obligated to fulfill several services to the *patron*. First, they had to pay a rent fee to the *patron* for use of the land, this was known as the *jullk'a* in Quechua. Added to the heavy workload of subsistence agriculture, the *colonos* had to maintain the personal fields and flocks of the *patron* as well. Each family was also required to give 10 percent of the maize harvest and 10 animals annually. This system was known as the *pongueaje*. The *patrones* lived in the city and went to the countryside to collect payments and for vacations.

In 1947, Pedro attended school for the first time. It was the *patrones* themselves that helped with the establishment of the school for young male children. The school moved from house to house and never met with much success. Despite these token attempts at education, the society was very repressive. Community meetings were forbidden. Games were also not permitted. People were unaware that the game of soccer existed. The farmers spoke only Quechua. Very few people spoke or understood Spanish beyond the basics.

THE AGRARIAN REFORM OF 1952

In the year 1952, all of this was about to change. "The land is for those who work it," was the call to arms of the then disenfranchised *colonos*. In Tipa Tipa, clandestine meetings were held at night or in out of the way places. Then, one day, as Pedro described it:

> We went to the hills behind our house. In those days we used to plant maize in the hills too; and we were out there harvesting our maize when we heard the sound of a *pututu* blowing just down below, near the river. Then we heard another one from further away, and another, till the whole valley was full of the sound of the blowing *pututu*. It was the *reforma agrarian*. It had come.

The *pututu* is a Quechua word for a cow's horn that is blown into to inform the people that a meeting is being called. In this case, the many sounds of the *pututu* were a call to arms. Pedro, then 11 years old, and his older brother rushed to see what was happening. At the meeting he saw over 1,000 *colonos* that had come from nearby communities. Word had finally reached the area that the agrarian reform was a reality, and the people began to organize themselves to remove the *patron* and redistribute the land. In Tipa Tipa, the *patron* escaped in the night, and no blood was spilled.

With the disappearance of the *patrones*, community self-government began to flourish, and a tradition of democratic self-rule established itself in Bolivia's rural sectors. By 1954, Tipa Tipa formally established itself by forming a *sindicato*. The *sindicato* is a village government responsible for conflict resolution, organizing community activities, and identifying and implementing community projects. The *sindicato* of Tipa Tipa is headed by the *dirigente*. He is always a man, and he is elected once a year. During the reform, the *sindicato* was responsible for dividing land among its members.

Just as the Agrarian Reform was a watershed event for Bolivia, it was equally so for the *colonos* of Tipa Tipa. Land was divided according to uses and customs. Even before the reform, families worked certain areas and parcels from one year to the next. These traditions were preserved when the land was divided up amongst the families.

POST-REFORM SOCIETY

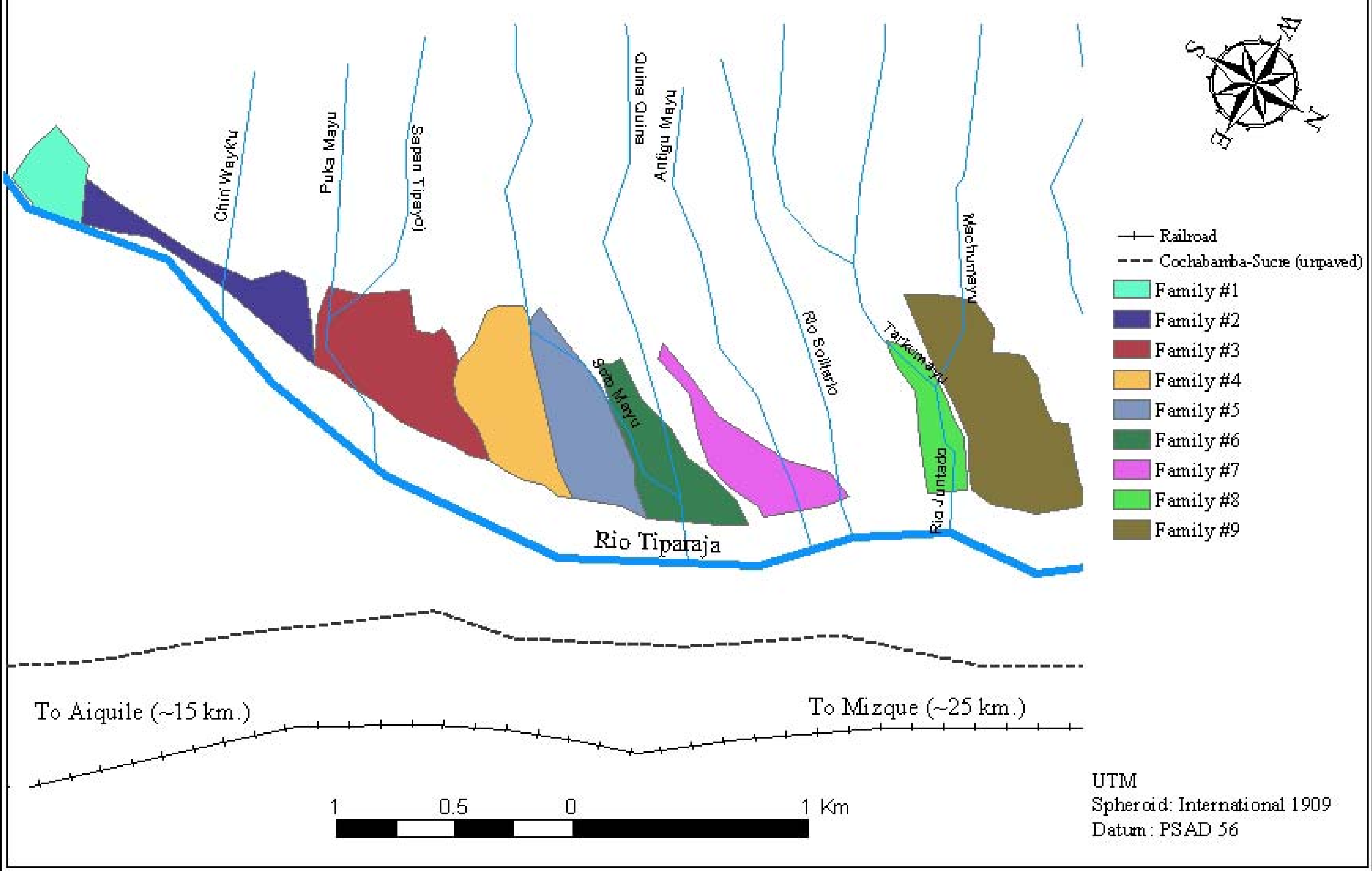
After the reform, *colonos* became known as *campesinos*. The liberation of the *campesino* was abrupt. He found himself in a world where he didn't understand the rules, much less the language, of land title. He suddenly had the right to vote; yet he was unable to read or write.

In the 20-year period from 1952 to 1972, community members in Tipa Tipa prospered. The onerous burden of the *pongueaje* system had been eliminated. As a result, families were able to save and sell more of their surplus production. Demographically, Tipa Tipa followed the same trend as Mizque, and indeed the same trend of the entire Bolivian popuplation (Table 2.1 page 8). Family sizes increased as the threat of malaria diminished. The introduction of modern medicine brought with it vaccinations and antibiotics, resulting in an overall decline in infant mortality. Families were larger than ever, and the abundance of land mandated that farmers have ever more children to help them with the backbreaking tasks of agriculture. Furthermore, the introduction of modern medicine was not accompanied by family planning, women's education, or a change in the role of women as domestic laborers and natal care providers. This mix of traditional culture and modern technology allowed average family size to reach as high as eight.

Figure 6.3 shows the level of infrastructure that existed in Tipa Tipa in 1961. The railroad was the primary means of transporting goods to Aiquile, Mizque, and Cochabamba. I do not know when it was first constructed. The road system was still unpaved and poorly maintained. Transporting goods was a tricky business, and this minimized the extent to which Tipa Tipa was integrated into the larger Bolivian economy. Other services, like electricity, health care, and quality education were still luxuries enjoyed by the wealthy elite

Analysis of aerial photos from August of 1961 reveals a community in desperate need of water. Small, hand-dug catchments can be identified across the landscape. The turbid, muddy water that these catchments held was used to meet the daily needs of the household and livestock. Figure 6.3 also shows the results of a land tenure analysis.

Figure 6.3: Land Tenure and Infrastructure, Tipa Tipa 1961



Based on aerial photos and lineage information from a key informant, I was able to identify the parcels of nine different families. I did this only for parcels that would, in the future, have access to irrigation water. The average size of these nine parcels is 20 hectares. So although water was scarce, this scarcity was partly alleviated by an abundance of land. As Don Pedro informed me, it was not unusual for a family to work between 10 and 15 hectares during a cropping cycle. Since the aerial photos were taken in August, well after the harvest but before the rains, it is impossible to gauge the amount of land each family had under cultivation during a given cycle.

Maize, wheat, and potatoes dominated the countryside in the area of Tipa Tipa. These crops require little maintenance, and can be grown purely with rain-fed agriculture. Land was abundant and labor was scarce. What they lacked in intensive production was made up for by a fairly stable system that did not require an enormous amount of labor per unit area. The abundance of land and a small population defused the impetus for change and intensification.

Maintaining fairly large herds of sheep, goats, and cows was a common method of minimizing risk under such water-limited conditions. The standard deviation for annual rainfall is 125 mm (SENAMHI n.d.), which means that in any given year crop yields could be drastically reduced by lack of rain. In the driest years the maize crop might fail altogether. Animals were, and still are, a means of securing a steady income and a food supply during even the driest years.

After the revolution, social change was a powerful force in rural Bolivia. Evangelical missionaries began to arrive from the United States in the early 1950s. They inspired some young community members to study both religious and secular subjects. Adherents to the new faith abstained from the use of alcohol, and many abandoned the age-old tradition of chewing coca. They spent their time in the church, singing, praying, and studying the Bible. The religion became a divisive force in Tipa Tipa, causing tension within the community. The village, in fact, is spatially divided between Evangelists and Catholics, with the Evangelists occupying the southern sector of the village.

This was the first generation of *campesinos* to learn Spanish. As access to schools increased, the new citizens were encouraged to learn the *lingua franca*, and they did. More and more Spanish began to infiltrate Quechua communities. The men were the first to become fluent Spanish speakers, while the women maintained their status as second-class citizens, which excluded them from the education process. Children began to speak Spanish in their homes, yet Quechua remained the language of daily discourse.

THE INTRODUCTION OF IRRIGATION

As this second generation came of age, it became clear that change was necessary if the land was to sustain the needs of a growing population. Networks of roads had begun to infiltrate rural sectors, giving farmers more access to chemical fertilizers, biocides, and other technologies. Aiquile and Mizque, occupying a central location between Cochabamba and Sucre, began to grow, becoming centers of local trade and sources for outside resources. The incorporation of rural communities into the outside world made change possible. Bolivia was becoming a modern nation.

As the children of the reform generation came of age, it was necessary to redistribute land (Table 6.1). The average amount of land per family was reduced. But these smaller parcels did nothing to control the steady growth of population, as these young farmers followed in the steps of their parents, often times having three children by the age of 23. Change was needed if farmers were to continue feeding their children.

Table 6.1: Land tenure analysis and land distribution for 1961, 2002, and future generations

Family #	Ha/Household (1961)	Ha/Household (2002)	Ha/Househould (Future)
1	No data	No data	No data
2	13	3.3	0.54
3	27.6	5.5	0.92
4	21.7	4.3	0.72
5	No data	No data	No data
6	16.5	3.3	0.55
7	15.5	3.1	0.52
8	9.3	2.3	0.39
9	35	5.0	0.83

The seminal event for Tipa Tipa in the intensification process was the introduction of irrigation technology. In the early 1970s, several well-organized, well-respected members of the community initiated the project. The project took several years to complete, and the labor was brutal and dangerous. The work involved digging an infiltration channel eight meters deep and more than 40 meters long. At some places they had to dig through solid rock. This was done with picks, shovels, hoes, and many calloused hands (Figure 6.4).

Figure 6.4: After walking 40 + meters, one reaches the end of the *galeria filtrante*

Once the infiltration gallery was completed, the community constructed a canal that measures five kilometers in length (Figure 6.5).

