NEGOWAT

Facilitating Negotiations over Land and Water Conflicts in Peri-urban upstream Catchments

RESEARCH REPORT Nº 1

Land Use Changes in the Valley Area of Tiquipaya Municipality

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The NEGOWAT Project (Facilitating Negotiations over Land and water Conflicts in Peri-urban Upstream Catchments) is a research project developed in Cochabamba (Bolivia) and Sao Paulo (Brasil). It is focused to develop tools to better understand water related competition and conflicts among different stakeholders in these areas.

In Bolivia, the NEGOWAT Project is executed by the Andean Centre for Water Management and Use (Centro AGUA) and the Study Centre of Social and Economic Reality (CERES). The Centro AGUA is an education and research centre of the Faculty of Agriculture and Livestock Sciences (FCAyP), San Simon University (UMSS).

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/ land / land use / irrigated agriculture / farming system /

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SUMMARY

The study treats the land use mapping in three years: 1983, 1992 and 2003. The study objective is to contribute with information to the discussion on the land use in the Tiquipaya municipality, promoting a participative and agreement atmosphere in the processes of decision making about the future land use.

The results show the quick and lawless growth of the urban area against mainly the agricultural and livestock lands. Between 1983 and 2003, the area covered with urban infrastructure increased from 36 ha (1.1 %) in 1983, to 215 ha (6.8 %) in 1992, and to 564 ha (17.9 %) for 2003, it means an increase of 529 ha in this period of 20 years.

A process of reduction of the land use intensity has been developed at farming system level. The farming systems with medium land use intensity devoted to the diary cattle breeding are dominant; these farmers are specialized in the cultivation of corn, alfalfa and oat, leaving aside the cultivation of potato, bean and several vegetable species.

1. INTRODUCTION

In the last 20 years, a quick change in the use of land has taken place in Cochabamba Central Valley. This change has affected the outlying urban area of Cochabamba city due to the growth and appearance of new populated centres (urban areas) against agricultural areas. This phenomenon is the result of a complex process dealing with the growing migration of peasants toward the cities, caused by the economic crisis and the adverse climatic phenomena, as well as the progressive establishment, in rural areas, of city people who see the rural environment as a resting space.

Consequently, in outlying urban areas, like those of the valley of Tiquipaya municipality, it is common to find areas where diverse land use types (agricultural, livestock and urban) interact with the rising conflict of interests among the diverse "*land users*", like farmers who require water for irrigation or people who settle down in the area demanding potable water for human consumption.

The group of activities involving land resources takes place in a certain context, using a certain quantity of available resources, fulfilling the land owners' specific necessity. In this way, the use that a land owner does in a certain land space is the result of a complex process of decision making, which is limited by diverse and multiple factors that put conditions to the present and the future land use.

In this manner, the study of land use changes arises as a specific demand of ASIRITIC (Tiquipaya–Colcapirhua Irrigators Association), who are concerned on how the quick and illegal change condition their actual and future land use, affecting in this way their farming systems.

The Andean Centre for Water Management and Use (Centro AGUA) and ASIRITIC, in the context of the NEGOWAT research project, outlined the realization of the land use mapping in three periods of time (1983-1992-2003), quantifying the produced changes, with the objective of contributing to the information for the discussion on the land use in the Tiquipaya municipality, promoting a participative and agreement atmosphere in the decision making processes about the future of land.

This document is a descriptive memory of mapping carried out in the valley area of Tiquipaya municipality on the basis of the delimitation of Land Use Units (LU) and Dominant Farming Systems Zones (DFSZ) in three periods: 1983, 1992 and 2003. Based on the mapping realized, it was possible to analyze the land use changes for the periods between 1983 and 1992 (9 years) and between 1992 and 2003 (11 years).

2. CONCEPTUAL FRAMEWORK

Regarding the land issue, there is a certain confusion in the use of concepts and terms which cause methodological errors that often result in errors in the analysis and result interpretation process. Consequently, it is necessary to consider that the land use study involve the establishment and development of concepts and methodologies according to the study objective, and the specific context of the study area.

2.1 Concept of Land

The concept of land should not be confused with soil, since land involves a much wider definition in which the soil becomes a land component, in the same way as vegetation, fauna, climate, and others. For the objectives of this document, it is considered the concept developed by FAO-UNEP (1997), mentioned by FAO-UNEP (2000):

> **Land** and **Land Resources** refer to a delineable area of the earth's land surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), the near-surface sedimentary layers and associated groundwater and geohydrological reserve, plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)

The stated land concept can be understood from an integral framework in which land is considered a system where, the land resources (climate, soil, relief, hydrology, flora, fauna, etc.) interact in a dynamic way. It is for this reason that the land state becomes the result of this dynamic process of interaction.

2.2 Land Use

In general terms, the land use can be defined as “land management that man does to satisfy his necessities”, also it can refer to “human activities related directly to the land”. However, the land use doesn't refer to any human activity done on the land, but rather it refers to the activities that consider the use of the land resources or that make some impact on these. Young (1994) defines land use as “the human activities that are directly related to the land, making use of their resources or having an impact on them”. In this concept, he makes an essential characteristic of the land use, whereas we cannot see the human activities as such directly, the land use cannot be visualized directly from remote sensors, and it can however be inferred from observed elements.

A valuable aspect to consider is the fact that the land use refers to the function or the purpose for which the land is used. It is in this sense that Di Gregorio and Jansen (1998), in FAO-UNEP (2000), define “the land use is characterized by the arrangements, the activities and the population's inputs to produce, to change or to maintain a certain type of land cover”. The land use defined in this way establishes a direct relationship between the land cover and the population's actions related to its biophysical environment.

Contrary to the land use, the term land cover refers to the observed covering, just as you can see on the surface or by remote sensors. Di Gregorio and Jansen (1998), mentioned by FAO-UNEP (2000), define the land cover as "the covering that is observed (bio) physically on the terrestrial surface". It is in this way, that the land cover becomes a consequence of the interaction among the natural environment (especially vegetation) and the land use. In a more precise way, it can be defined as "the vegetation (natural or planted) or human constructions (buildings, roads, etc.) which cover the terrestrial surface" (Young, 1994).

Considering that the land cover is the result of the land use at a certain time, the covering can change quickly For that reason, the same land unit can be classified in a different way (in terms of vegetable covering) the next year, or even the next day. However, the land cover is the main diagnoses characteristic that is used when a researcher makes land use maps although it is not the land use by itself.

2.3 Frameworks applied in land use studies

The characterization of the land use considers two important aspects: the obtained benefits of its use, and the operations carried out on the land in order to obtain these benefits. Accordingly, Young (1994) intends to differentiate two concepts: functional land use and biophysical land use. The first one refers to the benefits of the land use and the second to the required operations to obtain these benefits. The fact to consider one or the other aspect differentiates the many land use classification systems, being possible to group them in two frameworks proposed by Duhamel (1998), which correspond to the two concepts of land use formulated by Young:

- **Functional Framework (functional land uses**): It corresponds to the description of the land use in terms of its socio-economic purpose (agriculture, residential, forestation, etc.).
- **Sequential Frameqork (biophysical land use)**: It Considers the land use like a series of operations in the land, carried out by the man, with the intention of obtaining products and benefits through the use of the land resources.

Considering the land use like a sequence of operations for the achievement of a purpose, a narrow relationship settles down among the two proposed frameworks. However, in practice this is not very simple, considering that the user's decision on the land use is also addressed by other factors like the biophysical nature of the land; for example, the one mentioned above is clearly manifest in the fact that two same purposes can be achieved starting from the development of different operations.

According to Duhamel (1998), two main aspects indicate a clear separation of these frameworks:

- The first one is the one referred to the reach domain; the functional framework can be applied on the whole surface of the land. On the other hand, the sequential one can only be applied on agricultural lands.

- The second aspect is a pragmatic one; the functional framework is easy to develop since it simply requires a general understanding. On the other hand, the sequential framework requires the conceptualization and development of specific procedures with the objective of creating a specific information system.

On the basis of the above mentioned paragraphs, it is advisable to establish a clear separation of the two frameworks, where the sequential framework can be treated as a modulate framework over the agricultural function.

In the functional framework field, it is possible to infer the land use from the covering. On one hand, in the sequential framework, the land use characterization requires a more detailed field data gathering. Generally, the functional framework is more appropriate in exploratory classifications carried out at national or world level, where the remote sensors play a very important role, and where the field work is just a verification process. On the other hand, the sequential framework is applied in classifications at communal and regional level that require a bigger detail, being based mainly on field data gathering starting with a preliminary delimitation of land use units with the help of remote sensors.

An important aspect to consider is the objective of the classification. In studies of analysis of land use changes or of impacts of the land use, it is advisable to consider the sequential framework in the characterization and classification of the land use since it is required to characterize the process of change, identifying the changes in the objectives and in the developed activities for the achievement of these objectives.

3. GENERAL CONTEXT OF THE STUDY AREA

3.1. Location

The study area covers the valley area of the Tiquipaya municipality. It embraces 3158 ha It limits to the east with *Cercado* municipality, to the west with Quillacollo, to the south with Colcapirhua and to the north with the mountainous area of the Tunari Mountain range (Figure 1).

Tiquipaya is the third municipal section of Quillacollo province. This municipality is divided into six districts, the study area is located in the districts 4, 5 and 6. The populated center is located at 11 km away from Cochabamba city.

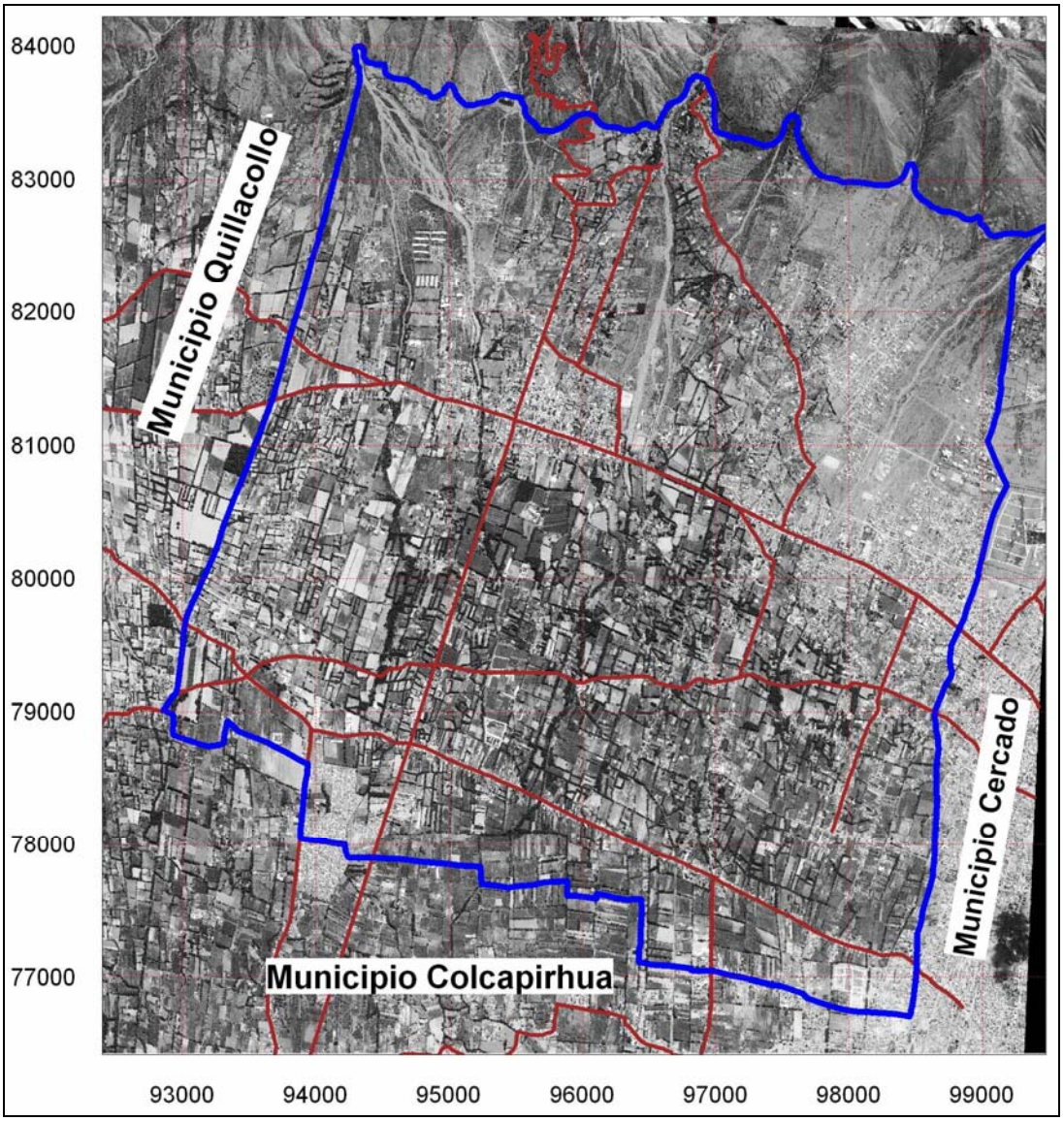

Figure 1. Study area, the valley zone of Tiquipaya municipality (Aerial photograph from 1992).

