CHAPTER 3

ENVIRONMENTAL SETTING

The mesothermal Cochabamba region consists of an intermontane group of valleys located on the easternmost slopes of the Bolivian Andes at about 2500 m.a.s.l., 17°15' south of the equator. The region is bounded to the north and west by the Tunari chain, the easternmost arm of the Cordillera Real (Figure 1). It consists of the Central Valley, the largest and agriculturally most productive area, the Capinota Valley to the southwest, the Santivañez Valley to the south, the Valle Alto to the southeast and the small Sacaba Valley to the east of the Central Valley. Two valleys lie 140 km southeast of Cochabamba's Central Valley: the Mizque and the Aiquile Valleys. These valleys lie beyond a mountain range reaching 4000 m.a.s.l. with **puna** environment.

The Capinota-Parotani and Mizque Valleys formed the research area of this investigation. The Capinota area, closer to the Cochabamba Central Valley, is a Spinous Steppe environment. In contrast, the Mizque Valley corresponds to a Spinous Forest area (Unzueta 1975). An essential difference between these two valleys lies in the year-round availability of water, a critical factor for agricultural productivity, especially maize. Although, precipitation and temperature features do not differ drastically, the Mizque Valley has a more regular and consistent year round supply of water from several rivers that enter the basin.

The Capinota-Parotani survey area

This area is located in the portion of the Rocha Valley running north to south from the town of Parotani to the town of Capinota, respectively. The northern and southern boundaries of the survey area are defined by the tributaries to the Rocha River: the Tapacari and the Arque rivers (Figure 1). The Rocha River, which flows westbound through the Central Valley --where most of its scarce water is used-- enters the Parotani-Capinota Valley with a very small load. The Tapacari River carries a larger water load during the summer, and flash floods, water the Rocha River during the rainy season. To the south the Rocha meets the Arque River, which also has an extremely heavy seasonal discharge during the summer. During winter, the silty, sandy and cobblestone river bed lies dry, as do most parts of the Rocha and Tapacari river beds.

This area has the two modern main access routes to the altiplano: the highway runs to the west from Parotani to the north, and the railway runs west from the southern side of the survey. The only prehistoric access route identified to date into the Cochabamba Valley is the Inka road that runs west-east about 10 km north of the northern limit of the survey area (Hyslop 1984). No prehistoric roads were found in our survey.

The eastern limit of the survey area, on the eastern bank of the Rocha River, is delineated by a steep mountain range dissected by gorges. It divides the Capinota Valley from the Santivañez Valley. The river bank is very narrow with an average width of 100 m. The western boundary of the Parotani-Capinota survey area extends farther west than the Rocha River. This edge is roughly 400-600 meters above the river alluvium, after progressing through a piedmont zone of gradual slope with medium to steep elevations and dissected by deep dry gorges. This area is extremely eroded and has extensive crevasses caused by the depletion of vegetation. The piedmont zone soils do not have the quality of the irrigated lands found along the immediate river banks, but the area is used for seasonal dry farming. The western bank of the Rocha River also has a narrow alluvial plain but broadens into the northern Parotani plain, the Chara Mokho plain, and the southern Capinota plain.

Including in the survey areas with higher elevations farther west of the Rocha River allowed us to investigate sites located at a 4-6 hour walking distance from the alluvial zone. These portions of the mountain and piedmont zone are today settled in a dispersed pattern on a seasonal basis during the rainy season. The productivity of the dry farming fields in these areas is extremely poor in comparison to alluvial valley yields. The survey revealed a very low density of prehistoric settlement in this zone, suggesting that settlements relying on a complete spectrum of altiplano crop production are to be found in elevations closer to the altiplano.