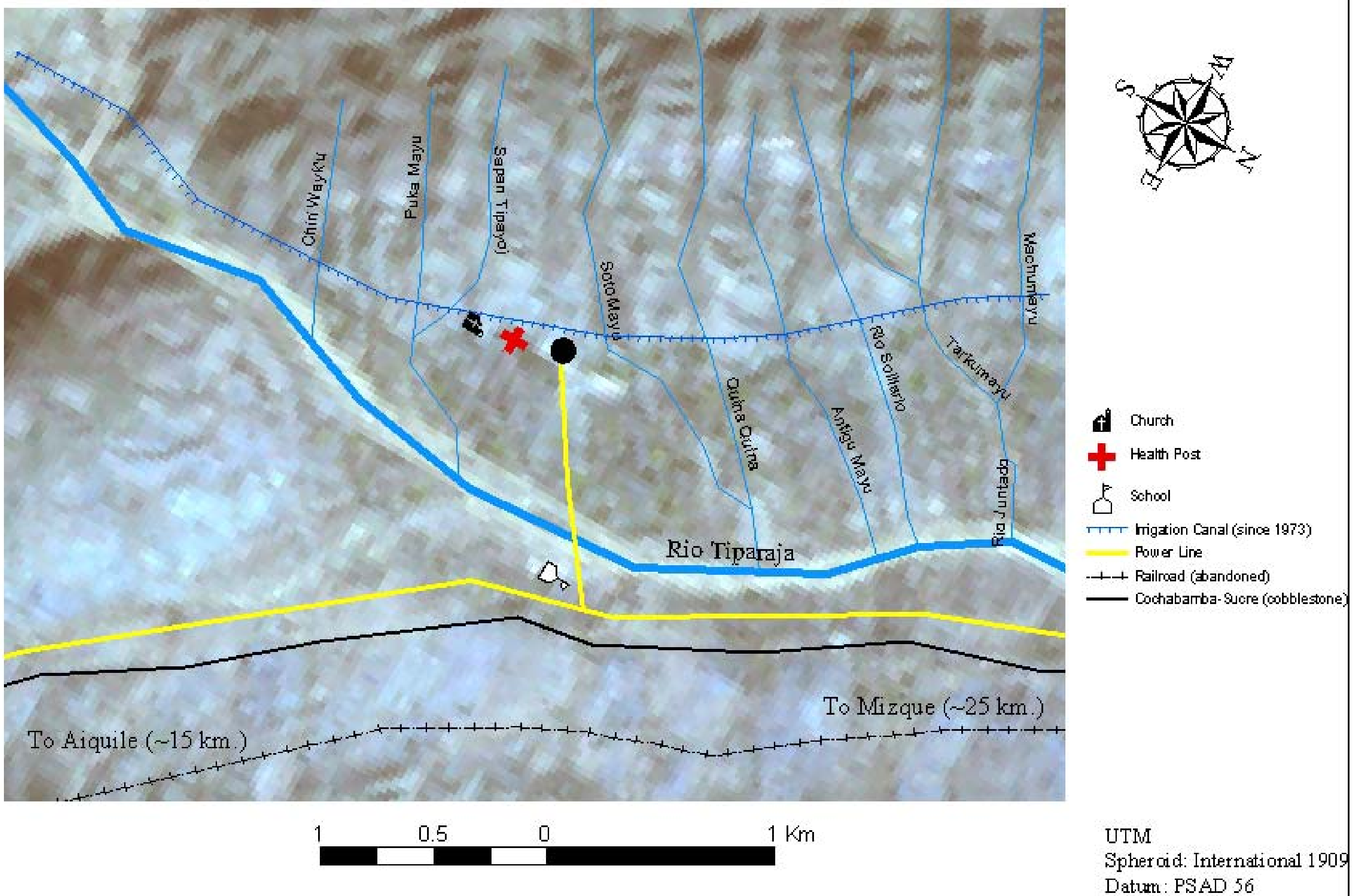

Figure 6.5: As is the case in many Bolivian communities, this irrigation canal is the lifeblood of Tipa Tipa

Water rights were distributed based on participation in the construction. Water was distributed using the *mit'a* as the unit of measure. One *mit'a* was given to each family that worked on the project. This was equivalent to six hours of irrigation in the canal. Though the use of the word *mit'a* came to be associated with the forced rotational labor in the mines of Potosi, here it is used in a more traditional fashion. It means to take one's turn at a task.

Irrigation technology had profound consequences for the entire structure of the village. The boundaries of Tipa Tipa were now more clearly defined, beginning and ending within the physical limits of the canal. By-laws were created and committees formed to regulate the use and cost of irrigation water. Irrigated parcels increased in value exponentially and were sub-divided among family members or sold as migration to the cities increased. People now had regular access to water, which allowed them to build their homes closer together and in a more central location. Scattered families, once diffused across the countryside, began to congregate in a more shared living space. The community began to resemble a village.

Over the years, Tipa Tipa benefited from its central location and its close proximity to the primary road between the larger cities of Sucre and Cochabamba. By 2002, Tipa Tipa had access to an improved road system (cobblestone), a health post, an evangelical church, electricity, and a school (Figure 6.6). For some reason, the railroad system was completely abandoned, and is now in total disrepair.

Figure 6.6: Infrastructure Tipa Tipa, 2002



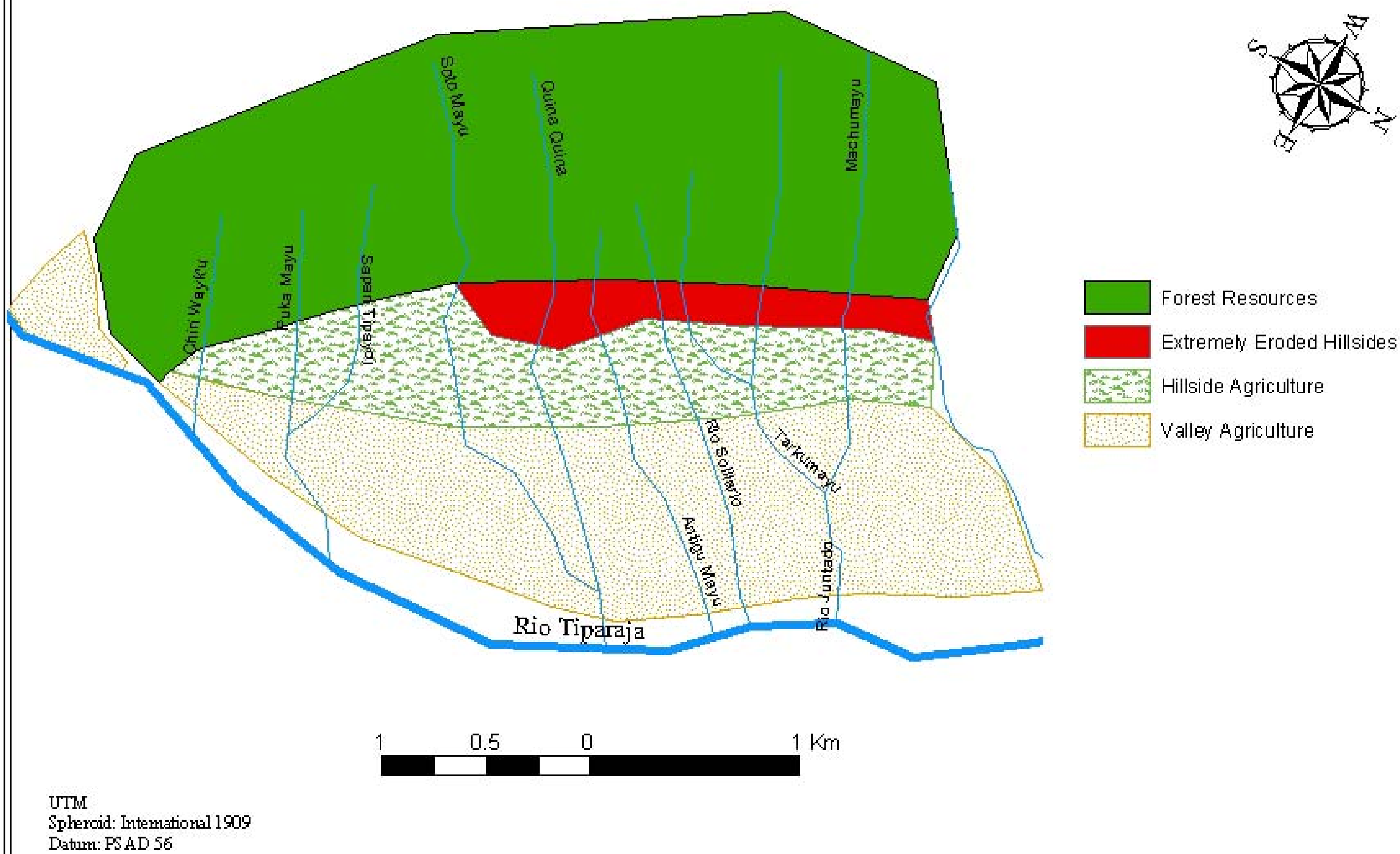
CHANGES IN LAND USE

Farm systems, too, experienced radical changes. Figure 6.7 depicts the nature of pre-irrigated agriculture in Tipa Tipa. This map was created from aerial photos from the year 1961. The aerial photos reveal a landscape that is almost completely deforested and intensively managed. Hillside agriculture was the norm in most communities, and Tipa Tipa was no exception. Several key informants have told me that the area has always been deforested and eroded. Even older community members expressed disbelief that the area could ever have maintained forest cover.

Indeed, the natural state of the Andes has been a point of contention among natural historians for many years. Until the 1950s, most natural historians believed that the treeless Andean landscape was a result of biophysical conditions rather than human intervention. As Gade (1999) states: "…one now starts with the assumption that the Andean highlands were covered with a montane forest, and the remaining wooded areas are understood to be results of habitat fragmentation."

Considering this evidence, it is therefore likely that deforestation occurred over many generations. Certainly grazing animals, especially goats, completely eliminated the possibility of sustainable forest management. High stocking densities disrupted the natural regeneration pathways of native woody species. Denuded hillsides, made more vulnerable by grazing and hillside agriculture, experienced high levels of soil erosion and compaction. It is likely that this process occurred over centuries. By looking carefully at the aerial photos for 1961 and based on oral history in the community, one reaches the conclusion that this is an area that required terracing, agroforestry, and other soil conservation measures at least 100 years earlier.

Figure 6.7: Land use and land cover, Tipa Tipa 1961



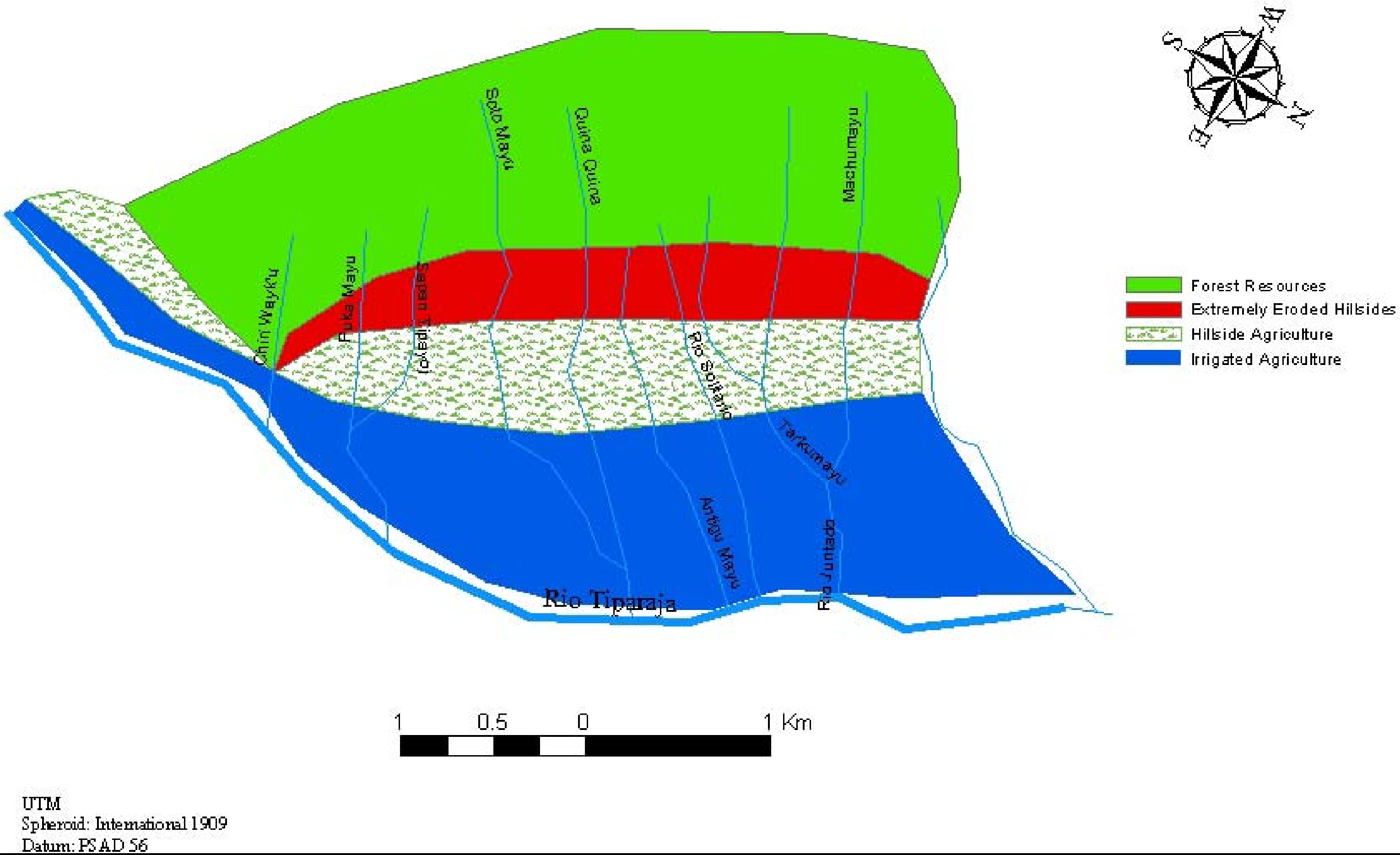
Irrigation made possible more specialized vegetable production. New crops were introduced. During these early years of irrigated agriculture, potatoes were the most commonly produced cash crop. Maize was maintained as a favorite, low maintenance staple, while wheat and chickpeas were totally abandoned. One can hardly find a farmer who plants wheat today. Similarly, chickpeas have been abandoned and only older farmers recognize the plant.