3.2. Climate

The climate of the area is mild. According to data of the "*La Violeta*" meteorological station, it presents an average minimum temperature of 7 ºC and an average maximum of 30 ºC. The average annual rainfall reaches the 548 mm, being able to distinguish two periods: the rainy one (November to March) and the dry one (April to October).

In general terms, the climate is favorable for the development of diverse crops. The scarce pluvial rainfall is, due to its bad distribution. The clime factor limits the production.

3.3. Soils

The soils are from alluvial origin, having been identified mainly *inceptisols* and *aridisols* that are characterized for presenting scarce horizons development. They are moderately deep to deep soil, of fine textures (clay and silty clay) and moderately fine (clay loam, silty clay loam and sandy clay loam). The topography of the area is plain, with slopes that vary from 2 to 10 %.

Most of the soils are capable of being irrigated for agriculture. According to the land classification system of the United States (USBR), they correspond to soils of second and third class. In the proximities of the rivers and in the mountainous region there are soils not capable for agriculture (class 6) due to slope and high stony.

3.4. Water Resources

The study area has diverse water sources like: rivers, springs, reservoirs and underground water. This water is used both for irrigation and for human consumption.

Due to the scarce pluvial rainfall, the farmers of the area should appeal to the irrigation water to assure and to increase their agricultural production. Thus , they develop several irrigation systems to use the different water sources:

- The irrigation systems *Lagum Mayu*, *Saytu Khocha* and *Chankas* that use the water from the mountain range reservoirs.
- The National Irrigation System Nº 1 uses the water from "*La Angostura*" dam, which is located in the High Valley.
- The *Machu Mitha* system uses the runoff water of the *Khora Tiquipaya* watershed.
- Small irrigation systems that have springs or wells as water sources.

The domestic water systems use mainly groundwater sources. Each system has one or more water wells.

3.5. Population

According to the National Population and Housing Census Data of 2001 year, the total population of Tiquipaya municipality was as high as 37791 inhabitants, of those, 29799 (79 %) live in the study area (districts 4, 5 and 6).

The population has increased quickly in the last 20 years. According to the data from the National Institute of Statistics (INE), the population of Tiquipaya in 1992 reached 13371 inhabitants, being the demographic growth of 283 % along 9 years, with an annual rate of growth of 11.2% (1992 census to 2001 census).

According to population's projections, in the year 2010 Tiquipaya would end up having an approximate population of 91318 inhabitants. Figure 2 illustrates the population's growth according to the projection of demographic growth among the year 2000 and 2010, carried out by the National Institute of Statistic (INE).

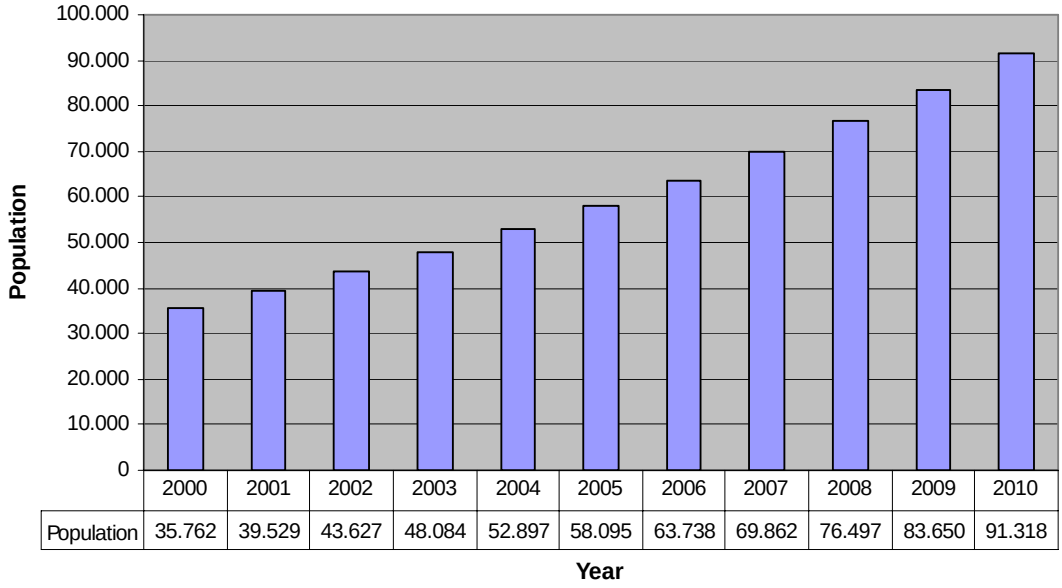

Figure 2. Population's growth projection 2000 to 2010
Source: Own elaboration with INE data

The quick demographic growth of the Tiquipaya municipality is due mainly to the appearance and growth of new populated centers as a result essentially of the migratory processes of people coming from other departments. In general, the inhabitants are distinguished into three types:

- ***Tiquipayeños:*** They are native residents of the area. Two clearly identified groups differ: the *tiquipayeños* who live in the populated center of Tiquipaya and develop diverse activities, and the *tiquipayeños* who live in the denominated rural and peri-urban areas. They mainly develop the agricultural activities.

- ***Citadinos***: They are people of urban origin (Cochabamba city mainly) who come into Tiquipaya looking for the ideal place to live. They build houses to reside definitively in the area or simply for the weekends.

- ***Migrants***: They are people coming from other departments of Bolivia, mainly from the rural areas (restaffed miners, peasants, etc.). They build their houses in this place and they work in Cochabamba city.

4. METHODOLOGY

The methodology combines mapping and photo-interpretation techniques with interactive techniques of information gathering and verification, that together with the structuring of a Geographic Information System (GIS) they allow the development of tools to be used in the

creation of discussion and agreement spaces on the land use. Figure 3 schematizes the methodology for the land use mapping, which is described below.

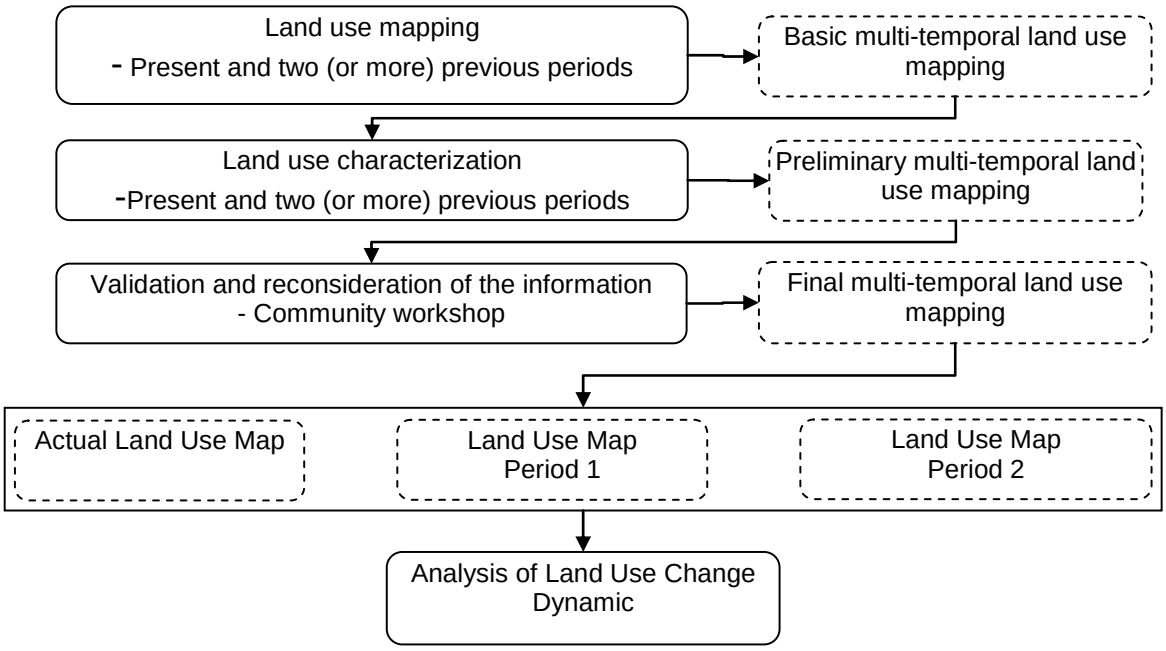

Figure 3. Methodology diagram for the land use change mapping

The GIS was developed using the ILWIS software that allowed the digitization of the cartographic information and the storage of thematic information into related attribute tables.

4.1. Establishment of agreements

Considering the objective and the reaches of the study, the first stage consisted of the establishment of agreements that facilitate the normal development of the foreseen activities. In this stage, meetings and workshops were arranged with the main interest groups in the area, having a working team staffed by two technicians of Centro AGUA, one technician of the government and two irrigators whose main responsibility are mainly the execution of the foreseen activities in the study.

Also, the communal discussion workshops were settled down, as the presentation and discussion of results spaces. At this stage, the first communal workshop was developed where residents were informed on the development of the study, specifying the objectives, reaches, activities and prospective results. Likewise it recalled a chronogram of activities specifying the moments when the communal workshops would be carried out, and also the working team and the population's responsibility levels were settled down.

4.2. Land use mapping

The land use mapping was carried out on the basis of the aerial photographs interpretation and field journeys, having defined previously the units and mapping approaches in agreement with the general context of the study area.

4.2.1 Mapping Units

The study considers two mapping units: Land Use Units (LUU) and Dominant Farming Systems Zones (DFSZ) that are defined as follows:

- ***Land Use Units (LUU):*** A Land Use Unit is defined as an earth space (cartographic unit) that is dedicated to a certain use in a certain period of time. This concept refers to a classification at a wide level, as being: agricultural use, livestock use, forest use and urban use.
- ***Dominant Farming Systems Zones (DFSZ):*** The Dominant Farming Systems Zones are subdivisions of the Land Units. They correspond to areas or land spaces where the inhabitants develop a structured group of agricultural and non agricultural activities, with the objective of guaranteeing the reproduction of their exploitation; it is the result of the combination of the means of production (land and capital) and of the labor force availability in a certain socioeconomic and ecological environment (based on Dufumier, quoted by Apollin and Eberhart, 1999).

The importance of considering these two levels in the mapping is related to the necessity of characterizing the land use in detail. It is done with the objective to develop a detailed study of the change processes in rural and suburban environments, where the productive land uses prevail (agricultural, livestock and forest).

4.2.2. Mapping approaches

Considering the study detail level, it was determined that the minimum mapping unit would be 1 ha. Also, the assignment of a certain land use to an area, does not imply that the whole area absolutely corresponds to this land use since it is accepted up to 25 % of inclusions, which means that when a certain land use is assigned in an area, it is guaranteed that at least 75 % of the area corresponds to this land use.

In the land unit case, six units are considered, where the Agricultural-Urban Use and Urban-Agricultural Use units are considered as units in a transition process, for that reason intermediate limits are accepted. Table 1 indicates the general approaches for the assignment of Land Use Units.

The DFSZ are defined considering the farming systems and the land use intensity, for that reason they are just applicable to the agricultural and cattle land uses.

Table 1. Mapping approaches of Land Use Units

Land Use Units	Description
Agricultural Use	Land area where more than 75 % of the unit is dedicated to the agricultural use
Livestock Use	Land area where more than 75 % of the unit is dedicated to the cattle use
Forest Use	Land area where more than 75 % of the unit is dedicated to the forest use
Agricultural-Urban Use	Land area where 50-75 % of the unit is dedicated to the agricultural use; and 25-49% is dedicated to the urban use
Urban-Agricultural Use	Land area where 50-75 % of the unit is dedicated to the urban use; and 25-49% is dedicated to the agricultural use
Urban Use	Land area where more than 75% of the unit is dedicated to the urban use

The farming systems are defined according to the crop pattern developed by the producers; that is why one crop pattern has been established for each farming system, where the main crops, the production calendar and the cultivated surface are specific. Table 2 summarizes the utilized approaches for the dominant farming systems identification.The land use intensity characterizes the dominant farming system considering the quantity of productive cycles developed by year, which is dependent on the irrigation water availability. The 4 established land use intensity levels are described below:

- ***Intensive (IN):*** Intensive land use is characterized to take place at least three growth periods per year. Generally these farmers have 3 to 4 annual cultivations, for that reason they have a high quantity of irrigation water availability.
- ***Medium intensity (SI***): Medium intensity land use, the land is used for 2 to 3 growth periods per year. These farmers have moderate irrigation water availability.
- ***Low intensity (ST):*** Low intensity land use, the land is used mostly for one growth period per year; however the limited irrigated water availability allows the farmers to advance sowings and to guarantee their production.
- ***Rainfed (T):*** Rainfed land use, the land is only used for annual growths. The farmers do not have access to irrigation water, which is why they only cultivate in the rainy period.

For the case of the forest and urban uses, the DFSZ are considered as subdivisions of the land use unit due to their own characteristics. In the case of the forest land use, the origin of the forest (native and implanted) is considered and, in the case of the urban land use, the urbanization type (urban centre and marginal urbanization).