Climate

The Capinota-Parotani survey area has a temperate climate with temperatures varying from 12° to 18° C degrees, and average summer and winter differences not exceeding five degrees. The rainless winter season has temperatures below zero (C°) and frost events. Rain ranges from 250-500 mm. per year (Figure 13) and the hydric balance is very favorable for agriculture (CIDRE 1988). The summer rainfall from November to May permits dry farming in piedmont areas. Cultivation of maize, wheat, barley, potatoes, and legumes is possible in this climate. In the dry period, only frost resistant crops (alfalfa, some legumes and temperate climate fruits) are cultivated with irrigation.

Geology

The Capinota-Parotani survey area is located in the central sector of the eastern Andean range of the Cordillera Real. Two geological groups dominate the survey area: Ordovician shale, slate, and quartz sandstones; and calcareous rocks of the Mesozoic age. The Ordovician layers characterizing most of the survey area are metamorphosed intrusive and extrusive igneous rocks of thick grey-bluish slates or micaceous black with inclusive layers of quartzitic sandstones. The calcareous outcrops of the second group are mainly restricted to the southern portion of the survey area. These layers are covered by

Tertiary and Quaternary Holocene deposits with soft calcareous clays that provide fertile soils (GEOBOL n.d.; Figure 14).

Vegetation

The Capinota-Parotani survey area represents a Spinous Steppe environment with a semiarid climate. The original vegetation has been partly deforestated by agricultural and herding activities. This process, aided by steep slopes and scarce vegetation has affected the evapotranspiration of soils, and accelerated the loss of soil nutrients in the western piedmont zone.

The most important formations in the valley are herbaceous communities, **chaparral** communities, and forests (Pedrotti et al. 1988; Figure 15). The herbaceous plants are diverse and vary depending on the type of soil and location within the valley's physiography. The chaparral community composed of native **Algarrobo** (*Prosopis laevigata*) and **Acacia** (*Acacia macracantha*) interspersed with cactii (*Opuntia* sp.) in open areas. Dense forested areas are composed of **Molle** (*Schinus molle*), **Jacaranda** (*Jacaranda mimosifolia*), Soto (*Schinopsis hankeana*) and Quebracho (*Aspidosperma* spp.). The dense forests with xerophytic species and microfoliated and perennial leaves are the typical vegetation for the dry forests of the Andes. These forests have an easier time with regeneration because goats do not eat their hard and pointy leaves. Human use of the forest for wood, however, constantly threaten its regeneration.

Soil Classification in the Capinota-Parotani survey area

The soil classification is based on agricultural use and potential productivity of soils (CIDRE 1987, 1988; CORDECO 1983; CUMAT 1991; MACA 1985 --based on the FAO soil classification). I have collapsed the CIDRE seven-class soil classification of land use patterns into three soil groups, where classes 1, 2 and 3 are my group 1 soils, classes 4 and 5 are my group 2 soils, and classes 6 and 7 are my group 3 soils (The tabulations in Appendices E and F use the seven class classification).

The soil classification relates to soil texture, gravel and stone contents, permeability, depth, erosion and slope gradient of the soil zones. In addition, water availability is a major factor in maize productivity. However, no detailed data exists on water table depth or precipitation patterns that would allow modeling different productivity within each survey area. The survey research has found no evidence of prehistoric canals.

Group 1 soils consists of arable soils, with few limitations to use; arable soils, with a limited spectrum of crops and that require special soil conservation practices; and arable soils with strong limitations to type of cultigens and requiring special conservation practices. Group 2 soils have severe limitations, both due to the few possible cultigens and problems with soil conservation; and non-arable plots of soil with high salinity, irregular composition, and inadequate drainage or excessive gravel and stone contents. Finally, group 3 soils are non-arable soils very difficult to cultivate, characterized by sandy and steep slopes.

Topography and soils in the Capinota-Parotani survey area

The survey area is composed of: (1) an alluvial zone with alluvial fans and terraces, and the river bed; which account for 17.1% and 7.4% of the 200 km^2 survey area, respectively; (2) a piedmont zone, 24.6% of the area; and (3) a mountain zone, 51.9% of the survey area (Table 1; Figure 16). Overall, 18.4%, 29.4% and 52.2% of the randomly drawn sample of survey quadrats were located in each of the three respective topographic zones, excepting the riverbed.