In the decades that followed land redistribution, foreign aid funded projects aimed at expanding the cultivated area of commercial crops and increasing yields per unit area of commercial crops became commonplace (Paulson 2003). In the late 1980s, a project funded by foreign aid worked diligently at introducing tomatoes and onions into the area. These higher yielding crops performed well in early trials. High yields through intensive inputs became the only way to maintain a family on increasingly small parcels. Farmers were quick to realize that they had to get more from less, and a greater reliance on fertilizers and pesticides became the norm as subsistence agriculture was supplanted by commercial agriculture.

By the mid 1990s, onions and tomatoes were the primary cash crops produced in the area. Farmers in Tipa Tipa had more cash than ever. Some saved their money and were able to accumulate more land and water. Others squandered it on parties and other luxury items. One thing, however, was universal: people continued to plant onions year after year, hoping to reap the same rewards from their labor.

With the advent of a commercialized onion-tomato economy, marginal hillside lands were abandoned as farmers put more labor into flatter, irrigated parcels (Figure 6.8).

Figure 6.8: Land use and land cover, Tipa Tipa 2002



As Paulson (2003) argues, the nation-wide, foreign aid funded emphasis on improving commercial agriculture was at the expense of women and poorer families, who rely upon the resource base of hillside lands for grazing, collection of edible and medicinal plants, and firewood collection. Furthermore, failure to conserve the ecosystem and prevent soil erosion resulted in an overall expansion of extremely eroded lands, which in 1961 covered a total land area of 47 ha (Figure 6.7), but in 2002 covered a total land area of 120 ha (Figure 6.8). Now, much of the hillside lands once dedicated to the production of cereals, grazing, or fuel wood collection, have completely lost the topsoil layer and severe gullying has become the norm. In addition, erosion has seriously compromised the productive capacity of those lands that are still used for productive purposes. (Figure 6.9).

Figure 6.9: Lands once used for grazing and hillside agriculture have been rendered almost useless by poor husbandry and soil erosion

If commercialization was unsuccessful in preventing further land degradation, it was equally unable to provide the *campesino* with the greater autonomy that the Agarian Reform had once promised. Lagos (1994) demonstrates that in the years following the Agarian Reform the Bolivian peasantry became reliant on the wealthy not for land, as they had been before the reform, but for the credit and loans which allow them to purchase the costly inputs required for intensive, commercial agriculture. A commercial system that relies heavily on outside inputs can only be successful when it is profitable for the farmer and when it does not adversely affect the overall health of the farm system and the resource base which it depends upon.

Today farmers are once again facing a crisis. Now the third generation of farmers is coming of age, and parcels of land can no longer be divided among children with any hope of maintaining a large family (Table 6.1). Thus far, the primary solution to the problem is migration. In the Tipajara watershed, 12% of all families indicated that as many as four family members migrated elsewhere in search of work or to study (Ugarte 2001). There is also migration from Tipa Tipa to Argentina. Community members, generally men in search of opportunity and more money, move to the Argentine capital and work in construction. This process of income diversification through migration to Argentina has also been observed elsewhere in Bolivia (Preston, Macklin, and Warburton 1997). The other form of migration comes in the form of education. A disproportionate amount of Tipa Tipa's youth is living in other towns and cities, studying in the high schools of Aiquile or the universities of Sucre or Cochabamba. They are abandoning agriculture. And still the land is not sufficient. For every child that migrates there is another one who stays, continuing to make his living from the land. To make matters worse, an onion monoculture has seriously compromised the farmer's ability to make a profit from farming.

CHAPTER VII: ONIONS

Onions are a member of the Alliaceae family, classified in the genus *Allium.* Though many varieties exist, the common onion is taxonomically described as *Allium cepa* var. *cepa*. Onions are an herbaceous biennial monocot cultivated as an annual (Rubatzky and Yamaguchi 1997).

Onions were domesticated in central Asia, and have been cultivated for more than 4000 years for food, flavor, health, and also for religious purposes. Onion cultivation was adopted in India around 600 B.C., from there they were introduced to Greek and Roman agriculturalists around 400-300 B.C. Onions were introduced into northern Europe in 500 A.D. In Bolivia, most onions are of the red, pungent variety. They were originally brought to Peru from Louisiana, where they were introduced from France and Italy. Onions found their niche in the temperate valleys and the *altiplano*, where cooler conditions and irrigated agriculture provided favorable conditions for cultivation (Meruvia et. al. n.d., Rubatzky and Yamaguchi 1997).

Onions are a cool season crop best adapted to temperatures between 13°C and 24°C. Growth is slowed at temperatures exceeding 30°C. Onions have some frost tolerance. To achieve optimum yields and large bulb sizes, onions require approximately 400-800 mm of water per crop (Meruvia et. al. n.d., Rubatzky and Yamaguchi 1997).

Photoperiod is an important factor that determines which variety of onion can be grown in a given area. Onion varieties can be classified into three groups: short day (11 hours of light), medium day (12 hours of light), and long day (>13 hours of light). A long day variety cultivated when available daylight is less than 13 hours will not form a bulb; likewise, short day varieties planted when available daylight is greater than 13 hours will form a small bulb with poor green matter production (Meruvia et. al. n.d.). It must be noted that these classifications are useful in Bolivia, where the tropical latitudes make variation in day length less significant than in temperate places. A long day variety at temperate latitudes requires 14 or more hours of daylight. From a worldwide perspective, all onion varieties grown in Bolivia are short and intermediate day. In the tropics, bulbing is induced by both temperature and day length (Rubatzky and Yamaguchi 1997).

Onions do well in a variety of soils, from light sands to heavy clay loams. Under irrigation, peat soils or sandy soils are preferred. Because onions have a shallow rooting system, soils with a high water holding capacity are better able to provide moisture; however, onions are sensitive to water logging, and good soil drainage is also important to prevent growth retardation and to avoid creating favorable conditions for soil borne disease. In mineral soils, a pH of 6.5-8.0 is considered desirable (Rubatzky and Yamaguchi 1997). As with most crops, onions prefer soils with high organic matter content. In Bolivia, an application of 10-20 tons/ha of fresh manure is recommended (Meruvia et. al. n.d.).

Nitrogen supplies must be adequate and uniform to ensure productive plant growth and large bulbs. Frequent applications of nitrogen in small increments are preferable to large quantities at one time. Late or large applications can cause thick necks, multiple centers, or bulb splitting. Onions also require large amounts of phosphorous (P_2O_5) and potassium (K_2O). To achieve a harvest of 30 tn/ha, onions remove 159 kg/ha of nitrogen, 220 kg/ha of phosphorous, and 200 kg/ha of potassium from the soil. Copper, manganese, and zinc deficiencies can occur in high-pH peat soils. At low pH, molybdenum deficiency is a possibility. Onions are sensitive to saline soils (Meruvia et. al. n.d., Rubatzky and Yamaguchi 1997).

In a survey conducted in Latin America, 11 of the 14 countries surveyed cited disease as the most significant constraint to onion production. The diseases cited as most problematic, in order of importance were: *Alternaria porri*, *Peronspora destructor*, *Pyrenochaeta terrestris, Sclerotium cepivorum,* and *Fusarium spp.* In all of the countries surveyed, except Costa Rica, thrips (*Thrips tabaci*) were mentioned as an important insect pest (Osman, Izquierdo, and Galmarini 1997).

A DESCRIPTION OF ONION PRODUCTION IN THE TIPAJARA WATERSHED

In the Tipajara watershed, the cropping season for onions begins in the month of January, the rainiest month of the year. Most farmers choose to plant their seedbeds during the rain because there is less risk that the crop will suffer from lack of water towards the end of the dry season. Also, the most commonly used variety, *Mizqueño*, is a short-day cultivar that forms its bulb in the winter months. Though the recommended amount of seed is 4 to 5 kg/ha, there is much variability from farmer to farmer (Meruvia et. al. n.d.) The farmers prepare the seedbeds with great care; many apply animal manure to the soil in the preparation process. The recommended practice is to rotate seedbeds to prevent the buildup of soil borne diseases, but the application of this technique is variable. Many times farmers clear new land of shrubby vegetation to plant the onion seedbed in the leaf litter of the shrubs. Once the seedbeds have been prepared, the farmers level them and distribute the seeds evenly across the surface of the bed. The bed is then watered and covered with the branches of a *molle* tree (*Schinus molle*) or with a tarp. The seeds germinate within 6 to 8 days of being planted (Figure 7.1).

Figure 7.1: Healthy onion seedlings in the community of Tipa Tipa

Management of the seedbed is a delicate operation. Approximately a week after germination, the seedbed must be weeded. This is a time consuming task requiring patience. Because rainfall patterns are variable, even during the rainiest months of the year, the farmers must be careful to water the onion seedlings when necessary.

At this time the young onion seedlings are susceptible to damping off, and many farmers have lost significant quantities of seedlings to this common disease. In Bolivia, there are several organisms responsible for this disease: *Fusarium* spp., *Pythium* spp., and *Rhizoctonia* spp. (Meruvia et. al. n.d.) Some farmers have tried to control the effects of damping off by planting in sandy, well-drained soils, by rotating seedbeds, and by covering the seedbed with a tarp during heavy rains.

After the seedbeds have been planted, the farmers prepare the land where the onion seedlings will be transplanted. Before tillage, the farmers apply manure to the fields, spreading it out over the field to be incorporated by the action of the plow. When manure is acquired locally, it is usually goat, cow, or sheep manure. In many cases chicken manure is purchased from the distant city of Santa Cruz and deposited in the field from the bed of a truck (Figure 7.2).

Figure 7.2: A pile of chicken manure brought from the distant city of Santa Cruz

Teams of two oxen, known in Spanish as a *yunta*, are used to plow the fields. Men are almost always responsible for managing the team of oxen. Women participate in the preparation by pulling up weeds that are exposed by the plow, especially Bermuda grass. Those families that can afford the hourly rate often hire a tractor to plow their fields. Sometimes the fields must be plowed many times, as the rain causes high levels of soil compaction. After the fields have been adequately plowed, the farmer once again uses the *yunta* to level the fields (Figure 7.3).

Figure 7.3: Unlike traditional rain-fed crops, onions require high labor inputs to create the appropriate conditions

A month after germination, the seedlings are ready to be transplanted. First, the onions are pulled from the seedbed and placed in a wooden box. Usually they are covered with something to keep the delicate stems out of the sun. The labor for this task is separated by gender. The men make the rows for the plants with a small pick, and they control the flow of the irrigation water that moves through the rows. The women and children plant the onions in the muddy rows, which must be kept wet to reduce high soil temperatures and facilitate the transplanting process (Figure 7.4).

Figure 7.4: Transplanting is backbreaking work
Photo taken by Toribio Maygua

The distance between plants is approximately 10 cm, and the distance between rows varies from 20 to 30 cm (Meruvia et. al. n.d.). Both sexes perform this task with amazing proficiency, the men are able to work long hours making row after row, and the women are extremely fast at pushing the thin stems into the wet ground. In comparison with other local crops, such as maize, the tillage and planting requirements for onions are much more labor intensive.

After the planting has been completed, the farmers must monitor field conditions carefully. As the rainy season reaches its end in March, timely irrigation of the early crop is essential. Several weeks after planting, the farmers begin the first important weeding operation. Known in Quechua as the *kachida*, male workers use a hoe to reshape the rows in which the onions were originally planted. The hoe is also used to remove any emerging weeds. Some farmers will take this opportunity to apply the first fertilizer treatment, usually a mix of Urea and commercial fertilizer (18-46-00). In the following weeks after the *kachida*, the farmers will weed the field a second time by hand. Both male and female laborers do this task.

Six to eight weeks after transplanting, the male laborers perform the most labor-intensive task of onion farming, called the *thamida* in Quechua. This operation involves the loosening of soil between the onion rows with a small pick. Weeds are removed as the workers pass over weedy patches. Once this has been completed, the farmers go back over the loosened soil with the same pick to recreate the rows that were destroyed in the loosening process (Figure 7.5).