Table 2. Mapping approaches for the dominant farming systems

Land uses	Farming system		Main activity	Secondary activity	Land use intensity
Agricultural use	AAGST	Grain producer, low intensity	Corn and oat cultivation	Occasional cultivation of alfalfa for animals feeding	Low intensity
	ADFIN	Diversified flower grower, intensive	Production of flowers like the chrysanthemum, carnation and daisy	Growing of potato, bean and corn in small surfaces for household consumption	Intensive
	AHLIN	Horticulturalist and milk producer, intensive	Growing of vegetables like: broccoli, cauliflower, cabbage, artichoke and sheaths	Milk production, for that reason they dedicate part from their lands for forage production (corn, oat and alfalfa)	Intensive
	AHLSI	Horticulturalist and milk producer, medium intensity	Growing of vegetables like: broccoli, cauliflower, cabbage, artichoke and sheaths	Milk production, for that reason they dedicate part from their lands for forage production (corn, oat and alfalfa)	Medium intensity
	AEAIN	Agricultural company, intensive	Companies or particular people dedicated to the cultivation of corn, alfalfa and potato, supplemented by the breeding of dairy cows, pigs and chickens		Intensive
	AEASI	Agricultural company, medium intensity	Companies or particular people dedicated to the growing of corn, alfalfa and potato, supplemented by the breeding of dairy cows, pigs and chickens		Medium intensity
	AEFIN	Flower grower company, intensive	Companies dedicated to flowers production, like: carnation and rose, mainly in hothouses		Intensive
	ACIIN	Research and production Centre, intensive	Institutions dedicated to research and agricultural production that dedicate their lands to the forage production like corn, oat and diverse forage grass species		Intensive
Livestock use	PPLSI	Milk producer, medium intensity	Dairy cow breeding; forage growing: alfalfa, oat and corn. They keep more than 3 cows in production	Small extensions to grow: potato, bean, pea and vegetables	Medium intensity

Table 2 (Continuation). Mapping approaches for the dominant farming systems

Land uses	Farming system		Main activity	Secondary activity	Land use intensity
Livestock use	PPLST	Milk producer, low intensity	Dairy cow breeding; forage growth: alfalfa, oat and corn. They maintain more than 3 cows in production		Low intensity
	PELSI	Milk producer company, medium intensity	Company or particular people dedicated to the dairy cow breeding, for that reason they dedicate their lands for forage production: alfalfa, corn and oat. They are characterized to have numerous livestock (15 to 30 cows in production)		Medium intensity
	PELST	Milk producer company, low intensity	Company or particular people dedicated to the dairy cow breeding, for that reason they dedicate their lands for forage production: alfalfa, corn and oat. They differ from PELST because their land use intensity is almost rainfed, due to its low irrigation water availability, that limits them the cultivated surface and consequently the size of the livestock is smaller (10 to 20 cows in production)		Low intensity
	PEANA	Poultry farming company	Companies or particular people that dedicate their lands to poultry production		
Forest use	FBINA	Implanted forest	This area is covered by implanted forests, mainly eucalyptuses		
	FBNNA	Native forest	This area is covered by forests with native species		

Both in the mapping and in the structuring of the GIS and the database, just one legend (Code) was used. This includes the land use unit, the dominant farming system, and the land use intensity, as it is illustrated in Figure 4.

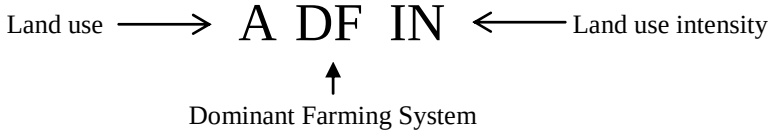

Figure 4. Used Codification in the study

4.2.3. Mapping phases

The mapping complies with two cycles of action:

- ***Cabinet mapping:*** The land use mapping for the years 1983 and 1992 were carried out starting from the aerial photographs interpretation. Firstly, land use units were defined at a general level (Agricultural, Livestock, Forest, Urban and Non Used). Later on, the land use units were subdivided, according to the main crops and to the land use intensity. Finally, a first approach to the Dominant Farming Systems was defined.
- ***Field mapping:*** For the field mapping realization, aerial photographs maps were enlarged (1:5000 at 1:10000), these maps provided, with transparencies were used for the gathering of cartographic information. The mapping was carried out starting with field journeys and interviews to key informants. This allowed on one hand, the verification of the units defined in the cabinet mapping, and on the other hand, the use of mapping for the year 2003.

4.3. Land Units definition

The Geographical Information System (GIS) structured required the delimitation of basic cartographic units (Land Units) that allow the storage and prosecution of the thematic information gathered in a related database. With this objective, there were delimited Land Units as basic mapping units with similar land use characteristics for the three years of study (1983, 1992 and 2003). These land units were defined starting with the three basic land use maps overlapping (Figure 5).

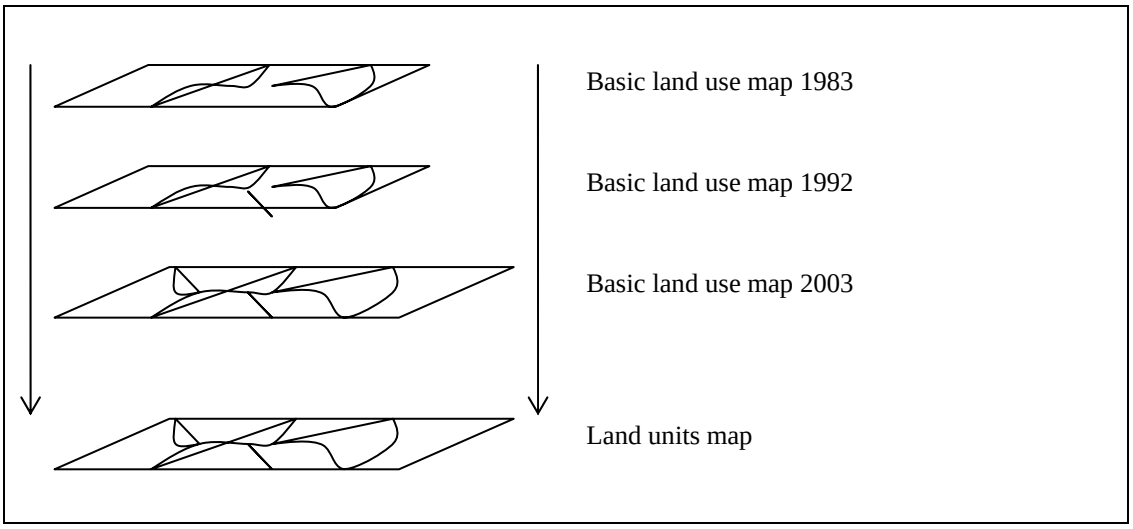

Figure 5. Land use maps overlapping process for the land units' delimitation

The same as in the land use mapping, the minimum mapping unit is one hectare, that is to say that smaller size units are not considered, for that reason an aggregation process was carried out for these cases. The process of overlapping and aggregation was carried out in a manual way, carrying out field journeys verifying the aggregation relevancy to one or another land unit on the basis of discussions with the residents of the area.

The Land Units map was digitized on a georeferenced aerial photographs mosaic prepared for it in the ILWIS software. The result of this process is a polygon map of land units, which was related to an attribute table to facilitate the thematic information storage for each land unit.

4.4. Land use characterization

The land use characterization was carried out at Dominant Farming Systems Zones (DFSZ) level. In this phase, field journeys and interviews to study area farmers were realized. Three complete interviews were carried out for each DFSZ identified; besides two or more open interviews were also realized to validate the gathered information and the delimitation realized.

The information gathered in the interviews was systematized and stored in an ILWIS database, which allowed the information prosecution and the production of the preliminary maps of land use for 1983, 1992 and 2003.

4.5. Communal workshops

The realization of communal workshops was planned for the presentation and discussion of the reached results and the planning of future activities, with the objective of achieving a bigger residents' participation in the study. For that reason, the study area was divided into 3 sub zones, having organized one workshop by zone with the participation of communities' representatives, like: base territorial organizations (OTB), drinking water committees, irrigation systems and other representative organizations of the area.

Initially, the realization of three communal workshops was planned in each sub zone; however due to problems unaware to the study; only one workshop carried out. In this workshop the following aspects were discussed:

- ***Description of the general study methodology:*** The study methodology was described emphasizing the activities where the residents' participation and the final results were required.

- ***Presentation of preliminary land use maps for 1983, 1992 and 2003***: With the help of a projector (Data Display) the preliminary land use maps were presented, specially emphasizing the zone where the workshop was carried out. At the same time, it was explained the utilized legend and the main characteristics of each Land Use Unit (LUU) and the Dominant Farming Systems Zones (DFSZ) that comprise them.

  The residents validated the collected information, having comprised some precisions to the maps for the years 1983 and 1992.

- ***Land use changes discussion:*** With the purpose of making out the land use changes, the maps were presented simultaneously and the surface data were provided on the areas corresponding to each land use unit and each Dominant Farming Systems.

  In the first instance the participants recognized the validity of the presented information; later on the diverse factors that caused the changes were discussed.

4.6. Correction of collected information

On the basis of the workshop results, new field journeys were carried out to verify the corrections made. If it was necessary, the land units' delimitation and the database information were corrected. Later on, it was analyzed the general coherence of the cartographic information and the database, and the final maps were processed.

4.7. General structure of Geographic Information System (GIS)

With the purpose of achieving an efficient handling of the collected information, a GIS was made out where the thematic information gathered is related to the cartographic information, which facilitates the recovery of information and the production of thematic maps.

The GIS was made out with the ILWIS Software, where the cartographic information was digitized and attribute tables were structured with thematic information for the maps production. Figure 6 illustrates a general outline of the developed GIS.

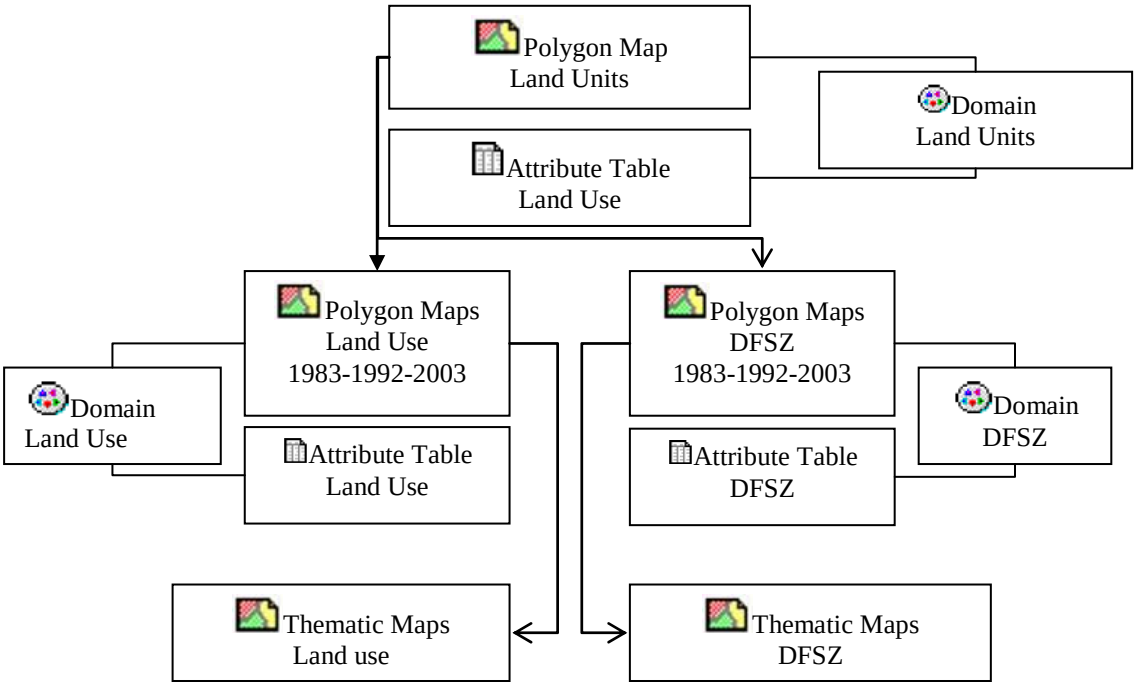

Figure 6. General structure of the Geographic Information System (GIS)

The general GIS structure is compound mainly by polygon maps and attribute tables. The attribute tables are related to the maps through the common domain, what allows the production of the attribute maps.

5. LAND USE DESCRIPTION

The mapping realized allowed the establishment of Land Use Units (LUU) and its respective Dominant Farming Systems Zones (DFSZ), for the three considered periods. Table 3 summarizes the identified units, which are described as follows.

Table 3. Land Use Units and Dominant Farming Systems Zones

Land Use Units	Dominant Farming Systems Zones	
	Farming Systems	**Land Use Intensity**
Agricultural use(A)	Horticulturalist milk producer (HL) Grain producer (AG) Diversified flower grower (DF) Flower grower company (EF) Agricultural company (EA) Research and production centre (IC)	Intensive (IN) Medium intensity (IF) Low intensity (ST) Rainfed (T)
Livestock use (P)	Milk producer (PL) Milk producer company (EL) Poultry farming company (EA)	
Agricultural-Urban use (AU)	Diversified Flower grower (DF) Horticulturalist milk producer (HL) Milk producer (PL)	
Urban-Agricultural use(UA)	Grain producer (AG) Diversified flower grower (DF) Milk producer (PL)	
Forest use (F)	Native forest (BN) Implanted forest (BI)	Non Applicable (NA)
Urban use (U)	Urban centre (UC) Marginal urbanization (UM)	
Non Use (S)	Without Agricultural Use (SUA)	

5.1. Land use in 1983

The valley area of the Tiquipaya municipality was characterized in 1983 to be dedicated mainly to the agricultural production, becoming one of the most important producer areas in Cochabamba. The land use in 1983 is illustrated in Maps 1 and 2, and it is summarized in Table 4.