The soil group zones are distributed as 15.35%, 7.55%, and 70.7% of the total survey area, and 17.2%, 12.2%, and 70.6% of the survey sample, respectively (Table 2; Figure 17). There is an overwhelming majority of group 3 soils, which have very low productivity. The group 1 soils are generally found on alluvial terraces of mixed ancient alluvial and colluvial origin where soil depth is medium to deep, and are dark brown, black-brown and reddish brown in color. On the immediate river bank, flat or gently sloping, soils are deep to very deep, generally dark brown in color, and exhibit medium to moderately fine texture. They have slow to very slow permeability, a moderate to strong alkaline reaction, and high salinization resulting in medium fertility.

Irrigation of the soils is difficult given the presence of dissolved and suspended salts and solids. Today, Capinota's water table is high as an effect of excessive irrigation in lands leveled to the riverbed. This generates salts and sodium in recently irrigated soils. Use of organic matter or seasonal sedimentation by flooding the fields are methods used to reduce salinization.

The piedmont zone has narrow and deep gorges with a restricted area for available cultivation. These are shallow to medium (.2-1 m.) soils, yellowish-brown to dark brown in color, with fine to medium texture. They have a poorly developed structure, medium to high gravel and stone contents, medium to high permeability, low to moderate fertility, irregular and undulating surfaces, and sandy soils with bedrock on surface; these features limit strictly dry farming agriculture in the piedmont areas. Finally, the mountain zone is characterized by steep slopes, medium to high erosion, high permeability, and high stone content. This results in low agricultural productivity.

The Mizque survey area

The Mizque Valley is one of the easternmost ridges of the Andean mountain range at this latitude. The circular shaped valley is bounded by a low to medium elevation mountain range with undulating surfaces subject to resultant bedrock exposure.

The basin is watered by six rivers and drained by one. The main river is the Mizque that crosses the basin from east to west running eastbound towards the lowlands. The Uyuchama and the Callejas rivers have year-round water and provide the bulk of water to the basin. However, today much of the water is diverted for irrigation before reaching the Mizque River (Figure 18). Water enters and exits to the main Mizque Basin through narrow gorges less than 200-400 m wide. The exception is the Tipajara Valley that connects with the southern Aiquile area through a wide valley.

Climate

The climate in the Mizque Basin represents typical mesothermal weather: dry with a short period of precipitation (500 to 570 mm). It receives 87% of the rainfall from November to March. Annual average temperature is 19° C degrees, with an average from May to September of 16.5 degrees, when occasional frosts may occur. Relative humidity ranges from 45-60% in winter and 70-80% in summer (CIDRE 1987; Figure 19).

Geology

The Mizque Basin is crossed by an extensive synclinal axis that runs NNW-SSE. The Mizque River is located in a fault zone where rocks less resistant to degradation form a bed (Figure 20). Paleozoic strata dominate the survey area, including Ordovician sandstones and orthoquartzites with vertical inclusions of black slates. Tertiary strata are red-yellowish basal conglomerates on a weathered surface or light brown on fresh surfaces. Tertiary strata dominate the current piedmont and mountain surface, interspersed with outcrops of dark shales of the former strata. Stone constructions in the survey area are mostly done with shale. Finally, Quaternary layers in the basin consist of unconsolidated and dendritic alluvial deposits of gravel and cobblestones interspersed with sandstones and shales, and, in lower percentages, clay and silts in ancient terraces, fans and the riverbed (CIDRE 1987).