Figure 7.5: The brute force required for loosening the soil means that it is almost exclusively performed by men
Photo taken by Toribio Maygua

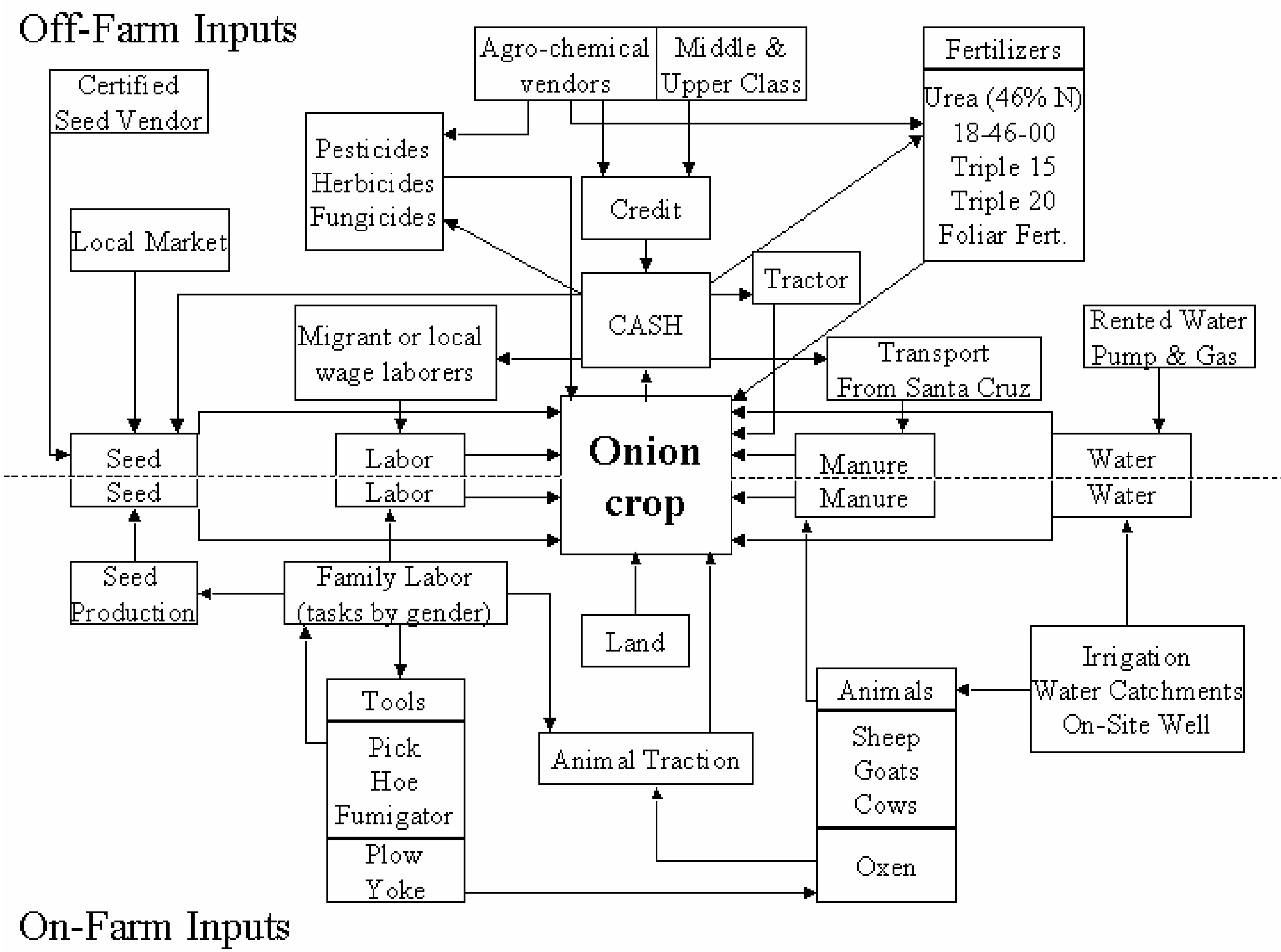
It is at this time that the remaining amount of chemical fertilizer is applied to the field, just before the digging occurs. Some farmers also apply chicken manure to the onion crop at this point. Once this final mechanical operation has been completed, the farmers' primary concerns are timely irrigation to maintain adequate soil moisture and fumigation to control insect pests and diseases.

As onion bulbs increase in size, photosynthate is transferred from foliage leaf blades into storage leaves. Once this happens, the onion leaves begin to collapse. This occurs 80 to 170 days after planting, depending on the cultivar. In the Tipajara watershed, the farmers step on the falling leaves or roll them over with a 55-gallon drum. This practice creates uniform conditions for the harvest. During the harvest labor is divided by gender. Men dig the rows of onions with a pick and make piles of the plants. The women and children cut the foliage from the onion and package the bulbs in large sacks (Figure 7.6). This is a very labor-intensive process.

Figure 7.6: Harvesting onions

Figure 7.7 is a graphic depiction of the inputs required to produce an onion crop, and the different actors involved in the production of the crop. The distinction made between on-farm and off-farm inputs is important, and illustrates the extent to which farmers are dependent on outside inputs and outside sources of capital. This makes for a very undesirable situation when the farmer is unable to recover his production costs

Figure 7.7: The primary inputs for onion production in the Tipajara watershed



INSECT PESTS AND DISEASES OF ONIONS

In the Tipajara watershed, the incidence of onion disease is determined by a number of climatological variables, primarily annual rainfall, temperature, relative humidity, and wind. Human behavior and farm management, however, greatly affect the incidence of disease and the yield of the crop. Closely planted onions encourage moisture and dew formation, which provides certain fungi with the perfect microhabitat for reproduction and dispersal. Poor fumigation techniques can lead to the development of resistant fungal strains. Most importantly, the lack of a scientifically designed crop rotation scheme causes the year-to-year increase in airborne fungal spores. The following is a synopsis of the diseases we have identified in the community of Tipa Tipa. In May of 2001, Dr. Walter Kaiser, Peace Corps plant pathologist, verified this information in the ITA laboratory in Sucre.

Downy mildew (*Peronospora destructor*) is one of the most serious diseases affecting onion production in the region. The disease attacks onion leaves, especially during periods of cool, moist weather, and causes serious losses in yield and bulb quality. Initially, infected plants have extended, light green lesions along the length of the leaf surface. In serious cases the fungus completely destroys the affected leaves, which causes the plant to form new leaves, resulting in dramatically reduced bulb size. The fungus remains dormant in onion plants, infected bulbs, and stored seed. Infection is initiated during cool temperatures (less than 22ºC) and in the presence of rain or dew on the leaf surface. Spore production occurs at night; newly produced spores are then dispersed by wind during the day. Suggested methods of control include destruction of contaminated crop residues, sufficient spacing between plant sets, and a 3-4 year rotation that excludes *Allium* crops. It is not advisable to irrigate the onion crop during the evening or early morning, as this creates the cool, moist conditions favorable to dew formation and mildew attack (Meruvia et.al. n.d., Schwartz and Mohan 1995).

Stemphylium leaf blight (*Stemphylium vesicarium*) is one of the most commonly observed diseases in the onion fields of the Tipajara watershed. The black, ash-like spores often mask the symptoms of Downy mildew, yet the two diseases seem to infect plants in tandem (Figure 7.8).

Figure 7.8: Onion plant tissue damaged by mildew and leaf blight
Photo courtesy Brad David Kennedy

The organism will often attack plants on lesions formed by Downy mildew, whereupon it reproduces and attacks the entire leaf surface of the plant, especially in periods of warm weather. Almost every farmer in the area complains about losses incurred from this disease. Given the serious nature of the disease and its failure to respond to fumigation, crop rotation is highly recommended for its control (Schwartz and Mohan, 1995).

Cladosporium leaf blotch (*Cladosporium alli-cepae*) is a serious disease affecting onions late in the cropping cycle. The defining symptom is a distinct yellowing of the leaf area (Figure 7.9).

Figure 7.9: Onion crop at the onset of a *Cladosporium* attack

Infected debris and infected seeds are most the most likely candidates for disease transmission from year to year. Low temperatures (5-8.5ºC) and high humidity in the absence of light encourage maximum sporulation. Plowing under of debris and fumigation late in the cropping cycle are suggested methods of control (Schwartz and Mohan, 1995).

Purple blotch (*Alternaria porri*) is commonly observed in the area. Although not isolated under laboratory conditions, the unmistakable symptoms of this disease make it easy to identify. Upon infection the leaf displays white, oval lesions that quickly expand in a concentric fashion, becoming purple in the center as they do so (Figure 7.10).

Figure 7.10: Typical lesions of *Alternaria*
Photo courtesy Brad David Kennedy

Favorable conditions for this disease are very similar to those for Downy mildew; it reproduces at night in the dew formed on the leaf surface of plant sets. Daytime temperatures in excess of 26ºC are favorable to the disease. It is dispersed by rainfall and wind. As with other diseases, it can be controlled by destroying crop residues, controlling the moisture on leaf surfaces, and through crop rotation (Meruvia et.al. n.d.)

Pink root (*Pyrenochaeta terrestris*) is a disease causing fungus that lives in the soil, sometimes at a depth of 45 cm, from where hyphae attack and penetrate root tips. Pink root is most severe in fields where onions are planted for consecutive years. It is possible to control the disease through soil fumigation, but considering the level of technology and available capital in the area, this does not seem to be a feasible solution. Again, crop rotation is the most advisable course of action to prevent the disease from reaching epidemic proportions (Villarroel Leon 1997). The recommended rotation is 3-6 years (Schwartz and Mohan 1995).

Thrips (*Thrips tabaci*) are the most commonly occurring insect pest attacking onions in the Tipajara watershed. Thrips are extremely small, measuring 0.5 to 1.2 mm when immature, reaching a size of 2 mm when fully mature. Most thrips seek refuge in the base of the leaves at the bottom of the plant. Adult thrips can fly. Though onions and garlic are the preferred hosts, thrips can be found in cabbage, cotton, celery, tomatoes, beans, cucumber and pineapple, and other weedy plants as well. Thrips can complete the life cycle in 14 to 30 days; at temperatures above 30ºC the life cycle is shortened to 10 or 11 days. Thrips feed by removing the green plant tissue from the surface of onion leaves. The damage can reduce yields drastically, by as much as 66% in some tropical countries. They can also act as a vector for *Alternaria*, and the lesions and plant stress generated by thrips make the onion plant more susceptible to attack by other pathogens. To reduce incidence of thrips, all onion volunteer plants must be removed from the field, especially during periods when onions are not being cultivated. Plants should be kept well watered and free from other stresses such as nutrient deficiencies. A continuous presence of onion plants, all the way from Mizque through the Tipajara watershed, means that thrips constantly have a refuge in which they can reproduce and disperse (Rueda and Shelton 1995)

Unaware of alternative disease control methods, farmers are increasingly forced to rely more and more heavily on the use of chemical fungicides as a means of control. Lack of proper equipment (e.g. masks, gloves, goggles, etc.) and poor fumigation techniques pose a serious threat to human health. Resistance, moreover, increasingly becomes a concern as farmers haphazardly spray chemicals without any well-designed fumigation plan. It is certain that many diseases in the area, not just those affecting onions, have already become resistant to chemical biocides. The highest incidence of disease occurs when the onions begin to bulb. In most cases in the Tipajara watershed, difficulties controlling disease results in a serious reduction in crop yields.

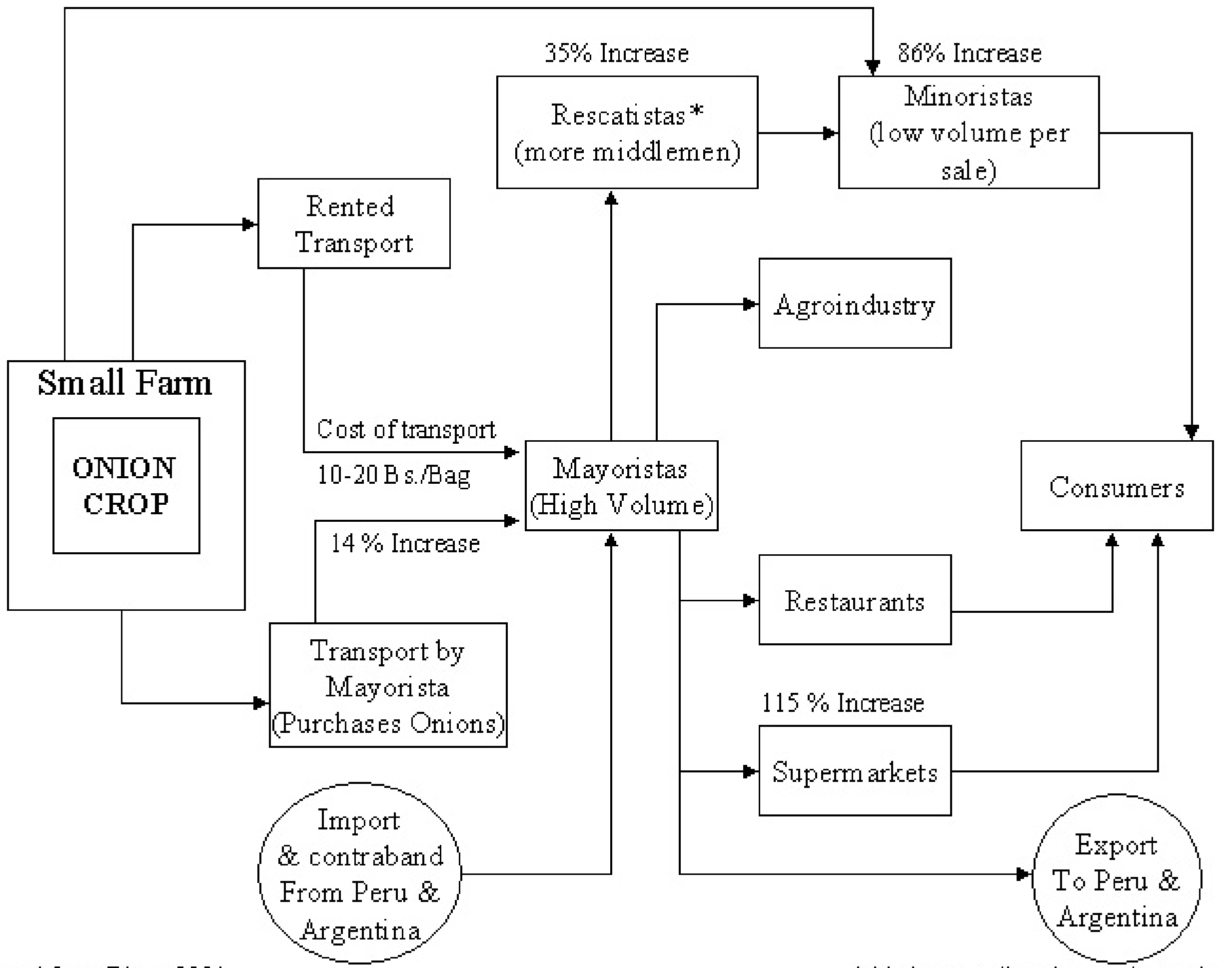
ONION MARKETING AND POST-HARVEST TECHNIQUES