Table 4. Land use in 1983

Land use	Dominant Farming System Zones		Area (ha)		Area (%)	
Agriculture	AAGST	Grain producer, low intensity	158	1485	5.0	47.0
	ACIIN	Research and production centre, intensive	41		1.3	
	ADFIN	Diversified flower grower, intensive	391		12.4	
	AEAIN	Agricultural company, intensive	15		0.5	
	AEASI	Agricultural company, medium intensity	29		0.9	
	AHLIN	Horticulturalist milk producer, intensive	292		9.2	
	AHLSI	Horticulturalist milk producer, medium intensity	559		17.7	
Livestock	PEANA	Poultry farming company	17	1088	0.5	34.5
	PELSI	Milk producer company, medium intensity	114		3.6	
	PELST	Milk producer company, low intensity	9		0.3	
	PPLSI	Milk producer, medium intensity	948		30.0	
Forest	FBINA	Implanted forest	19	19	0.6	0.6
Urban	UCUNA	Urban centre	13	36	0.4	1.1
	UUMNA	Marginal urbanization	23		0.7	
Non Use	SUANA	Without Use	440	530	13.9	16.8
	SUTNA	Stream	90		2.8	
Total			**3158**	**3158**	**100.0**	**100.0**

5.1.1. Land Use Units in 1983

In 1983 the valley area of Tiquipaya municipality was mainly dedicated to the agricultural use, making up a total surface of 2573 ha (81.5%), with 1485 ha (47.0%) dedicated to agricultural production and 1088 ha (34.5%) to livestock production. Figure 7 illustrates the proportion of each land use unit mapped.

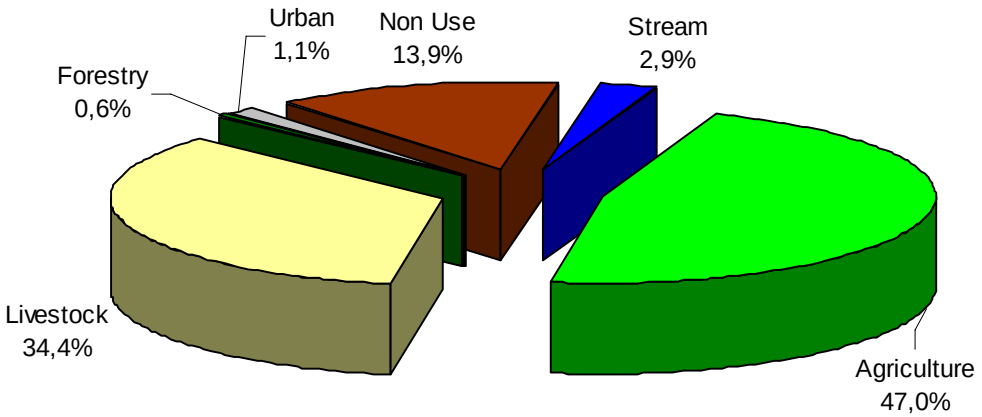

Figure 7. Land use proportion in 1983

An important quantity of land (530 ha), which represents 16.8 %, was not used for productive activities; this due to the serious soil and slope limitations. The urban area covers a total of 36 ha that represents 1.1 % of the study area. It includes the Tiquipaya urban centre, the "*Ciudad del Niño*" building and the outlying areas of the Cochabamba city.

5.1.2. Dominant Farming System Zones (DFSZ) in 1983

The farming systems dedicated to milk production with medium land use intensity (PPLSI) were the predominant DFSZ. They cover a total of 948 ha (30.0 %). These farming systems are mainly dedicated to the corn and alfalfa production for dairy cattle feeding. The production of vegetables was another such an important sector. It is the case of the Horticulturalist milk producers with medium land use intensity (AHLSI), which were covering 559 ha (17.7%); and the Horticulturalists milk producer with intensive land use (AHLIN), which were covering a total of 292 ha (9.2%). In these DFSZ, the farmers were devoted mainly to the growth of diverse vegetables for the sale, and also they grow corn and alfalfa for their reduced dairy cattle feeding. Figure 8 schematizes the proportion of each DFSZ mapped.

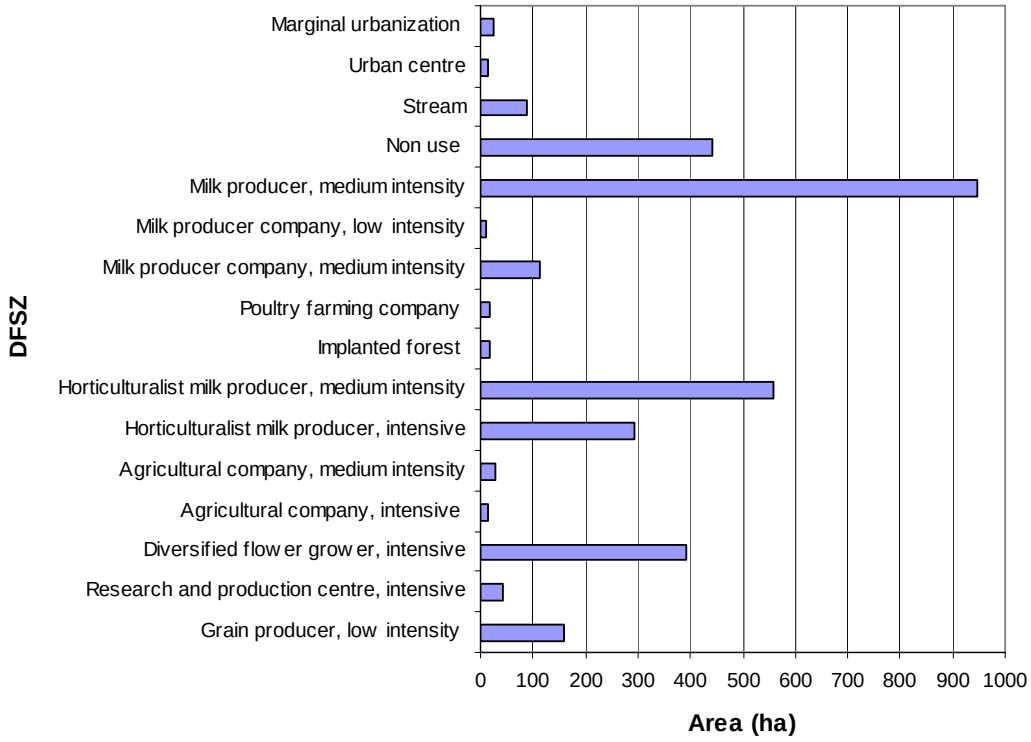

Figure 8. Dominant Farming Systems Zones in 1983

The diversified flower grower with intensive land use (ADFIN) was another important DFSZ in 1983. It covered a total of 391 ha (12.4 %). These farming systems were devoted mainly to the growth of diverse crops (corn, potato and bean) both for the household consumption and for sale, combined with the production of diverse flower species for sale.

A total of 175 ha (5.5 %) belongs to companies or private people, who dedicate their lands to agricultural production. Among those, the milk production companies (PELSI) were the most important occupying 114 ha.

The soil and climate characteristics, and also the high irrigation water availability were the ideal conditions for the development of intensive and medium intensity farming systems. Farmers were allowed to carry out from 3 to 5 annual growths.

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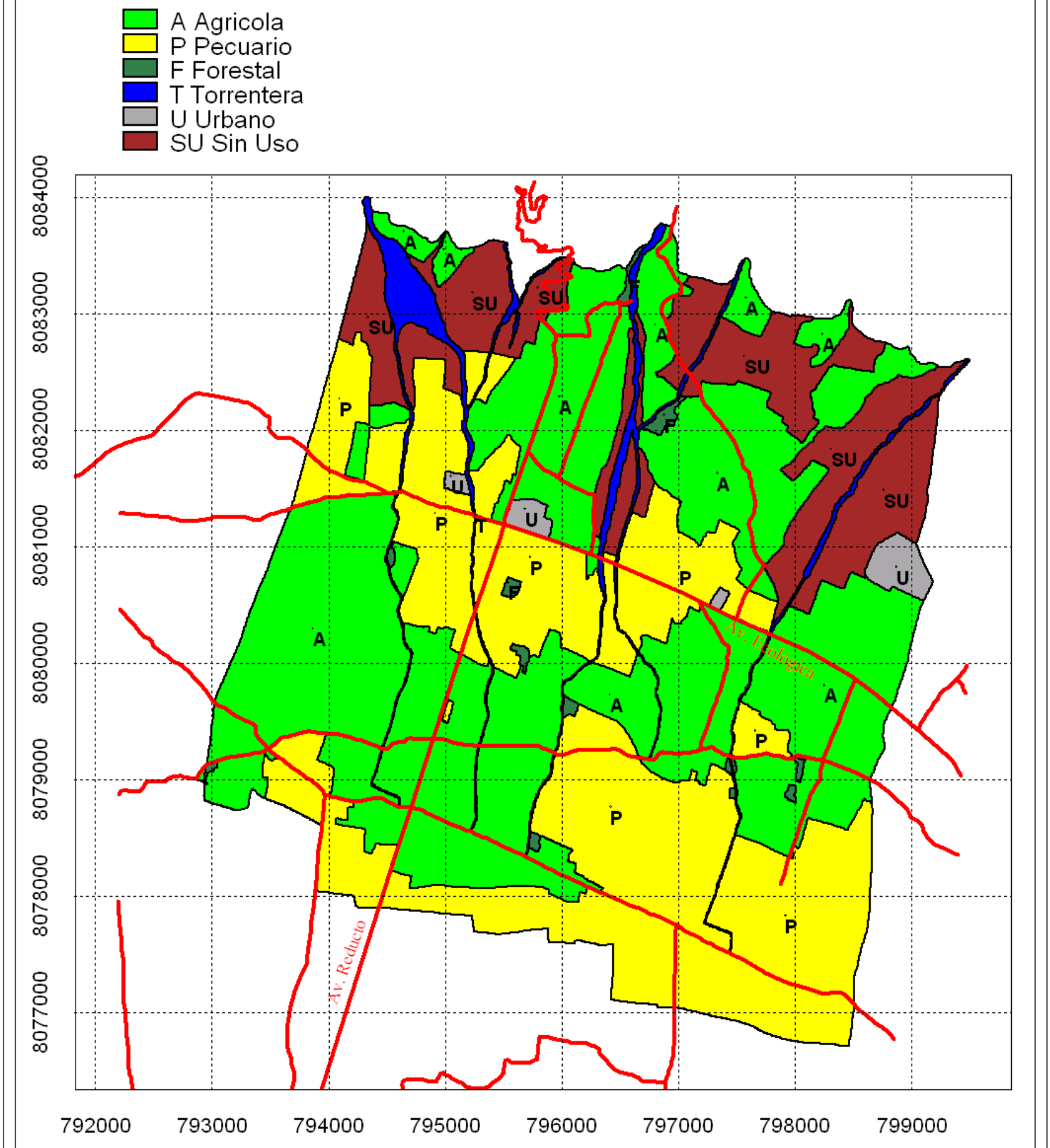
MAPA 1
USO DE TIERRA 1983
ZONA DE VALLE DEL MUNICIPIO DE TIQUIPAYA