Vegetation

The process of desertification stemming from wood cutting and goat grazing in Mizque is not as dramatic as in the Capinota-Parotani survey area. The Mizque Valley has neo-tropical vegetation of semi-arid and semi-humid character. Three types of vegetative domains occur: **Chaqueño**, Andean-Patagonic, and Amazonian (in order of their importance, CUMAT 1991). The first is a forest formation dominated by Soto (*Schinopsis hankeana*) and molle (*Schinus molle*), and has humid and dry communities in the valley. Smaller forest formations are composed of Willca (*Anadenanthera colubrina*) and Palosanto (*Gochnatia palosanto*). The Chacatea arbust (*Dodonea viscosa*) occurs in areas of degraded soils, such as the western margins of the basin where eroding soils expose bedrock. Algarrobo forests (*Prosopis laevigata*) occur in the lower piedmont areas.

The Andean-Patagonic formation is basically composed of Quewiña (*Polylepis spp.*), a tree clustered in small areas on the higher slopes and upper elevation gorges, surrounded by herbaceous plants. Finally, the Amazonian formation occurs in the humid and warmer settings of deep gorges in the bedrock with dense forests of Tillandsias (spp.), Bromeliaceas, and Ferns. This formation includes the *Podocarpus parlatorei*, the only native Andean conifer.

Topography and soils in the Mizque survey area

Alluvial plain, river bed, piedmont, and mountain zone, make up 15.85%, 7.25%, 32.4%, and 44.5% of the total Mizque survey area, respectively (Table 3; Figure 21). Their proportion in the sample of survey quadrats is 16.25%, 37.5%, 46.25% in the three topographic zones, respectively, excluding the river bed.

As for the three-group collapsed soil zones, their distribution in the total survey areas is 17.2%, 15.9%, and 59.6%, respectively (Table 4; Figure 22). Their occurrence in the sample of survey quadrats is 19.7% in the first group, 19.1% in the second group, and 61.7% in the third group.

The alluvial plain is flat with low slopes, and alluvial fans and terraces. This zone includes the most productive soils. Salinization is not a major factor affecting soils. However, this area is subject to frequent flooding that puts some alluvial areas with good soils in group 2.

The piedmont zone is composed of low elevation mountains and extremely eroded hills with deep gorges. Higher elevations have a gentle (2-10%) slopes with little consistency in the surface soil. Lower slopes are steeper and have cliffs and gorges. Morphological processes of sliding in higher and medium slopes and alluvial and eolian erosion on lower slopes are characteristic. The lower hills have a Quaternary sediment cover with low arboreal vegetation.

The mountain zone has slopes and summits producing irregular relief and Tertiary soil deposits with Ordovician rock outcrops. The higher elevations have a slope of 14-21%, and deep cliffs. Water accumulation and diffused water drainage on those slopes shape the relief, but on gentler slopes slower drainage produces salt layers.

Summary

Two aspects of land use and settlement pattern analysis need to be emphasized: (1) distribution of soil groups in both areas; and, (2) the differences in water availability. Overall, the average rainfall for both areas is very similar, 550 to 650 mm a year. The differences in water availability lie in the flow to the valley lands, that produces flooding to create richer soils, and in the quality of soils that retain water. Unfortunately, no data on prehispanic irrigation, from which maize production would have certainly benefited, has been gathered.

The size of the alluvial zone in each area is roughly similar. The Capinota-Parotani area has a larger mountain zone, whereas the Mizque area has a larger piedmont zone. In terms of soil group zones, the Capinota-Parotani survey area has more individual class 1 soils than the Mizque survey area, but then the Mizque survey area has a much larger total area of the most productive soils of group 1 soils. The Capinota-Parotani survey area, in turn, has a larger area of group 3 soils, the least productive of the soil groups.

The Mizque survey area has a significantly larger piedmont (topographic zone 2) than the Capinota-Parotani survey area. In contrast to the latter area, a larger part of the piedmont in Mizque possesses group 1 soils, the best agricultural soils. Settlement in the piedmont zone therefore would allow occupation on the best soils. In contrast, settlement in the piedmont of the Capinota-Parotani survey area would mean occupation on low productive soils.