Once the onions have been harvested and bagged, onion farmers are primarily concerned with getting their crop to market and the day-to-day fluctuations that occur in the market price. Historical prices for onions are presented in Appendix II. Rivas (2001, 2002) has argued that the primary constraints to profitability for onion farmers in the valleys of Bolivia are poor post-harvest and marketing techniques. An analysis of these arguments is necessary to fully understand the dynamics of onion production in the Tipajara watershed.

First, it is important to realize that almost all farmers in the Tipajara watershed apply no post-harvest techniques to improve the marketability of their crop. Farmers do not cure their onions to increase the product's shelf life. These uncured onions have fresh, open wounds at the neck where the green foliage was cut from the bulb. Such wounds, combined with poor handling techniques, cause the onions to decay quickly once they have been loaded onto a truck for transport. Some onions will sprout green foliage after only several days. Others will become infected by various decay-causing organisms, which quickly rot the inside of the onion and make it unfit for sale. The farmer has a small window of time in which to get his crop to market. He is, therefore, more susceptible to fluctuations in the market price, as he does not have the luxury of waiting until the price has reached a satisfactory level. To compound this problem further, few farmers actually calculate the cost of production.

An onion will change hands many times from the moment it leaves the farm until it arrives to the consumer's household (Figure 7.11). In the Tipajara watershed, there are two primary ways in which an onion crop is transported to the city. The first, and most frequent, occurs when a *transportista* arrives in the community with a heavy-load transport vehicle, called a *camion* in Spanish. This person knows which communities offer which products at different times of the year. Often times the *transportista* has already been in contact with the farmer via telephone. In other cases, he will visit different farms and offer to buy recently harvested onions. In both instances, the farmers are subject to the going market price. Though this leaves some room for negotiation between the two parties, the farmer has a limited time in which to sell because he is unable to store his crop. Sometimes the farmer transports the crop himself, generally when a local *camion* owner is making a trip to a nearby city. This is often the case when the farmer feels that he can get a higher market value by paying the price of transport and negotiating a price in the city markets.

Figure 7.11: The market distribution network for onions†



Adapted from Rivas 2001

*this intermediary is not always involved

†This figure shows percent increase of the product from the perspective of the farmer, representing a cumulative percent increase from the moment the product leaves the small farm.

From the rural farm, the onion crop has three major urban destinations: Cochabamba (148 km), Sucre (187 km), and Santa Cruz (497 km) (Rivas 2001). The province of Mizque has the benefit of being centrally located relative to these three major urban centers. Variable market prices, city of origin, and road conditions are just a few of the factors that determine the destination. Although each city market functions according to different systems and norms, the underlying system from one city to the next is quite similar.

Upon arrival to the city, the heavy transport vehicle goes directly to a central market. In the central market the *mayoristas* are the first to buy the onions from the arriving *camion.* In the Santa Barbara market of Cochabamba, for example, approximately 15 *mayorista* women are the primary recipients of the arriving cargo. The power that these women wield is expressed in a commonly repeated adage: "If you don't sell to them, you can sell once, but after that you can't sell anymore." This rule also applies to buyers. The system is one of unwritten rules and social customs, but is so effective that 100% of all *camiones* sell their product to the well-known *mayoristas* (Rivas 2001). Though little is done in terms of packaging or selection, at this stage the onions have an average price increase of 14% (Figure 7.11)

From here the onions might be directly sold to the *menoristas*, usually indigenous women who sell a variety of agricultural products at low volume in different markets around the city. Those who buy from the *menoristas* are usually the consumers. In some cases, however, other middlemen will purchase the onions and transport them to other markets at smaller quantities or even to other cities and towns.

These are known as *rescatistas*. In every instance, the product's market price escalates enormously relative to its original value at the farm level (Figure 7.11).

The unit price of an onion increases as it travels through this system for a number of reasons. The *menoristas* are largely responsible for selecting the onions according to size and for eliminating rotten and sprouting onions; in some markets, however, the *mayoristas* are responsible for this task (Rivas 2001, Rivas 2002). Losses incurred and time are compensated for by a higher market value. Also, we must keep in mind that Bolivia is largely an agricultural society. A large peasant population, mostly indigenous, relies on agriculture, in some form or another, for its economic well-being. This elaborate distribution system is effective in two ways: it distributes the product to the farthest corners of the country and it provides a livelihood for thousands of people.

DIMINSHING RETURNS IN THE TIPAJARA WATERSHED

Fundamentally, low yields and high production costs are what make onion farming such a difficult business for so many farmers. Though the law of diminishing returns may have some exceptions, this is not one of them. Samuelson (1967) gives this thorough definition of the law of diminishing returns:

> An increase in some inputs relative to other fixed inputs will, in a given state of technology, cause total output to increase; *but after a point the extra output resulting from the same additions of extra inputs is likely to become less and less*. This falling off of extra returns is a consequence of the fact that the new "doses" of the varying resources have less and less of the fixed resources to work with.

This law holds true for all inputs, e.g. labor, fertilizer, and manure. Those farmers that desire success must find a way to balance the costs of these inputs with the fact that at some point, the crop will experience a reduced response to the applied input as a result of diminishing returns. Many farmers have yet to realize this, as they believe that constant fumigation will alleviate their problems with disease.

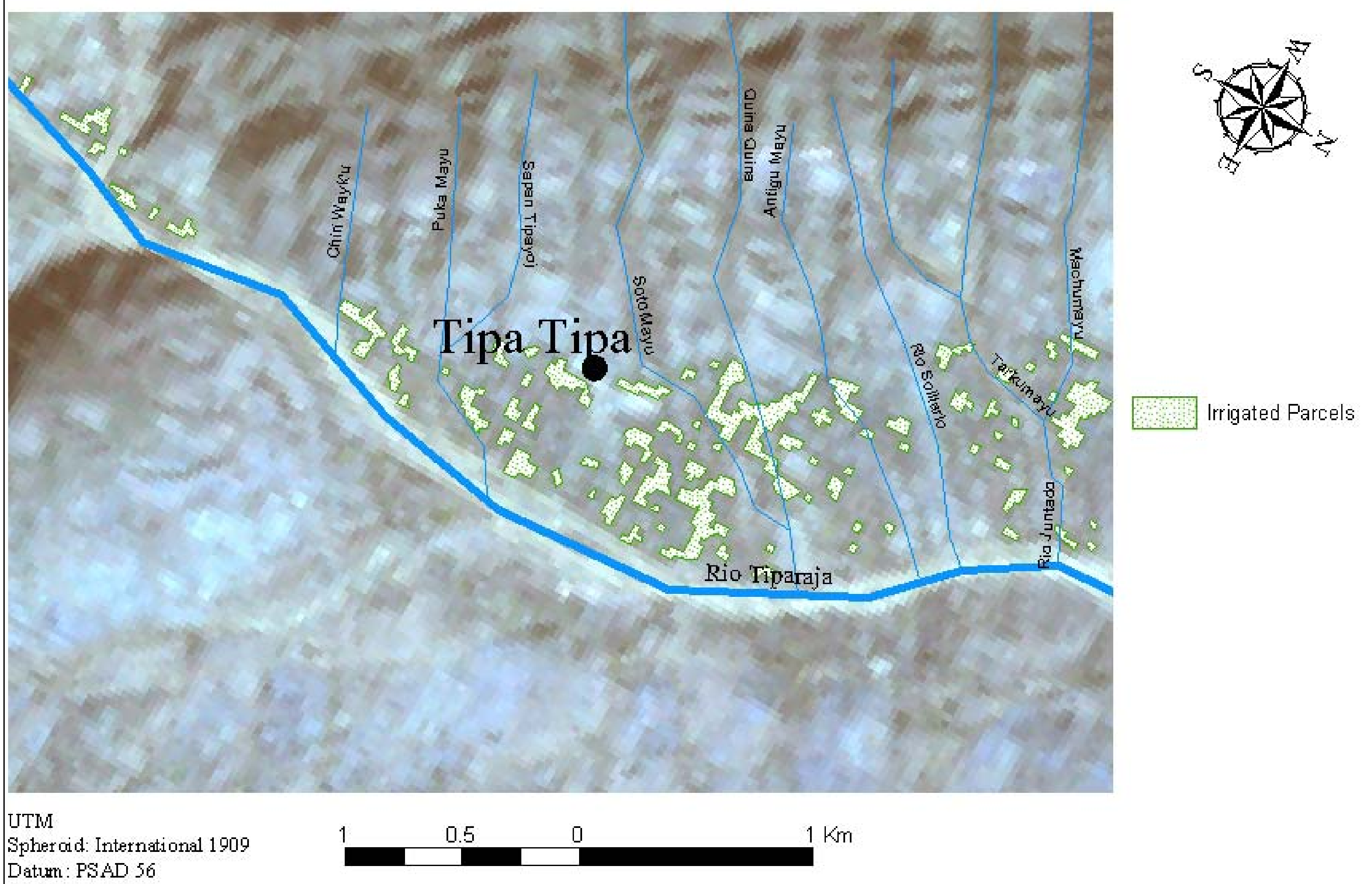
The problem of diminishing returns is exacerbated by the year-to-year increase in disease causing organisms. The diseases that attack onions in the region show no signs of disappearing. On the contrary, they have become more abundant and more virulent with time. Fumigation and monoculture have become a tenuous business for the small-holder farmer in the Tipajara watershed.

CHAPTER VIII: RESULTS AND DISCUSSION FOR ONION PRODUCTION

Onions are one of the most important crops in the Tipajara watershed. Though a distant third to maize and potatoes in total land area cultivated, onions account for 53.3 percent of the total volume of agricultural products in the province of Mizque, compared with 5.2 percent and 19.7 percent for maize and potatoes respectively (Ugarte 2001). Certainly they are the primary cash crop for most families with irrigation for the six-month period during which they are cultivated.

The importance of this crop and the magnitude of the crisis in which most onion farmers now find themselves was one of the primary factors that drove my research interests throughout the course of my Peace Corps service. It is the goal of this study to provide a detailed, quantitative description of this crucial component of the farm system, and perhaps in the process discover some potential solutions to the chronic problems of disease and profitability that plague the majority of farmers in this region. Figure 8.1 shows irrigated parcels in Tipa Tipa during the month of July 2002, the same cropping season for which this study was performed. 45 hectares of land had a crop cover at this time, most of which was certainly onions. Since the cropping season of 2002 was unusually dry, less irrigation water meant an overall reduction in total land area cultivated.

Figure 8.1 : Irrigated Crops Tipa Tipa, July 2002



REGRESSION MODELS FOR YIELD

I used a multivariate regression analysis to measure the effect of changes in inputs on yield (Hill, Griffiths, and Judge, 1997). The variables selected for this final version of a yield model were selected based on several important criteria. I made the logical assumption that only those variables directly related to the process of onion production (i.e. inputs) would generate a practical, descriptive model of the process. Further statistical analysis corroborated this assumption.

First, I eliminated all those measured variables that were not directly related to onion production, such as the number of animals a farmer owns or the size of his family. In most cases, these variables were not correlated with yield. Some variables were combined with others; for example, female labor was combined with male labor to create a total labor variable. Many of the variables in Table 8.1 were eliminated from the regression model because the use of economic values, rather than quantities (e.g. the difference between the cost of total labor and total labor days) yielded better R^2 values. This could be because the farmers themselves think in terms of economic values. Relative prices may mean economic optimization uses a different set of inputs than does physical optimization. Costs of N, P, and K were summarized in the single variable of fertilizer cost. Table 8.1 shows the Pearson correlation coefficients that were statistically significant but not included in the regression model.