Superficie: 3158 Ha Escala 1:50 000
Cochabamba, Octubre de 2003



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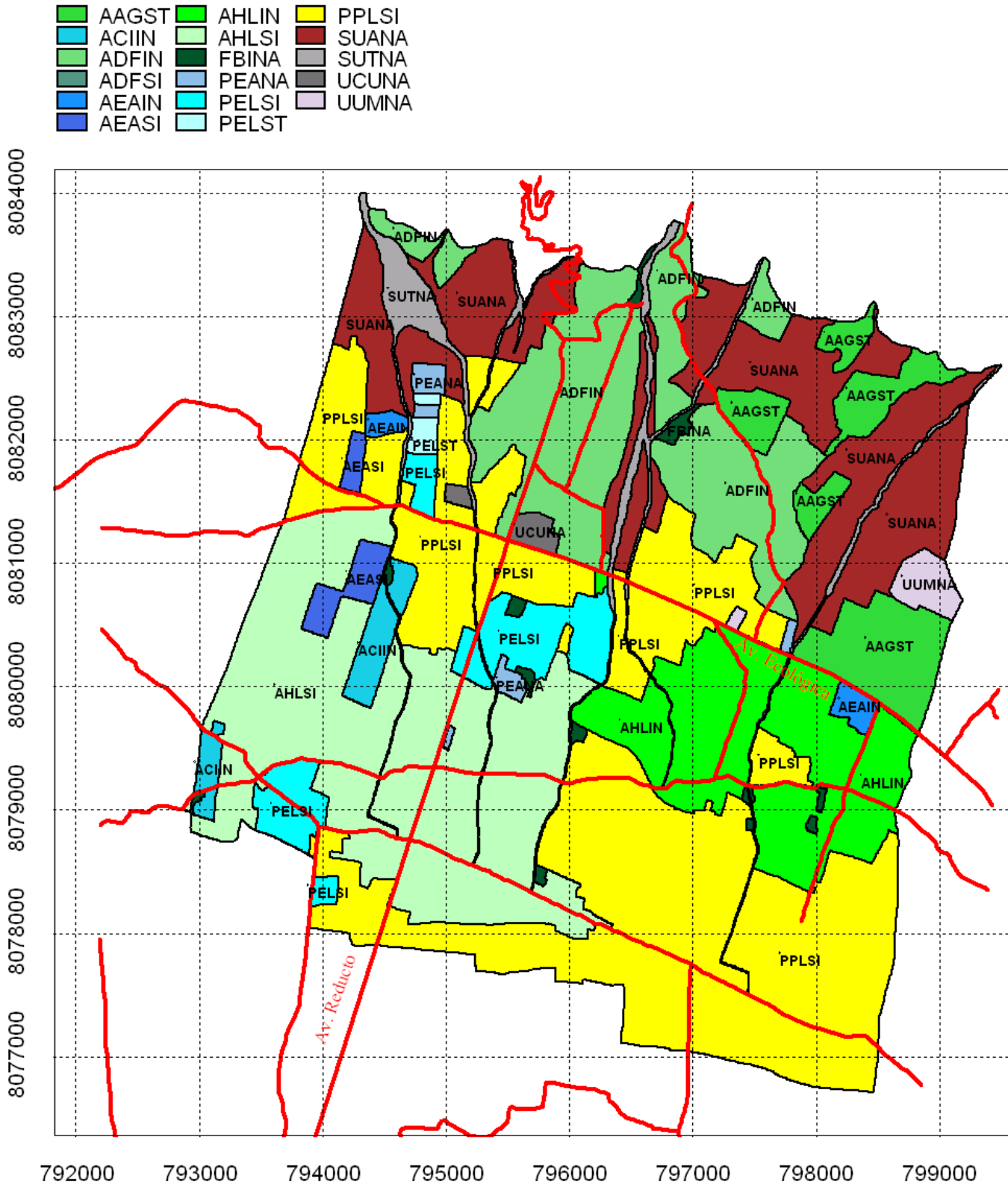
MAPA 2
SISTEMAS DE PRODUCCION DOMINANTES 1983
ZONA DE VALLE DEL MUNICIPIO DE TIQUIPAYA

Superficie: 3158 Ha Escala 1:50 000
Cochabamba, Octubre de 2003



5.2. Land Use in 1992

In 1992, the valley area of Tiquipaya municipality was characterized for being mainly dedicated to agricultural production, just as you can see in Table 5 and in maps 3 and 4.

Table 5. Land use in 1992

Land use	Dominant Farming Systems Zones		Area (ha)		Area (%)	
Agriculture	AAGST	Grain producer, low intensity	91	838	2.9	26.5
	ACIIN	Research and production centre, intensive	41		1.3	
	ADFIN	Diversified flower grower, intensive	358		11.3	
	ADFSI	Diversified flower grower, medium intensity	14		0.4	
	AEAIN	Agricultural company, intensive	22		0.7	
	AEASI	Agricultural company, medium intensity	29		0.9	
	AEFIN	Flower grower company, intensive	5		0.2	
	AHLIN	Horticulturalist milk producer, intensive	278		8.8	
Livestock	PEANA	Poultry farming company	23	1608	0.7	50.9
	PELSI	Milk producer company, medium intensity	114		3.6	
	PELST	Milk producer company, low intensity	9		0.3	
	PPLSI	Milk producer, medium intensity	1420		45.0	
	PPLST	Milk producer, low intensity	42		1.3	
Forestry	FBINA	Implanted forest	20	20	0.6	0.6
Urban	UCUNA	Poultry farming company	47	215	1.5	6.8
	UUMNA	Milk producer company, medium intensity	168		5.3	
Non Use	SUANA	Non use	387	477	12.3	15.1
	SUTNA	Stream	90		2.8	
Total			3158	3158	100.0	100.0

5.2.1. Land Use Units in 1992

In 1992, the agricultural production was the main activity, a total of 1608 ha (50.9 %) was dedicated to livestock use, and 838 ha (26.5 %) to agricultural use, representing both a total of 2446 ha (77.5 %). Figure 9 schematizes the proportions of the land use units mapped for 1992.

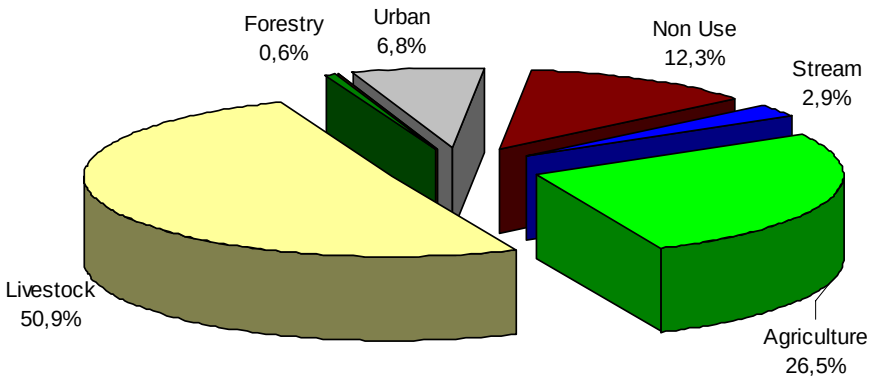


Figure 9. Land use proportion in 1992

A total of 477 ha (15.1 %) was considered as lands without use, due mainly to its high stony conditions. The urban area covered a total of 215 ha, that represents 6.8 % of the study area.

5.2.2. Dominant Farming System Zones (DFSZ) in 1992

In 1992, one can observe the predominance of *Milk producer with medium land use intensity* (PPLSI) that covered a total of 1420 ha (45.0 %). These farming systems were dedicated mainly to corn and alfalfa production for dairy cattle feeding. Another important farming system was the *Diversified flower grower with intensive land use* (ADFIN) that occupied 358 ha (11.3%). These farming systems mainly grew diverse crops (corn, potato and bean), both for the household consumption and for sale, and also they grow diverse flower species for sale. It is necessary to stand out the importance of flower production because it is the main economic income for several families.

The vegetable production was another important agricultural sector in Tiquipaya such is the case of the *Horticulturalist milk producer with intensive land use* (AHLIN) that covered a total of 278 ha (8.8 %). In this DFSZ, the farmers were devoted mainly to the growth of diverse short cycle vegetables (broccoli, sheath, cauliflower and cabbage), with at least five annual crops. This farming system is supplemented with the corn and alfalfa cultivation for dairy cattle feeding; this activity guarantees them a sure daily income with the sale of milk.

A total surface of 202 ha (6.4 %) belongs to companies or private people that dedicate their lands to agricultural production, among those the most important are the *Milk producer companies* (PELSI and PELST) that occupy 123 ha. Figure 10 schematizes the covered surface for each DFSZ mapped.

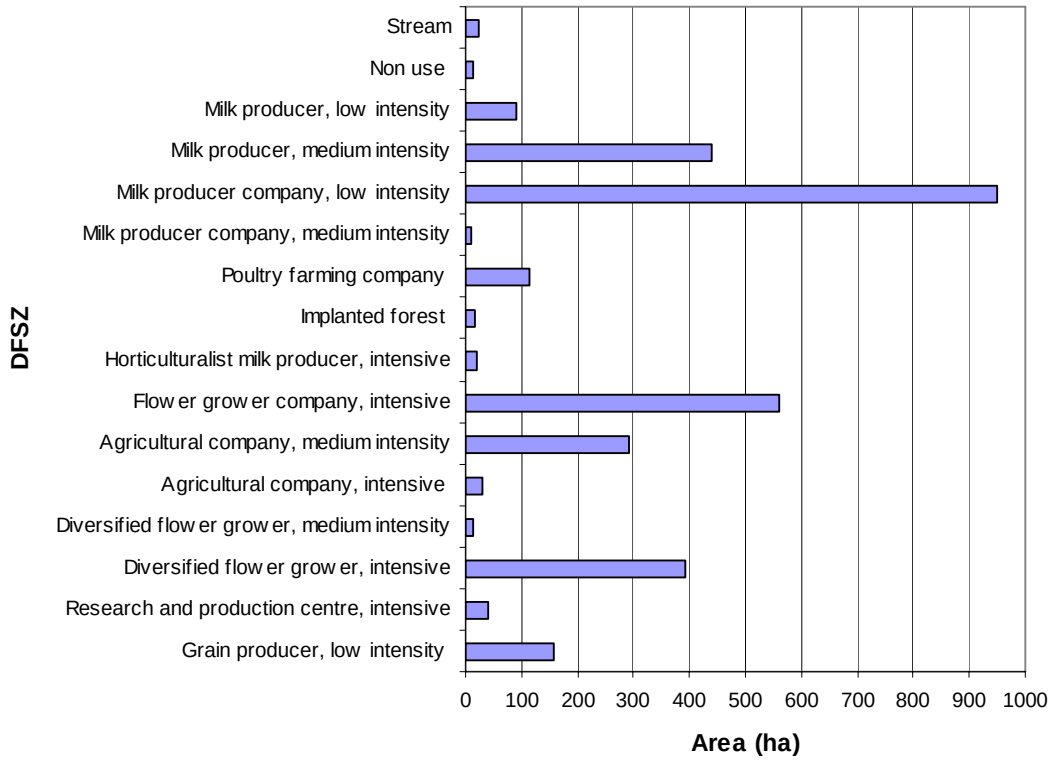


Figure 10. Dominant Farming System Zones in 1992

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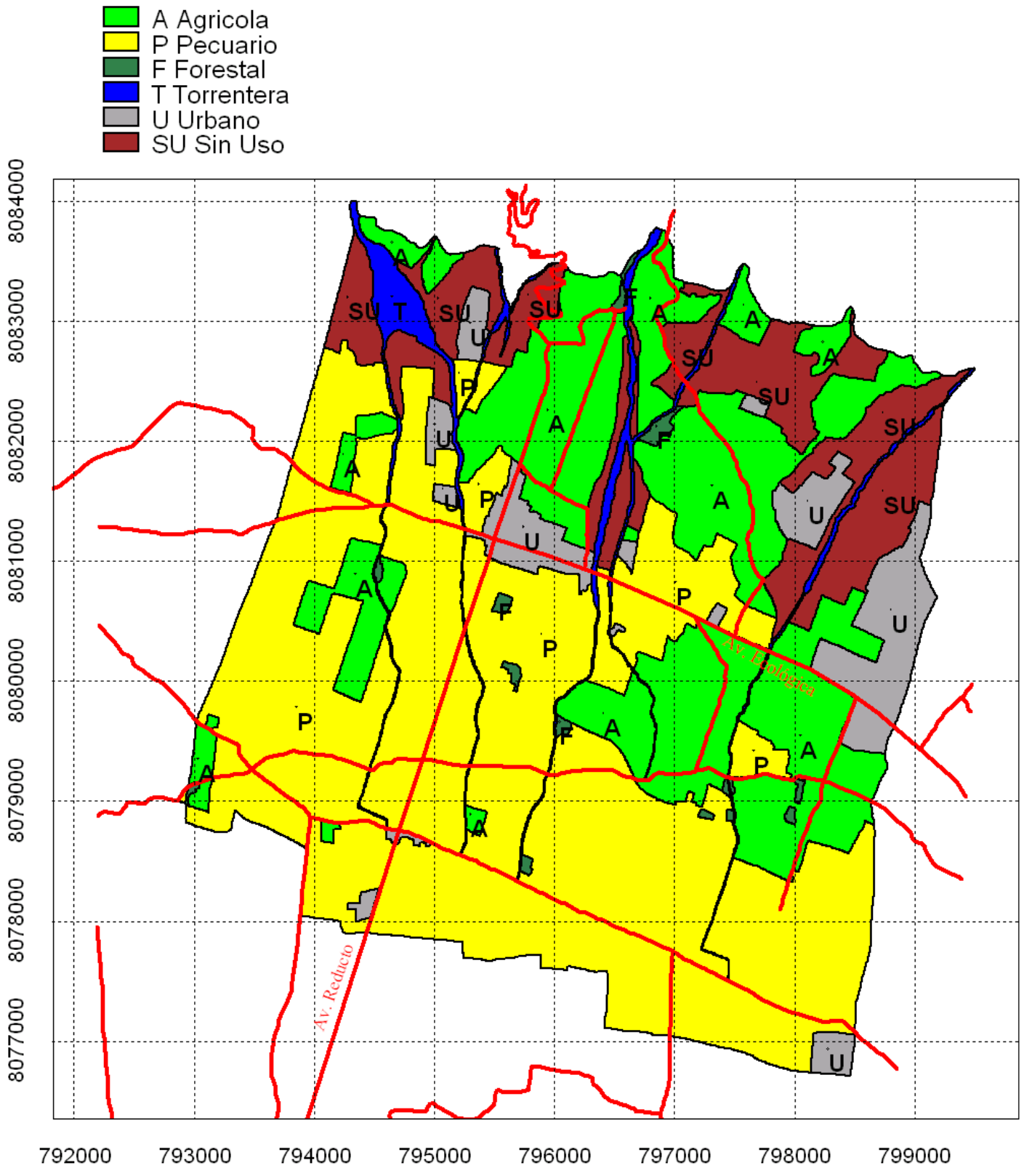
MAPA 3
USO DE TIERRA 1992
ZONA DE VALLE DEL MUNICIPIO DE TIQUIPAYA