Table 8.1: Pearson correlation coefficients with yield for variables not included in regression model

Parameter	Pearson Coefficient	P Value
Price per Bag	0.3888	<.0001
N	0.3353	<.0001
P	0.3649	<.0001
K	0.1748	0.0230
Labor Male	0.3163	<.0001
Days Male	0.3081	<.0001
Gross Income	0.9275	<.0001
Net Income	0.5675	<.0001
Days Female	0.2071	0.0069
Total Days	0.5477	0.0466
Tractor Hours	0.2319	0.0024
Oxen Days	0.2048	0.0076
Trucks of Manure	0.1931	0.0119

Based on my understanding of the farm system, I eliminated some variables and combined other variables to create a final list of the variables to be included in the equation. The resulting variables were consistent with my observations of the significant inputs that the farmer invests in the production process. The following regression equation had an R^2 value of .38 and a Pr>F of .0001. The regression equation is:

$$
\begin{aligned}
\text{Yield (Tn/Ha)} = \; & 9.24 \\
& - 4.90(\text{Parcel Size}) \\
& - .0009(\text{Total Labor/Bs/Ha}) \\
& + .0026(\text{Tractor/Bs/Ha}) \\
& + .0084(\text{Oxen/Bs/Ha}) \\
& + .0011(\text{Manure/Bs/Ha}) \\
& + .0022(\text{Seed}) \\
& + .0051(\text{Fertilizer}) \\
& + .0008(\text{Fumigation/Bs/Ha}) \\
& + .0005(\text{Irrigation Value})
\end{aligned}
$$

Other important statistical indicators of statistical signficiance are included in Table 8.2.

Table 8.2: Variables for onion yield regression model

Parameter	Estimate	P Value
Intercept	9.2436	0.0012
ParclSz (Ha)	-4.9039	0.0112
TotLabor (Bs/Ha)	-0.0009	0.1325
Tractor (Bs/Ha)	0.0026	0.2681
Oxen (Bs/Ha)	0.0084	0.0221
Manure (Bs/Ha)	0.0011	0.0036
Seed (Bs/Ha)	0.0022	0.1748
Fertilizer (Bs/Ha)	0.0051	0.0142
Fumigation (Bs/Ha)	0.0008	0.2919
Irrigation Value (Bs/Ha)	0.0005	0.0219

Table 8.2 shows that although not all values are significant in the equation as a whole, a collinear relationship affects the statistical significance of several variables. The Pearson coefficients of correlation show that collinear variables are correlated with yield (Table 8.3).

Table 8.3: Pearson correlation coefficients with yield for variables included in regression model

Parameter	Pearson Coefficient	P Value
Parcel Size (Ha)	-0.1849	0.0161
Total Labor (Bs/Ha)	0.2811	0.0002
Tractor (Bs/Ha)	0.1811	0.0185
Oxen (Bs/Ha)	0.1980	0.0099
Manure (Bs/Ha)	0.2697	0.0004
Seed (Bs/Ha)	0.3827	<.0001
Fertilizer (Bs/Ha)	0.4308	<.0001
Fumigation (Bs/Ha)	0.3364	<.0001
Irrigation Value (Bs/Ha)	0.0176	0.8485

Table 8.3 shows each variable correlated with yield, and all variables have a P value that indicates statistical significance at the .10 level. So while some variables may not contribute to the statistical power of the model because of collinear relationships, each one has been chosen to create a logical, descriptive model for yield.

The variables that constitute the regression equation presented above represent the fundamental inputs that the onion farmer in the Tipajara watershed uses to optimize yield. The variables were generated from the original data set by calculating a monetary value for each variable. Total labor takes the amount of days worked by male workers and female workers and multiplies it by the market value for a day's labor for each gender. Tractor and oxen involve an almost identical conversion, the difference for tractor being hours rather than days worked. It is important to note that in many cases the farmers are not actually paying for the service provided. Figure 5.7 (page 41) provides a graphic depiction of those inputs that are on-farm compared with those that are off-farm.

Many families own oxen, others do not and must rent them by the day, but the maintenance costs for those families who own the oxen justify the inclusion of their cost in the regression equation. Most families provide a good deal, if not the majority, of on-farm labor that here has been included as an actual expense to the farmer. Even though the farmers are not paying money for familial labor inputs, these inputs must be included in the equation to achieve an accurate model of onion production. The difficulty of measuring the amount of labor paid for versus the amount of labor provided by family members precluded the quantification of these two different values.

Fertilizer and fumigation values are outside inputs in every sense. The farmer must pay for these with money, and if the farmer does not have cash readily available he must seek credit from storeowners or moneylenders.

Seed is sometimes produced onsite, and other times it is purchased from other farmers or companies which sell certified seed. In either case, attaching a monetary value to onion seed is necessary, especially because quality onion seed has an excellent value on the local market. Manure is another input that can be produced on-farm, but many times a lack of animals dictates that the farmer purchase all or some of the manure that is applied to the farm fields before the land is tilled. I know from personal experience, the majority of manure that I have seen applied to onion fields was chicken manure trucked in from the distant city of Santa Cruz. Those poor local farmers who had significant quantities of goat or sheep manure often sold it to the wealthier farmers engaged in the input intensive task of producing onions.

Although this yield model provides some clues regarding the relationship between outputs and inputs, it is rather weak in explaining which farmers and which practices are successful. I therefore found it necessary to distinguish between the winners and the losers in the data set. I did this by simply looking at the net income of each farmer; those farmers with a net income above zero I classified as winners, and those farmers with a net income below zero were classified as losers. This classification provides a much more compelling model of onion production.

The model for losers has an R^2 value of .36 and a Pr>F of .0003. Table 8.4 lists all of the variables for the regression equation.

Table 8.4: Regression model for losing farmers

Parameter	Estimate	P Value
Intercept	5.9113	0.0362
Parcel Size (Ha)	-2.2358	0.2014
Total Labor (Bs/Ha)	0.0001	0.825
Tractor (Bs/Ha)	0.0010	0.6335
Oxen (Bs/Ha)	0.0049	0.1518
Manure (Bs/Ha)	0.0006	0.2474
Seed (Bs/Ha)	0.0020	0.1944
Fertilizer (Bs/Ha)	0.0010	0.6761
Fumigation (Bs/Ha)	0.0005	0.5579
Irrigation Value (Bs/Ha)	0.0003	0.1953

It is important to notice that none of the included variables has a significant P value. The model suggests that those farmers who lose money do not have a systematic approach to onion production.

The regression model for those farmers who earn money is quite different. The model has an R^2 of .70 and a Pr>F of 0.0001. The variables are summarized in Table 8.5.

Table 8.5: Regression model for winning farmers

Parameter	Estimate	P Value
Intercept	6.3889	0.1253
Parcel Size (Ha)	-5.4892	0.0806
Total Labor (Bs/Ha)	0.0004	0.6424
Tractor (Bs/Ha)	0.0067	0.0915
Oxen (Bs/Ha)	0.0130	0.0172
Manure (Bs/Ha)	0.0009	0.0077
Seed (Bs/Ha)	0.0026	0.3033
Fertilizer (Bs/Ha)	0.0042	0.1097
Fumigation (Bs/Ha)	0.0012	0.2276
Irrigation Value (Bs/Ha)	0.0009	0.0094

The contrast between the two models is telling. The model for winners is much better at explaining how farmers produce onions, which is indicated by an R^2 of .70 compared to the losers R^2 of .36. Moreover, several of the variables that were not significant in the model for losers now become significant in the winner's model. Parcel size, tractor, oxen, manure, and irrigation value all have significant P values in the winner's model.

These striking differences suggest a very logical conclusion: farmers who earn money are more systematic at balancing costs to optimize yields. Those farmers who earn money behave in a more predictable, uniform fashion. Ultimately, it is the management of the farm system that yields positive outcomes. The low R^2 value for the losers indicates that yield cannot be accurately estimated based on inputs, whereas the reverse is true for the farmers that earn money. Here we must keep in mind the law of diminishing returns and its impact on the farm system. For every household each input has a different relative value. For example, a farmer with a large herd of goats is unlikely purchase chicken manure to apply to his fields. The relative value of chicken manure for this farmer is much higher because he already has a steady supply of goat manure. So while the model does not indicate what the ideal proportions of each input should be for each farmer, it does explain that the successful farmer is the one that attributes the appropriate value to each input based on his unique situation. Successful farmers are capable of thinking economically to balance costs and optimize yields.

Surely there are other factors that were not measured that must affect yield, such as soil type, microclimate, and access to credit, but we must keep in mind that inputs and the management of those inputs are the single greatest factor that the farmer has direct control over. And while soil texture and slope may have an effect on yield, these physical constraints are much more difficult for the farmer to manage and change.

Inevitably, we must address the question that arises when looking at these models: How important is yield? Obviously the farmer wants to maximize his net income, which doesn't necessarily mean that he wants the greatest possible yield per unit area. I have created a separate model for net income that provides some insight into these basic questions. The regression equation is summarized below. It has an R^2 of 0.94

$$
\begin{aligned}
\text{Net Income/Ha} = & -5979.84 \\
& - 1.02(\text{Cost/Ha}) \\
& + 481.12(\text{Yield/Ha}) \\
& + 110.96(\text{Price/Bag})
\end{aligned}
$$

The high R^2 value is an outcome of the way in which net income was initially calculated. Net income was not measured as a separate variable in the field, but instead was calculated by multiplying yield per hectare times price per bag. The resulting number was gross income; I then subtracted cost per hectare from gross income, which is net income. The regression equation above does not conform to the formal definition of a statistical model because the dependent variable was not collected from field observations. It does, however, provide a useful tool for creating a graphic representation of the relationship between the three variables that determine net income. After developing this model, I used it to create several graphs to show the relationship between the three primary variables that determine profitability: cost per hectare, price per bag, and yield. These figures demonstrate the importance that each of these variables has in the final outcome. They also show that the primary factor driving profitability is yield.

These figures show income lines for different levels of yield, each figure represents a different yield level. The income lines were created using the regression model for net income described above. In each figure, there are two income lines. The blue line represents net income at Bs. 3000/Ha; the green line represents net income at Bs. 0, the break-even point. The points scattered within the diagram are the actual data points for yields within 2.5 tn/ha of the yield indicated for the figure. The figures show the effect that cost per hectare and price per bag have on net income at a given yield. Any data points that occur below the blue line are instances where the farmer made a profit of Bs. 3000 or greater. I selected the quantity of Bs. 3000 based on my experience in the field; this is the minimum amount of money that a farmer would like to earn for six months of labor. It is a conservative estimate, as I have heard some farmers indicate that Bs.7000 would be the ideal amount. Naturally, as price per bag increases the farmer has the option of incurring greater production costs, thus the upward slope of the income lines. Any data points that occur below the green line are instances where the farmer earned a positive return on onion production. All data points that occur above the green line indicate that the farmer lost money. Outliers were removed from the charts to facilitate comparisons between them.

The relationship is clear: higher production costs at low yields make profitability nearly impossible (Figure 8.2, 8.3). Even those farmers who sold onions at a higher price per bag were unable to make a profit. As yield increases, profitability becomes a greater possibility (Figures 8.4, 8.5). The graphs also indicate that higher yields and their relationship to cost of production are more significant than price per bag in determining which farmers make money and which farmers do not. At higher yields, price per bag could be an important factor in causing the shift from loser to winner.