Superficie: 3158 Ha Escala 1:50 000

Cochabamba, Octubre de 2003



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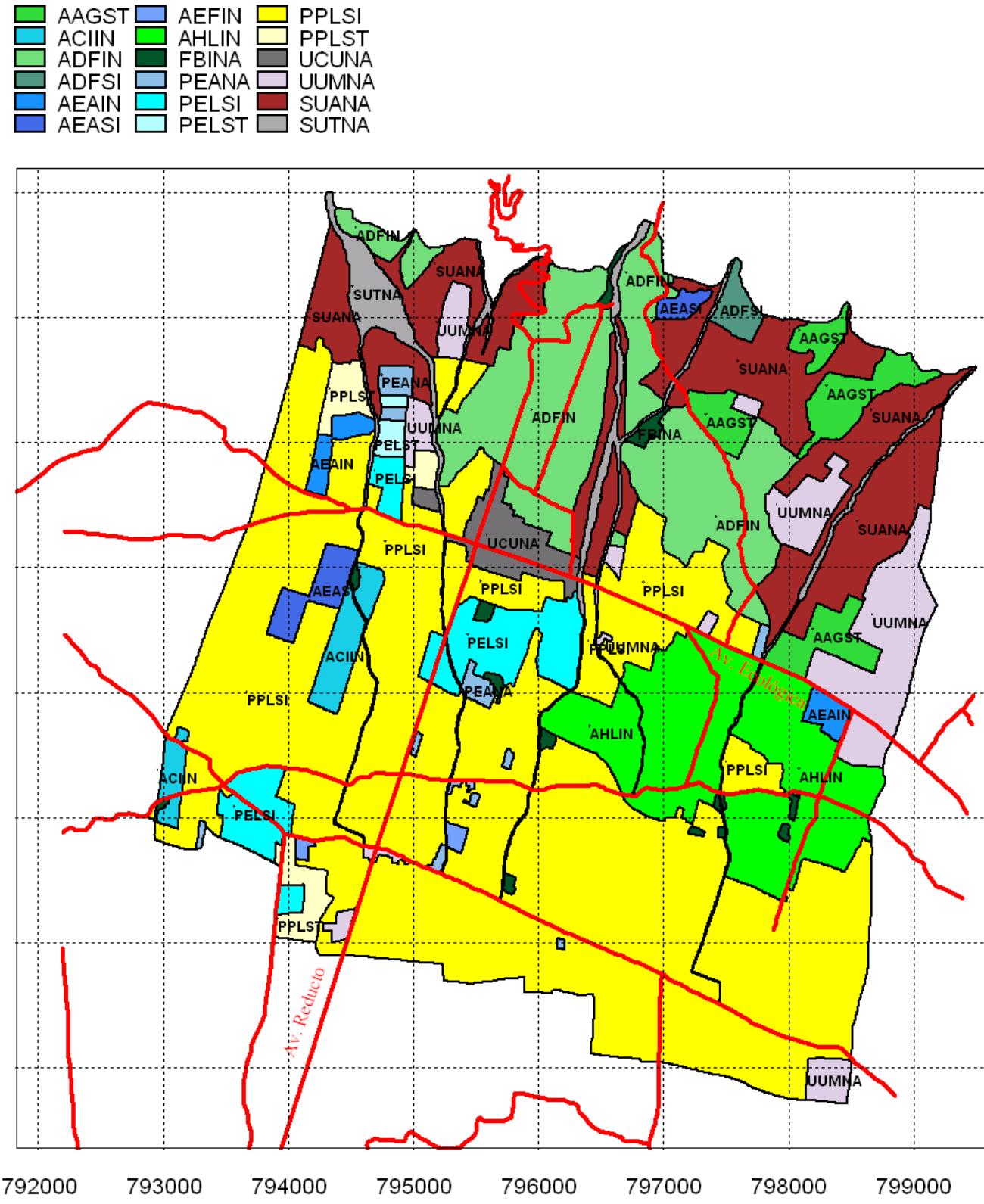
MAPA 4
SISTEMAS DE PRODUCCION DOMINANTES 1992
ZONA DE VALLE DEL MUNICIPIO DE TIQUIPAYA

Superficie: 3158 Ha — Escala 1:50 000

Cochabamba, Octubre de 2003



5.3 Land Use in 2003

In 2003, most of the lands in the valley area of Tiquipaya municipality are set aside to agricultural production, then to areas covered by urbanizations. Table 6 summarizes the mapping of the land use for 2003.

Table 6. Land use in 2003

Land use	Dominant Farming System Zones		Area (ha)		Area (%)	
Agriculture	AAGST	Grain producer, low intensity	48	591	1.5	18.7
	ACIIN	Research and production centre, intensive	41		1.3	
	ADFIN	Diversified flower grower, intensive	241		7.6	
	ADFSI	Diversified flower grower, medium intensity	14		0.4	
	AEAIN	Agricultural company, intensive	15		0.5	
	AEASI	Agricultural company, medium intensity	36		1.1	
	AEFIN	Flower grower company, intensive	16		0.5	
	AHLIN	Horticulturalist milk producer, intensive	122		3.9	
	AHLSI	Horticulturalist milk producer, medium intensity	58		1.8	
Agriculture-Urban	AUDFIN	Diversified flower grower, intensive - Urban	70	165	2.2	5.2
	AUDFSI	Diversified flower grower, medium intensity - Urban	16		0.5	
	AUHLIN	Horticulturalist milk producer, intensive - Urban	47		1.5	
	AUPLST	Milk producer, low intensity - Urban	32		1.0	
Livestock	PEANA	Poultry farming company	32	1306	1.0	41.4
	PELSI	Milk producer company, medium intensity	96		3.0	
	PELST	Milk producer company, low intensity	20		0.6	
	PPLST	Milk producer, low intensity	1158		36.7	
Forestry	FBINA	Implanted forest	18	33	0.6	1.0
	FBNNA	Native forest	15		0.5	
Urban-Agriculture	UAAGST	Urban - Grain producer, low intensity	18	148	0.6	4.7
	UADFIN	Urban - Diversified flower grower, intensive	16		0.5	
	UAPLST	Urban - Milk producer, low intensity	114		3.6	
Urban	UCUNA	Urban centre	47	564	1.5	17.9
	UUMNA	Marginal urbanization	517		16.4	
Non Use	SUANA	Non use	261	351	8.3	11.1
	SUTNA	Stream	90		2.8	
Total			3158	3158	100.0	100.0

5.3.1. Land use units in 2003

In 2003, most of the surface of the Tiquipaya valley is dedicated to agricultural production. A total surface of 1897 ha (60.1 %) is used for this activity. The livestock production is the main activity, with a total of 1306 ha (41.4 %), remaining a total surface of 591 ha (18.7 %) for crop production.

The urban area has a special importance since it covers 564 ha, being 17.9 % of the studied area. Also a total surface of 313 ha (9.9 %) is in process of transition from Agricultural to

Urban use with 148 ha (4.7%) with predominance of urban areas, and 165 ha (5.2%) with predominance of agricultural areas.

The land without use covers a total of 351 ha (11.1 %), representing mainly the streams. Figure 11 schematizes the proportions of the land use units for 2003.

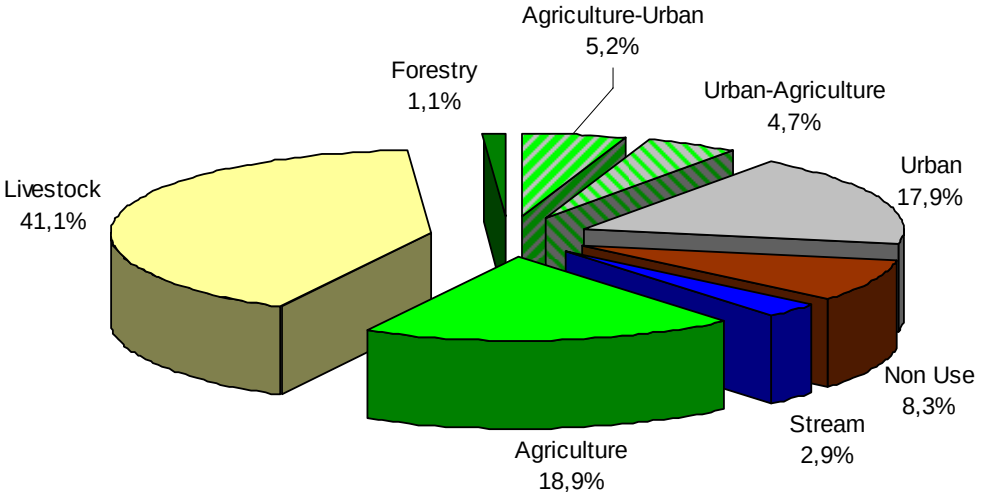


Figure 11. Land use unit proportion in 2003

5.3.2. Dominant Farming System Zones (DFSZ) in 2003

In 2003 year, one can observe the predominance of farming systems dedicated to milk production such is the case of the *Milk producer with low and use intensity* (PPLST) that covers a total surface of 1158 ha (36.7 %). These farming systems are dedicated mainly to corn and alfalfa production for dairy cattle feeding.

In the northern area, the *Diversified flower growers with intensive land use* (ADFIN) occupy a total surface of 241 ha (7.6 %). These farming systems are devoted mainly to the growth of diverse flower species for selling in the main markets of Cochabamba. In a complementary way, the farmers produce diverse crops (corn, potato and bean), dedicated mainly to household consumption.

The vegetable production is an important agricultural activity in Tiquipaya such is the case of the *Horticulturalist milk producer with intensive land use* (AHLIN) located in Kanarancho occupying a total of 122 ha (3.9 %). In this DFSZ, the farmers grow mainly diverse vegetables of short cycle (broccoli, sheath, cauliflower and cabbage). These farmers are also dedicated to milk production For that reason, they dedicate part of their lands to corn and alfalfa cultivation for dairy cattle feeding.

A total surface of 215 ha (6.8 %) belongs to companies or private people that dedicate their lands to agricultural production. The *Milk producer companies* (PELSI and PELST) are the

most important; they occupies 116 ha. Figure 12 schematizes the covered surface for each DFSZ in 2003.

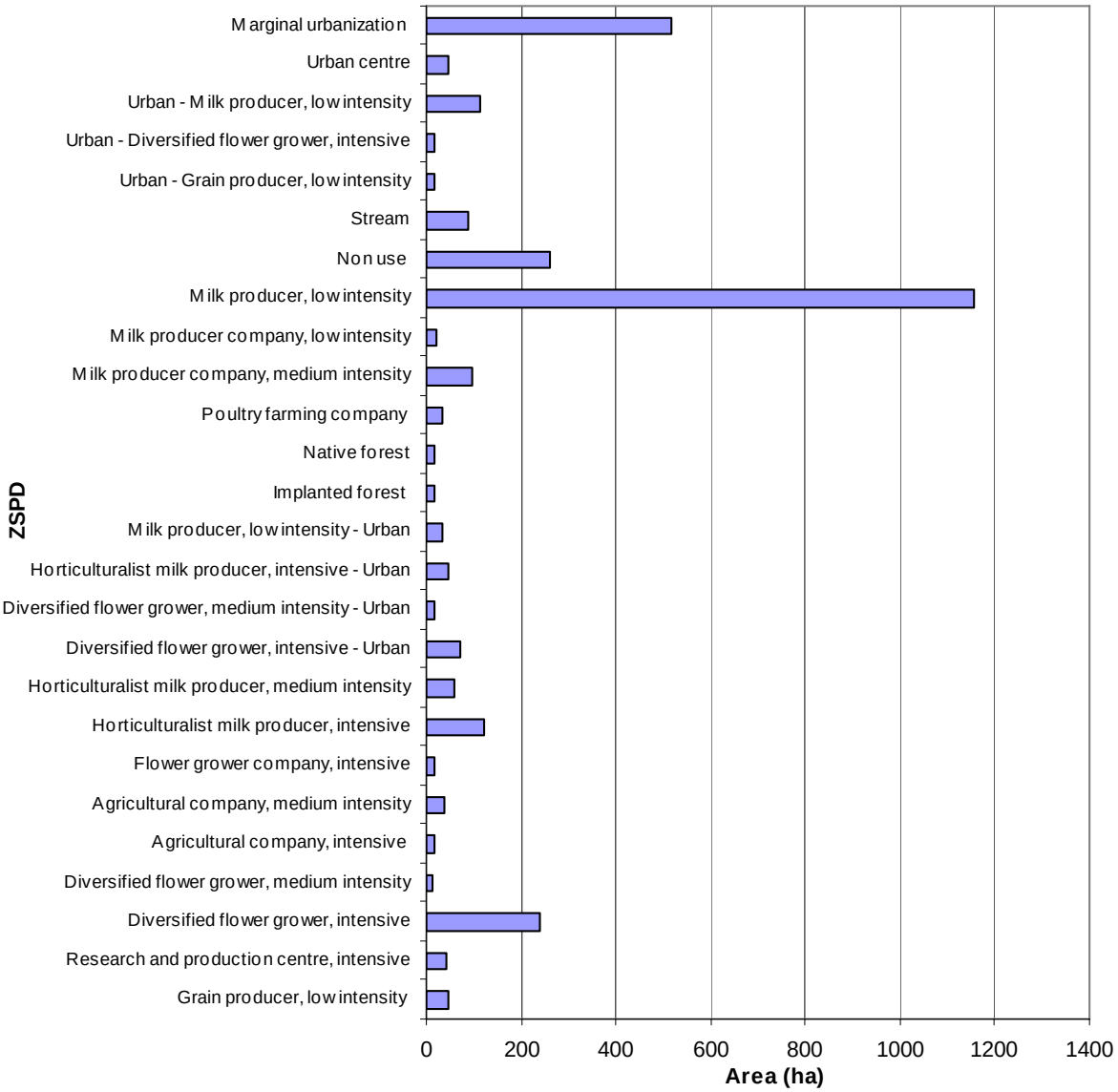


Figure 12. Dominant Farming System Zones in 2003

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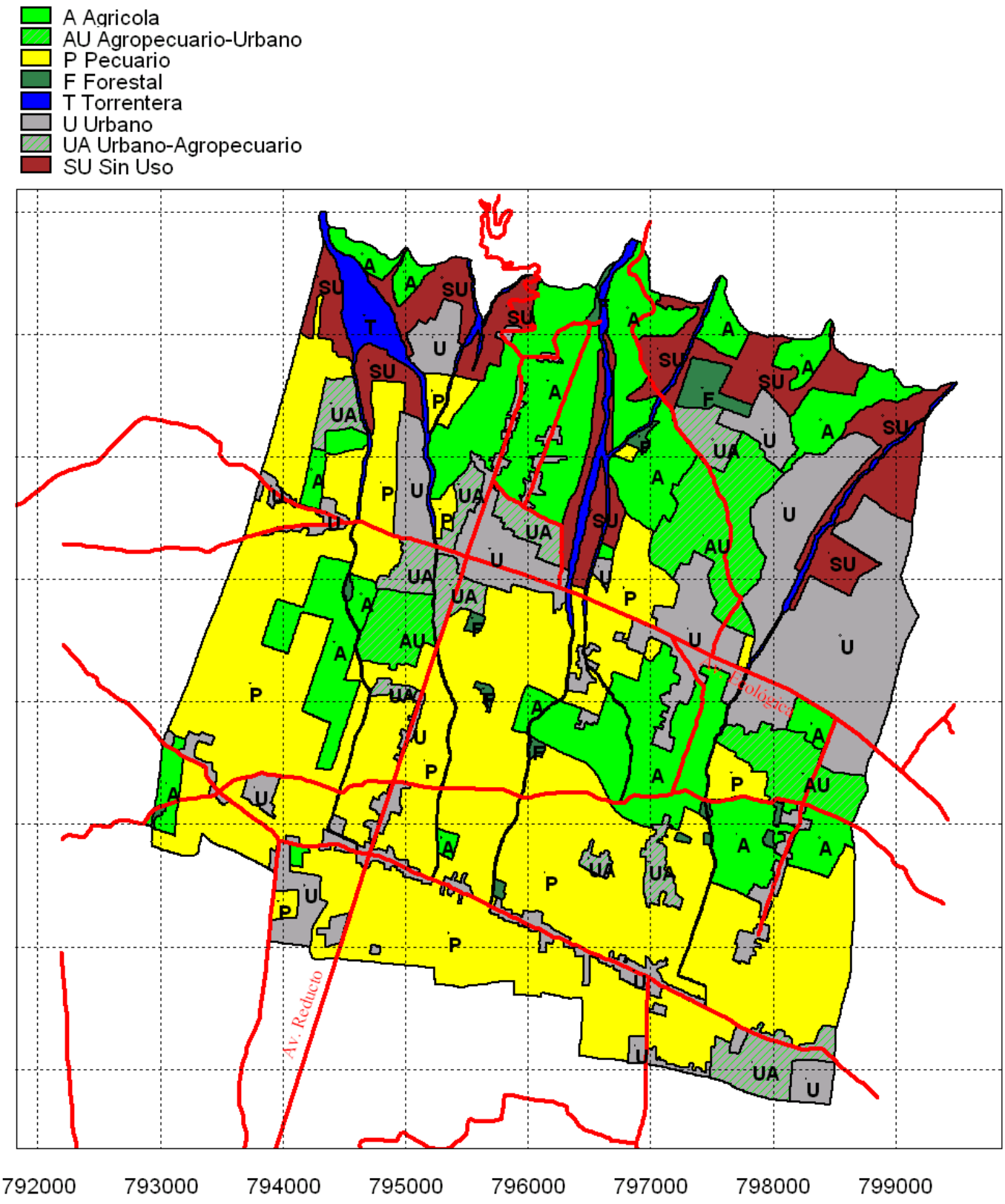
MAPA 5
USO DE TIERRA 2003
ZONA DE VALLE DEL MUNICIPIO DE TIQUIPAYA

Superficie: 3158 Ha — Escala 1:50 000

Cochabamba, Octubre de 2003



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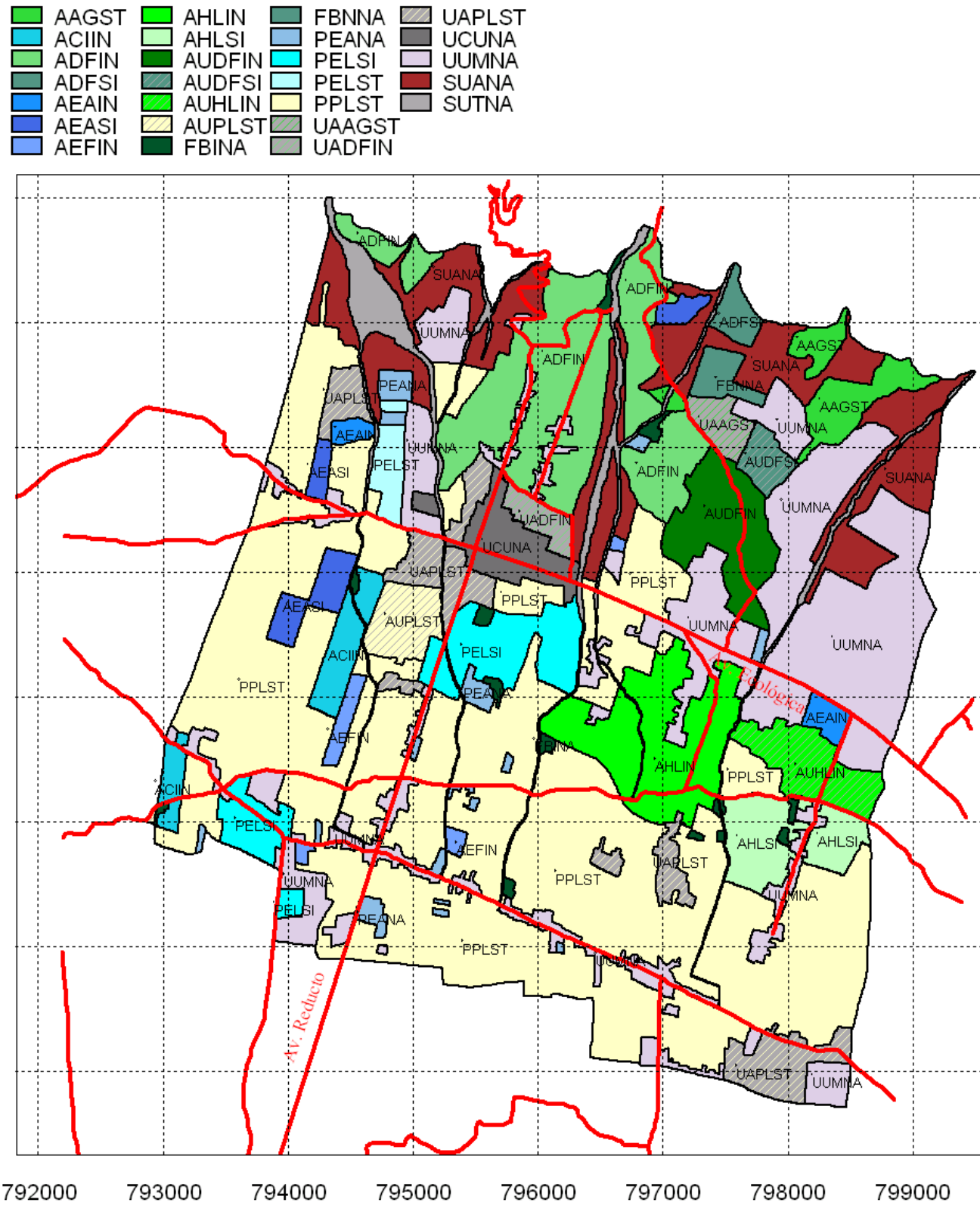
MAPA 6
SISTEMAS DE PRODUCCION DOMINANTES 2003
ZONA DE VALLE DEL MUNICIPIO DE TIQUIPAYA

Superficie: 3158 Ha Escala 1:50 000

Cochabamba, Octubre de 2003



6. LAND USE CHANGES

Among the years 1983 and 2003, the valley area of Tiquipaya municipality changed quickly; one can observe this situation on Table 7 and Figure 13, which synthesize the mapping results.

Table 7. Land use changes in the period 1983-1992-2003

Land use	1983		1992		2003	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Agriculture	1485	47.0	838	26.5	597	18.9
Livestock	1088	34.4	1608	50.9	1299	41.1
Forestry	19	0.6	20	0.6	34	1.1
Agriculture-Urban	0	0.0	0	0.0	165	5.2
Urban-Agriculture	0	0.0	0	0.0	147	4.7
Urban	36	1.1	215	6.8	565	17.9
Non Use	440	13.9	387	12.3	261	8.3
Stream	90	2.9	90	2.9	90	2.9
Total	**3158**	**100.0**	**3158**	**100.0**	**3158**	**100.0**

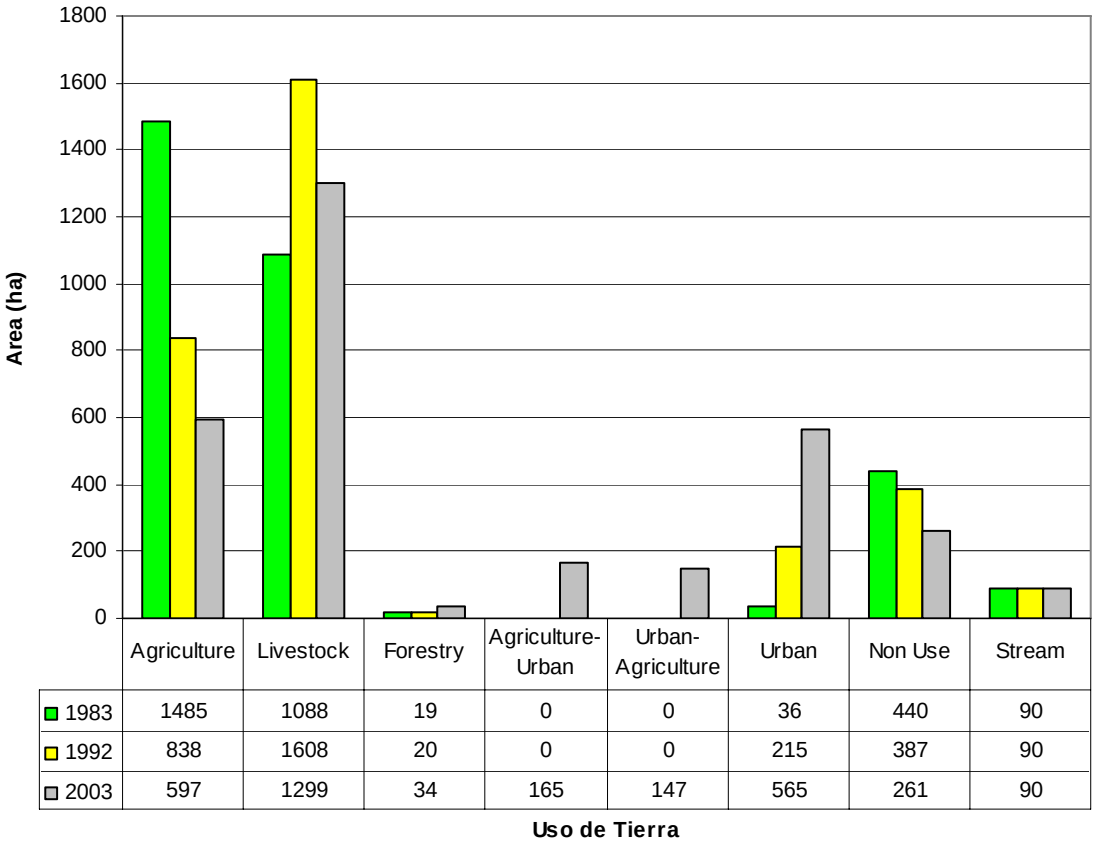
All the area dedicated to agricultural production (Agriculture use and Livestock use) has not suffered big changes considering the land use units, while in 1983 a total surface of 2573 ha (81.5 %) was dedicated to this activity; in 1992, it decreased down to 2446 ha (77.4 %), reaching 1896 ha (60.0 %) in the year 2003. Between 1983 and 2003, there was a reduction of 677 ha dedicated to agriculture production.