Figure 8.2: Income Lines for Yield of 15 Tn/Ha

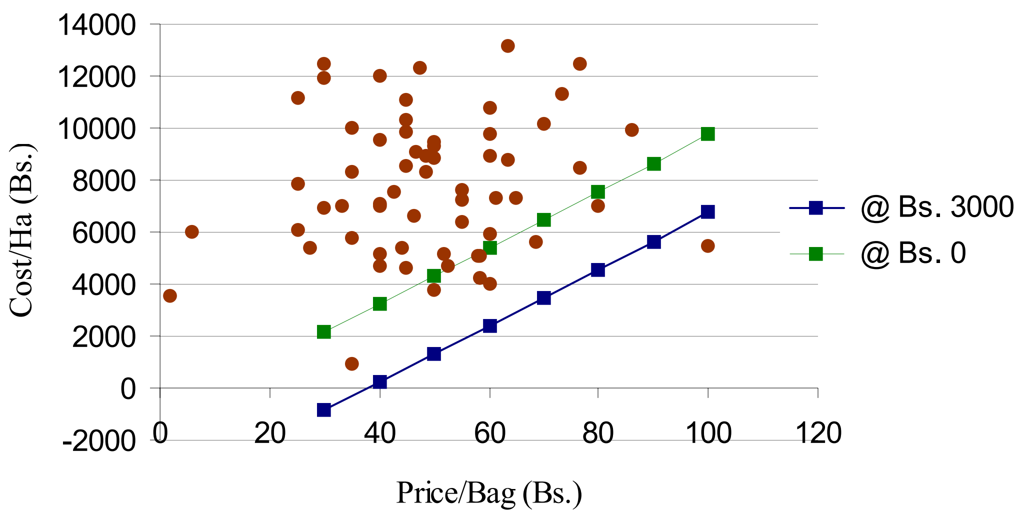


Figure 8.3: Income Lines for Yield of 20 Tn/Ha

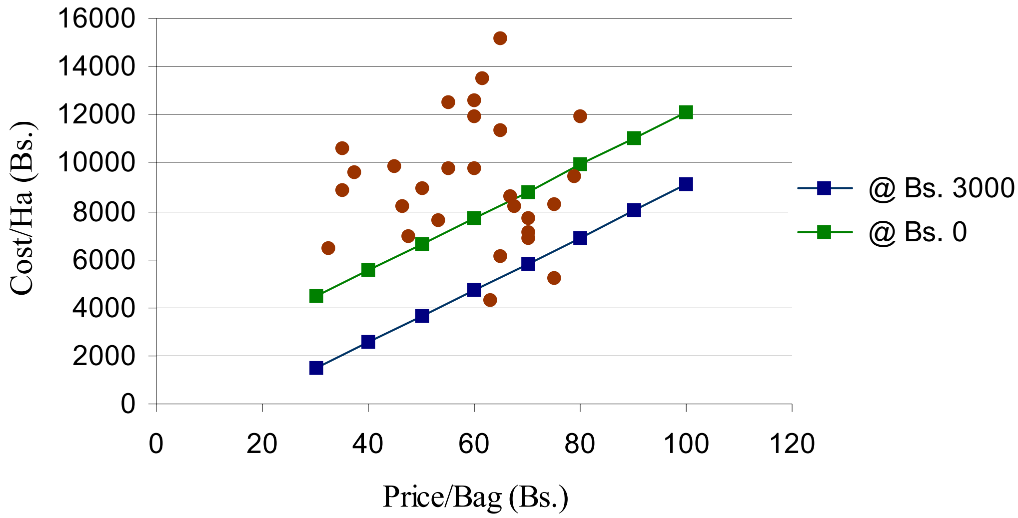


Figure 8.4: Income Lines for Yield of 25 Tn/Ha

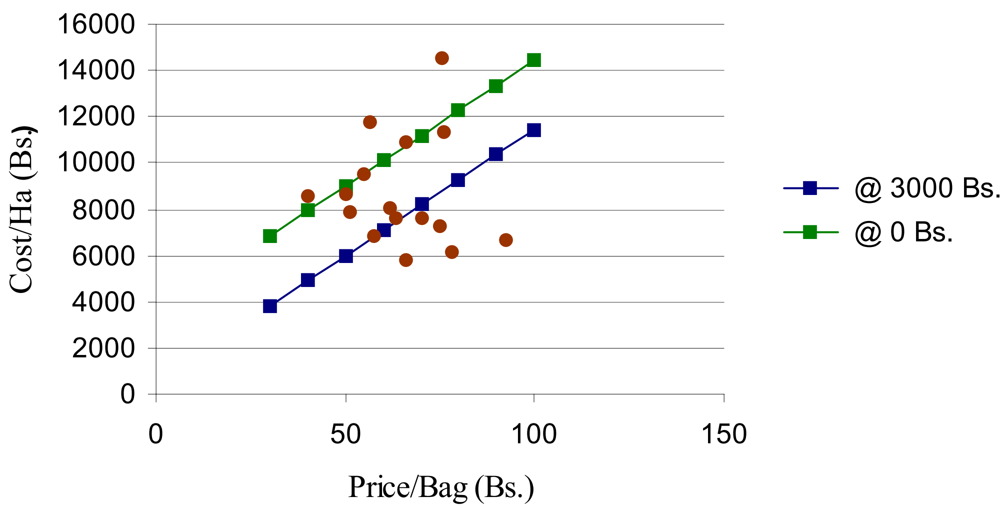
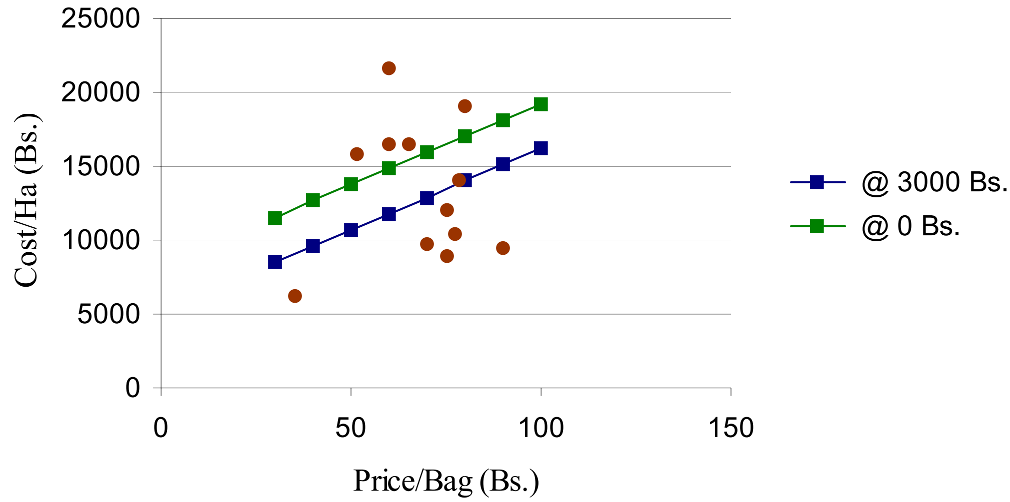


Figure 8.5: Income Lines For Yield 30 Tn/Ha



TUKEY TEST FOR PARCEL SIZE CLASSES

I used Tukey's w-procedure to test for differences in farm inputs between parcel size classes (Table 8.6).

Table 8.6: Parcel size classes for Tukey test

Class	Hectares
1	<.5
2	.5 – 1.0
3	1.0 – 1.5
4	>1.5

The summarized Tukey tests reveal an interesting relationship between parcel size and farm inputs. The regression analysis has already established that there is a slight negative relationship between parcel size and yield. The Pearson correlation coefficient for yield and parcel size was -.185 with a P-value of .1061. The data suggest that those farmers with smaller parcels have higher yields. The Tukey tests for parcel size provide more insight into this relationship.

Figures 8.6, 8.7, 8.8 and 8.9 show that farmers with smaller parcel sizes use more total labor, more oxen, more seed, and more nitrogen per hectare than farmers with larger parcels. The difference has the highest incidence of statistical significance between the largest parcel size class and the smallest. Logically, Figure 8.10 shows that the smallest parcel size class has a per hectare cost of production that is higher than the largest parcel size. Yields per hectare were also higher for the smallest parcel size class as compared with the largest (Figure 8.11)

1 2 3 4

Figure 8.6 : Results of Tukey test (.05 confidence level) for difference in use of total labor (Bs/Ha) by parcel size class

1 2 3 4

Figure 8.7: Results of Tukey test (.05 confidence level) for difference in use of oxen (Bs/Ha) by parcel size class

1 2 3 4

Figure 8.8 : Results of Tukey test (.05 confidence level) for difference in use of seed (Bs/Ha) by parcel size class

1 2 3 4

Figure 8.9: Results of Tukey test (.05 confidence level) for difference in application of N (kg/ha) by parcel size class

1 2 3 4

Figure 8.10: Results of Tukey test (.05 confidence level) for difference in production cost (Bs/Ha) by parcel size class

1 2 3 4

Figure 8.11: Results of Tukey test (.05 confidence level) for difference in yield (Tn/Ha) by parcel size class

These results demonstrate that in smaller parcel sizes onion crops tend to receive more inputs per hectare and hence have higher yields. The Tukey tests gave no indication, however, that farmers with smaller parcel sizes have a higher net income. It has already been established that yield is the main factor that determines profitability in onion farming, and so it is therefore reasonable to conclude that smaller parcel sizes yield better results. This is not to say that all farmers with small parcel sizes earn money, for it has also been demonstrated that a failure to balance costs with yield will always result in a net loss.

Rivas (2001, 2002), in collaboration with the technical team of FDTA-Valles, proposes several improved post-harvest practices that have the potential to increase the value of the onion crop at the farm level and to solve the problem of storage. First, the farmers must cure the onions by placing them in long rows in the farm fields and keeping them there for several days (Figure 8.12)


Figure 8.12: Curing onions in the field

At this time the translocation of photosynthetic material occurs, resulting in the desiccation and yellowing of onion leaves and the enlargement of the bulb. This operation allows the stem to form a scar, and facilitates the cutting of the stem and the protection of the bulb from invasive pathogens. After cutting the stem, the onions are then transferred to burlap sacks, where they will cure and dry for several more days (Figure 8.13).


Figure 8.13: Curing is facilitated by good ventilation

Once the onions have been cured, they are then sorted into three size classes. Finally, the onions are placed in plastic sacks with proper labeling (Figure 8.14). The application of these simple techniques allows the farmer to store his onions for up to four months.

Figure 8.14: Bags designed to improve marketing

These techniques are intended to form the basis of a larger marketing strategy that seeks to improve the quality of the product and the negotiating power of the small farmer in the larger market. Currently, FDTA-Valles is implementing this project in the Tipajara watershed. Rivas (2001, 2002) assumes that these practices will increase the value of the onion at the farm level instead of within the market. The project hopes to create several cooperatives of onion farmers in several different onion producing provinces in Bolivia. Rivas (2002) estimates that the farmers will incur an additional cost of approximately Bs. 4,400/Ha to implement this technology; increased costs can be attributed to the cost of burlap bags, increased labor costs, and the cost of the mesh bags for transporting and selling the crop. It is also estimated that the application of this technology has the potential to increase earnings by Bs. 7,000/Ha, though it is not specified if these are gross earnings or net earnings (Rivas

2002). As of January of 2003, however, these results had yet to manifest themselves. Table 8.7 shows the price per bag in Bolivianos the participating farmers received after applying the described technology. Comparing these prices to the price per bag in Table 6.4 (page 43), it is readily noticeable that the average change in price is negligible; in fact, it is below the average price per bag that a farmer receives selling his crop in the traditional fashion.

Table 8.7: Price per bag and # of farmers applying improved marketing technology by size class of onions, Tipajara watershed

	Large	Medium	Small
# of Farmers	32	38	38
Average Price/Bag (Bs/Bag)	56.88	57.76	37.89

Source: ACDIVOCA 2002

The data presented above was collected in the earliest phase of project implementation. This information therefore provides no conclusive evidence regarding the efficacy of this project, as these changes, if successful, will most likely manifest themselves in the long-term. I have included this information because it illustrates that even with improved marketing technologies, it is extremely difficult for farmers in the Tipajara watershed to turn onion farming into a profitable enterprise. In fact, any attempts at improved marketing will inevitably encounter a certain degree of difficulty, mostly because the primary constraints to profitability begin with production, and not, as FDTA-Valles has argued, with marketing. Certainly the increase in price that the product experiences as it travels through the chain of the market is considerable, and it is a worthy goal to introduce technologies that will increase the bargaining power of the farmer vis-à-vis this complex network of distribution. Nevertheless, the increased costs incurred and the apparent lack of compensation with a higher market price could drive the most inefficient farmers more deeply into debt. Selecting onions by size class, moreover, is actually a disadvantage for those farmers that have generally low yields, as do the majority in the Tipajara watershed. Selecting onions under these circumstances, when disease has already decimated a crop, actually reduces the value of the product because the farmer has willingly categorized the majority of his crop into the small category, the lowest price class.

Many farmers in Tipa Tipa lamented the declining yields in onions and the reduced response of disease to chemical controls. Among local farmers there was a general consensus, disease had gotten much worse since the early days of onion production. The cropping season of 2001 seemed to catch every farmer by surprise. Never before had they seen disease attack their onion crop so severely. "There wasn't this much disease before," was a phrase that I heard repeatedly from the local farmers. One farmer, in an exasperated tone, once told me: "What are we going to do about these diseases?" Another, explaining the disease to my Peace Corps project coordinator who was visiting the community, had this to say: "We have such great problems with onion diseases here, and they seem to be almost incurable." A local farmer, oblivious to the law of diminishing returns, became so desperate to control disease that he prepared batches of fungicide in a 55-gallon drum, believing he could out-muscle the organism with the brute force of quantity. So despairing had local farmers become of the vicious cycle of fumigation and disease that a persistent rumor began to spread that the disease was mixed in with the agrochemicals as a way to sell more of the product. As Beets (1990) asserts: "…all continuous cropping with a monoculture leads to problems. Most crops start to suffer excessively from pests and weeds." This is certainly the case in the Tipajara watershed (Figure 8.15).

Figure 8.15: Various diseases are destroying this onion crop

Unfortunately, the farmers seem incapable of believing that the golden age of onion production is over. Appendix II shows the zenith of this era, when in July of 1997 a bag of onions was worth between Bs. 461 to Bs. 532.

CHAPTER VIII: CONCLUSIONS AND RECOMMENDATIONS

In this study, I have provided a detailed description of certain key components of the farm system in the Tipajara watershed. I have documented the agricultural intensification process that occurred after the Agrarian Reform of 1952, and I have shown how increasing land fragmentation due to larger family sizes spurred the introduction of irrigation technology in the community of Tipa Tipa. I have also shown how national and local changes in infrastructure caused changes in village life and the farming system. Agricultural intensification has done little to halt environmental degradation; evidence suggests that intensification may accelerate environmental degradation and have adverse affects on certain groups within the community, e.g. women and the poor. A shrinking land base has resulted in high levels of migration to urban areas, but future gains in production are still necessary if the land is to sustain continued population growth.

Onions, one of the primary cash crops in the region, suffer from an epidemic of disease causing organisms that drastically affect yields and thereby reduce the possibility that farmers will make a profit. Within the population of onion farmers, there are farmers that earn money and farmers that do not; those that do not earn money are in the majority. The winning farmers were measurably different from the losing farmers. Farmers that earn money are able to properly balance costs to optimize yields and returns. For the vast majority of farmers, improvements in yield have greater potential to improve profitability than improvements in marketing techniques. Improved marketing techniques have the potential to increase the amount of money a farmer earns, especially for those farmers that already have high yields. Still, improved marketing techniques have not yet been proven effective in increasing the average price per bag for onions.

The case for change is overwhelming. The current state of agriculture in the Tipajara watershed is unsustainable. Chronic problems with disease and reduced yields have driven many farmers to desperate and ineffective farming practices. Environmental degradation continues through many channels: increased erosion, deposition of toxic chemicals into the environment, and more deforestation. I have written several recommendations that, if properly implemented, have the potential to address many of the problems outlined in this thesis.

RECOMMENDATIONS

Realizing that different management strategies are necessary for different land types, I have divided the lands of Tipa Tipa into three distinct categories based on land cover and current use (Figure 7.8 page 64). Zone one comprises irrigated lands. Zone two is hillside agriculture and extremely eroded lands. And zone three is forest resources. Based on these divisions, I have made recommendations for each zone, which could be used as the basis for future improvements in the farm system.

Zone One

This irrigated area is used primarily for the production of cash crops and for the production of some staple crops. The primary objective of any agricultural project in this zone should be crop diversification and the development of a successful rotation scheme combined with an earnest attempt to reduce the total cultivated area of onions. The evidence in this thesis is conclusive: smaller parcels yield better results; crop rotation is imperative. This does not necessarily mean that abandoning onions altogether is wise. As the statistical model for onions indicates, a careful balancing of costs and the appropriate management of farm inputs greatly improves the possibility of turning a profit. The reduction of total area cultivated has numerous advantages:

1. Allows better management of a crop that is extremely input intensive
2. Improves the possibility of profitability
3. Makes more resources available for crop diversification
4. Facilitates control of disease

In the future, onions must be cultivated under an Integrated Pest Management (IPM) scheme. Organic alternatives to chemical biocides exist and should be experimented with. The destruction of volunteer plants, infected bulbs, and crop residues could have an enormous impact on the year-to-year increase in airborne fungal spores. Farmers could benefit greatly from learning the procedures for pesticide and fungicide application. Learning about and understanding the life cycle of the causal organisms will help farmers to combat them.

Agricultural technicians in India were able to reduce the cost of harvesting by 70% when using a simple, self-propelled onion digger windrower to perform the mechanical operation of harvesting (Jadhav, Gharte, and Turbatmath 1995). Such a technology has the potential to reduce the labor-intensive nature of the onion harvest in rural Bolivia.

There is great potential to introduce intensive gardening techniques into zone one. A move towards an organic, intensively managed polyculture would improve family nutrition and provide a greater diversity of marketable crops. Such a risk management strategy would mitigate the effects of fluctuating markets, natural disasters, and disease epidemics.

Zone Two

Hillside lands are in desperate need of rehabilitation. These lands are excellent candidates for the use of agroforestry and silvopastoral systems. Ideally, these lands could be rehabilitated for the production of a number of useful products: grazing paddocks, cut and carry fodder, wood products, and rain fed cereal crops. There are also great opportunities for the construction of water catchments to expand the area of irrigated agriculture. Foreign aid dollars will certainly be necessary to subsidize the early rehabilitation process, as most local farmers have already dismissed the idea of investing labor and time into these highly eroded areas. This zone requires labor intensive soil conservation measures to halt the process of land degradation. Both live and dead barriers have great potential to curb erosion. Ideally, three dimensional GIS models would be used to develop a detailed management plan.

Zone Three

Due to the communal nature of these areas, it is extremely difficult to develop a plausible management plan. Few forest trees remain on these steep slopes, as most forest vegetation has been replaced by the shrubby pioneer species known as *chacatea* (*Dondonea viscosa*). The soils that support this vegetation are generally infertile, steep, and rocky. Goats and cows are commonly seen trampling through these areas in search of the most palatable vegetation. Perhaps, as the PDAR (1991) suggests, the best approach to managing these lands would be to leave them alone. Priority should be given to the most intensively managed areas in the watershed, i.e. zones one and two. Under ideal conditions and proper management, sustainable practices in these zones could be adopted within 20 years. In the meantime, laws that preserve remaining trees need to be enacted and enforced. Once sustainability has been achieved in zones one and two, a province wide, landscape level approach to forest management could be adopted. This approach would seek to promote natural regeneration pathways using active fire management practices and relic forest trees as a seed source. Such a project would require at least 50 years before the area began to recover its original forest vegetation.

Unfortunately for Bolivians, conditions are far from ideal. Corruption is rampant, local officials suffer from a chronic lack of resources, and many rural community members have become disenchanted with agricultural development projects that all too often deliver questionable results. Still, the *campesinos* never ceased to amaze me with their extreme resiliency. Their acceptance of things as they are struck me as both naively childish and impossibly wise. More than any single thing, their talent to make something, however crude and rudimentary, out of almost nothing, stands out in my mind. Surely such skill is grounds for optimism. I truly believe that this skill is their key to a successful future. Only projects that seek to enhance local innovation and build upon it will be successful in the future. This requires an enormous investment of time and energy into the human resources that exist at the rural level. For in the end, the development of human resources within local contexts is the only real solution to global poverty.

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APPENDIX I: SOILS

Translated from PDAR 1991

Order Entisols

Typic Ustorthents:

The characteristics of these soils in the study area are presented as follows. They have no lithic contact within the first 50 centimeters. They are not saturated with water in the control section for more than 1 month out of the year. They have no cracks in the surface layer. They have thick textures that are very permeable, without any grade of compaction, and with a large amount of round and angular fragmented rocks.

In the Tipajara watershed these soils represent a total surface area of 2,749 hectares, which is 11.2% of the total area. These soils are moderately deep with a texture ranging from loamy silt to loamy sand. They have a granular structure in the surface horizon without structure in successive horizons. External drainage is imperfect, while internal drainage is good. The parent material is alluvial.

The soil pH ranges from 7.5 to 8.0, slightly to moderately alkaline. The electric conductivity in suspension fluctuates between .130 to .264 mmhos/cm. There is a slight concentration of salt, which is no problem in these soils.

The cation exchange capacity is between 6.0 and 11.0 meq/100g. of soil. Total nitrogen content varies from .0009 a .0095%. Available phosphorus ranges from 1.2 to 2.8 p.p.m. Potassium content ranges from .12 to .38 meq/lt. Organic material falls between .18 and 1.95%, and is considered very low. These chemical characteristics, therefore, indicate low soil fertility.

The riverbed in this watershed occupies a surface area of 320 hectares, which represents 1.4% of the total land area.

Lithic Ustorthents*:

These soils have all the characteristics of a Typic Ustorthent, except they posses a lithic contact within the first 50 cm. of the soil profile. These soils have a texture loamy to loamy sand, with structure in the entire profile. External drainage is excessive, and internal drainage is imperfect. Slopes vary between 25%-65%. Parent material is colluvial.

The pH varies from 6.0 to 6.4, being slightly to moderately acid. They generally have a scarcity of macro-elements and no concentration of salts. The morphological characteristics of these soils indicate very low soil fertility.

Order Inceptisols

Aridic Ustochrepts:

These soils have all the characteristics of a Typic Ustochrept, except they are dry 6/10ths of the time during most years. These soils exist in the Tipajara watershed with a surface area of 1,992 hectares, representing 8.1% of the total area. They are deep soils with a sandy texture to a sandy clay loam. Soil structure is blocky sub-angular that go from weak to moderate, usually weak in the top horizon, moderate in successive horizons, without any structure at all in the lowest horizons. External drainage is imperfect, internal drainage is moderate. Parent material is alluvial.

The pH varies from 6.2 to 6.9, slightly acid to neutral. Electrical conductivity fluctuates between .031 to .069 mmhos/cm, which shows that there are no significant concentrations of salts. The cation exchange capacity is between 8.4 and 9.9 meq/100 g., and is considered low. The percent of exchangeable sodium shows no adverse effects, as it is below 15%.

Total nitrogen varies from .02 to .103%, which is considered low to moderate. Available phosphorus is between .4 to 1.3 p.p.m., which is also low. Potassium is between .18 and .46 meq/100 g., which is identified as moderate. Organic material varies from .97 to 2.06%, considered low. Chemical data from these soils indicates poor soil fertility in those soils located in the Tipajara watershed (Inceptisols).

Order Alfisols

Aridic Haplustalfs:

These soils have all the characteristics of a Typic except they are dry for more than 6/10 of the year, in half or more than half of all years. These soils occur in the Tipajara watershed, representing a surface area of 4,137 hectacres, which comprises 16.9% of the total area.

These soils are deep with a texture that ranges from silty clay loam to silty clay. The soil structure is in moderate sub-angular blocks in the surface horizon, and moderate to strong in subsequent horizons. External and internal drainage are both imperfect. The parent material is alluvial.

The pH varies between 5.8 and 7.7, moderately acid to slightly alkaline. Electric conductivity in suspension fluctuates between .025 and 1.020 mmhos/cm., which is considered moderate in its concentration of salts.

The cation exchange capacity is between 13.0 and 24.0 meq/100 g. of soil, which is considered moderate. The percent of exchangeable sodium fluctuates between 2.04%. This presents no significant problem as it is below 15%.

Total nitrogen varies from .0001 to .0072%, which is identified as very low. Available phosphorus is from .5 to 17.2, high in the upper horizons and very low in the lower horizons. Potassium goes from .86 to 2.8 meq/lt., which is considered very high. Organic material is .12%, generally high in the upper horizons and very low in the lower horizons. These chemical characteristics indicate that these soils have a moderate to good fertility.

APPENDIX II: HISTORICAL PRICES FOR ONIONS

Onion Prices Mayorista Santa Cruz Market

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
1990	105.00	107.50	127.50	102.50	110.00	117.50	110.00	100.00	102.50	60.00	57.50	57.50	96.46
1991	42.50	40.00	40.00	40.00	60.00	75.00	75.00	95.00	137.50	147.50	112.50	82.50	78.96
1992	92.50	77.50	82.50	92.50	102.50	115.00	125.00	127.50	157.50	232.50	195.00	175.00	131.25
1993	125.00	125.00	125.00	132.50	142.50	80.00	80.00	147.50	117.50	127.50	67.50	77.50	112.29
1994	97.50	85.00	85.00	100.00	95.00	87.50	85.00	72.50	70.00	72.50	102.50	102.50	87.92
1995	122.50	120.00	92.50	100.00	87.50	182.50	160.00	117.50	100.00	82.50	90.00	82.50	111.46
1996	102.50	77.50	80.00	82.50	97.50	97.50	70.00	57.50	45.00	57.50	87.50	80.00	77.92
1997	122.50	160.00	162.50	242.50	292.50	345.00	465.00	302.50	180.00	110.00	102.50	77.50	213.54
1998	97.50	107.50	150.00	175.00	197.50	257.50	97.50	80.00	92.50	127.50	107.50	80.00	130.83

Source: Rivas 2001

Onion Prices Mayorista Cbba Market

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
1999	60.00	54.17	73.33	52.50	64.58	50.00	54.17	55.00	59.17	50.83	55.00	55.00	56.98
2000	93.33	83.33	66.67	66.67	72.92	87.50	106.67	70.83	108.33	54.17	91.67	100.00	83.51
2001	87.50	87.50	79.17	83.33	-	-	-	-	-	-	-	-	84.38
Avg.	80.28	75.00	73.06	67.50	45.83	45.83	53.61	41.94	55.83	35.00	48.89	51.67	74.95

Onion Prices Mayorista Sucre
Market

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
1998	80.00	70.00	120.00	195.00	120.00	300.00	120.00	360.00	40.00	160.00	140.00	80.00	148.75
1999	80.00	80.00	80.00	80.00	120.00	100.00	80.00	100.00	80.00	80.00	80.00	100.00	88.33
2000	100.00	180.00	180.00	140.00	160.00	140.00	160.00	120.00	100.00	100.00	100.00	80.00	130.00
2001	60.00	80.00	100.00	80.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.67

Source: Rivas 2001