The Agriculture land use has been the most affected. While in 1983, 47.0 % of the study area was dedicated to the agricultural production; in 1992, it decreased down to 26.5 %, registering a total loss of 647 ha in 9 years. In the year 2003, the area dedicated to the agricultural use reached 597 ha (18.9 %), registering a surface loss of 241 ha since 1992.

In the period 1983 to 1992, the lands dedicated to livestock production have increased, of 1088 ha (34.5%) in 1983 to 1608 ha (50.9 %) in 1992, registering a growth of 520 ha. However, in the period 1992-2003, the livestock land use registered a decrease of 309 ha. Although at the moment it became the most important productive sector with 41.4 % of the total surface dedicated to this activity.

The areas without use have diminished considerably in this period. Between 1983 and 2003, the non used lands diminished dramatically, registering a decrease from 440 ha in 1983, to 387 ha in 1992, and 261 ha in 2003.

Contrary to what has been mentioned above, in the period of 1983 at 2003, the urban areas increased in the ration of 1574 %, registering along these 20 years an increase of 179 ha in the period 1983-1992, and 350 ha in 1992-2003 period.



	Agriculture	Livestock	Forestry	Agriculture-Urban	Urban-Agriculture	Urban	Non Use	Stream
1983	1485	1088	19	0	0	36	440	90
1992	838	1608	20	0	0	215	387	90
2003	597	1299	34	165	147	565	261	90

Figure 13. Land use changes in the period 1983-1992-2003

Next appears the description of the land use changes at Land Use Unit and Dominant Farming System Zones level for the periods 1983-1992 and 1992-2003.

6.1. Land use changes in the period 1983-1992

As it has already been said in the previous section, the Agriculture land use has suffered the biggest change in this period, registering a total lost of 60 % of the area dedicated to this land use. A total surface of 554 ha, that in 1983 was dedicated to the agricultural use, in 1992 was dedicated to livestock use. Likewise a total surface of 104 ha (7.0 % of the agricultural area in 1983) is dedicated to housing construction and urban infrastructure. On Table 8, the land use changes for the period 1983-1992 is shown in detail.

Table 8. Land use changes in the period 1983-1992

Land use 1983	Land use 1992	Area (ha)
Agriculture	Agriculture	827
	Livestock	554
	Urban	104
Livestock	Livestock	1043
	Agriculture	3
	Forestry	1
	Urban	41
Forestry	Forestry	19
Urban	Urban	36
Non Use	Agriculture	7
	Livestock	11
	Urban	34
	Non Use	387
Stream	Stream	91
Total		**3158**

In 1983, a total surface of 1088 ha was dedicated to the livestock production. In 1992, the 3.8 % (41 ha) of this area has changed to urban use. However, in general terms the surface dedicated to livestock use has been increased for 1992, a total area of 554 ha that in 1983 was dedicated to agriculture use, in 1992 it was specialized in the cultivation of corn, oat and alfalfa for feeding the increasing number of dairy cattle.

In the case of the lands that in 1983 were without use, for 1992 the 1.3 % (7 ha) of this surface was dedicated to the agriculture use, and 6.4 % (34 ha) changed to urban use.

Analyzing Table 9, one can observe that at a general level the farming systems have been changed towards the milk production (PPLSI, PPLST, AHLIN). These farmers have been specialized in the cultivation of corn, alfalfa and oat, and they left off aside crops like potato, bean and several vegetable species. Such is the case of the *Horticulturalists milk producers with medium land use intensity* (AHLSI): in 1983, they cultivated a total surface of 559 ha, and in 1992, the 98 % (548 ha) of this area was dedicated to forage production for dairy livestock, becoming *Milk producers with medium land use intensity* (PPLSI).

The farming systems with intensive land use maintain at an extent their characteristics. Such is the case of the *Diversified flower grower with intensive land use* (ADFIN). In 1983, they cultivated a total of 391 ha. In 1992, just the 5.1 % (20 ha) was changed to urban use, maintaining 91.0% of its area with the same farming system. Also, the *Horticulturalist milk producers with intensive land use* (AHLIN) that in 1983 were occupying a total of 292 ha, in 1992, the 95.2 % maintained their land use, and only 13 ha (4.5%) changed to urban use (UUMNA).

Table 9. Changes of DFSZ in the period 1983-1992

Dominant Farming System 1983	Dominant Farming System 1992	Area (ha)
AAGST	AAGST	91
	UUMNA	67
ADFIN	ADFIN	356
	ADFSI	14
	UCUNA	20
AHLIN	AHLIN	278
	UCUNA	2
	UUMNA	13
AHLSI	AEFIN	3
	PEANA	5
	PPLSI	548
	UUMNA	2
AEASI	AEAIN	7
	AEASI	22
AEAIN	AEAIN	16
ACIIN	ACIIN	41
FBINA	FBINA	19
PEANA	PEANA	17
PELSI	PELSI	114
PELST	PELST	9
PPLSI	ADFIN	1
	AEFIN	2
	PEANA	1
	PPLSI	872
	PPLST	31
	FBINA	1
	UCUNA	12
	UUMNA	29
SUANA	PPLST	11
	SUANA	387
	UUMNA	34
	AEASI	7
UCUNA	UCUNA	13
UUMNA	UUMNA	23
SUTNA	SUTNA	90
Total		**3158**

6.2. Land use changes in the period 1992-2003

Along these 11 years period, the agricultural use surface suffered new reductions, a total surface of 94 ha that in 1992 was dedicated to agricultural use, for the year 2003 was dedicated to urban use. This means that in this period of 11 years 11.2 % of the total agricultural area in 1992, for the year 2003 it's dedicated to house construction and urban

infrastructure. Likewise a total of 166 ha that represents 19.8 % of agricultural area in 1992; there is in transition process from agricultural to urban use. The Table 10 details the land use changes in this period.

Table 10. Land use changes in the period 1992-2003

Land use 1992	Land use 2003	Area (ha)
Agriculture	Agriculture	577
	Agriculture-Urban	133
	Urban-Agriculture	33
	Urban	94
Livestock	Agriculture	16
	Livestock	1287
	Agriculture-Urban	32
	Urban-Agriculture	114
	Urban	160
Forestry	Livestock	2
	Forestry	18
Urban	Urban	215
Non use	Agriculture	3
	Livestock	11
	Forestry	16
	Urban	96
	Non use	261
Stream	Stream	90
Total		**3158**

Moreover, the livestock production land use decreased from 1608 ha in 1992 to 1306 ha in 2003. A total surface of 160 ha dedicated to livestock production in 1992, changed to urban use in 2003. Besides, a total of 146 ha are in a transition process from livestock use to urban use.

As one can see on Table 11, along these 11 years (1992-2003) a total of 350 ha became urban areas, from which 26.9 % (94 ha) corresponded to agricultural lands; 45.7 % (160 ha) to livestock production lands; and 27.4 % (97 ha) to lands without use. This evidences the growing loss of agricultural lands to urban land use.

Considering the DFSZ (Table 11), one can see that at a general level the farming systems are in process of change toward the milk production (PPLST). Farmers are specializing their lands mainly in the corn and alfalfa cultivation, and they are leaving off aside crops like potato, bean and several vegetables.

Also, in this period the land use intensity diminished, being noticed the domain of farming systems with low intensity land use. Nowadays, the 64.6 % (1226 ha) of the total agricultural production land use (Agriculture use and Livestock use) belong to farming systems with low intensity land use (AAGST, PPLST and PELST).

Table 11. Changes of DFSZ in the period 1992-2003

Dominant Farming Systems 1992	Dominant Farming Systems 2003	Area (ha)
AAGST	AAGST	45
	UUMNA	28
	UAAGST	18
ACIIN	ACIIN	41
ADFIN	ADFIN	241
	AEFIN	1
	UUMNA	14
	UADFIN	16
	AUDFSI	16
	AUDFIN	70
ADFSI	ADFSI	14
AEAIN	AEAIN	16
	AEASI	7
AEASI	AEASI	29
AEFIN	AEFIN	5
AHLIN	AHLIN	122
	AHLSI	58
	UUMNA	51
	AUHLIN	47
FBINA	FBINA	18
	PEANA	2
PEANA	PEANA	23
PELSI	PELSI	96
	PELST	11
	UUMNA	7
PELST	PELST	9
PPLSI	AEFIN	9
	PEANA	7
	PPLST	1147
	UUMNA	126
	UAPLST	99
	AUPLST	32
PPLST	UUMNA	27
	UAPLST	15
SUANA	AAGST	3
	PPLST	11
	SUANA	261
	UUMNA	96
	FBNNA	15
UCUNA	UCUNA	47
UUMNA	UUMNA	168
SUTNA	SUTNA	90
Total		**3158**

An example of what has been mentioned makes up the case of the *Milk producers with semi-intensive land use* (PPLSI). These farmers in 1992 occupied a total surface of 1420 ha. In the year 2003, they changed their farming system to medium land use intensity (PPLST). The PPLSI farmers practically disappeared for the year 2003.

What has been mentioned implies that if in 1992 the farmers had up to three crops per year and their water availability let them cultivate small plots of potato and bean, at present they only use the irrigation water to maintain their alfalfa plots and to carry out the pre-sowing irrigation, which fact lets them to advance the sowing period and to assure the production of, at least, one crop a year, or up to two annual crops in a rainy year.

Another aspect to be stood out in this period is that the DFSZ with intensive land use, maintained, at great extent, its farming system such is the case of the *Diversified flower growers with intensive land use* (ADFIN). These farmers that in 1992 used a total surface of 358 ha at present the 67.3 % (241 ha) of this area stays with this land use.

6.3. Urban area growth in the period 1983-2003

The urban land use is the one with the most growth in the study period (1983-2003). While in 1983 a total area of 36 ha (1.1%) was covered by urban use, in 1992 the urban area reached 215 ha, that meant an increment of 597.2 % in relation to the urban area in 1983. The mapping of the land use registers at present that a total of 565 ha is dedicated to urban uses, registering an increment of 350 ha since 1992; that means an increment of 262.8 % in relation to the urban area in 1992. Table 12 shows the urban growth data in Tiquipaya, which is illustrated on Map 7.

Table 12. Urban area growth in the period 1983- 2003.

Year	Urban area		Urban area growing		Urban area growing rate
	(ha)	(%)	(ha)	(%)	(ha/year)
1983	36.0	1.1			
1992	215.0	6.8	179.0	597.2	19.9
2003	565.0	17.9	350.0	262.8	31.8

Between 1983 and 1992, the study area marks an urban area growth of 19.9 ha/year. In 1992-2003 period, the urban area grows to a ratio of 31.8 ha/year; which implies an increase of 60 % in the growth rate. This means that the urban area has almost grown 0.6 times in 1992-2003 period than in the 1983-1992 period (Figure 14).

It is worth clarifying that most of this urban growth corresponds to the growth of Cochabamba city. For that reason, this new urban areas are located mainly in the east zone of Tiquipaya. The former implies that the new urbanizations are made up by outlying urbanizations of

Cochabamba city with which the residents of the area have bigger relationship, since it is there where they work and they carry out most of their activities.

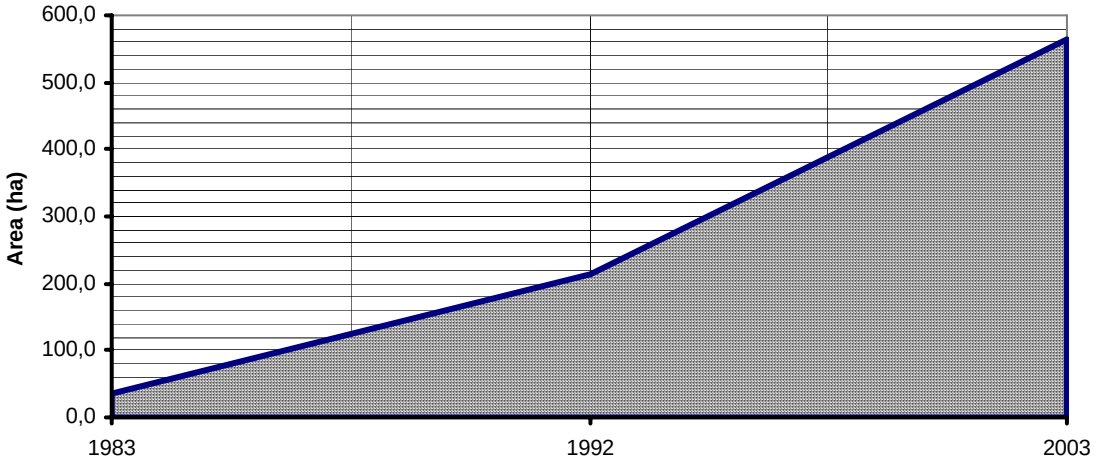


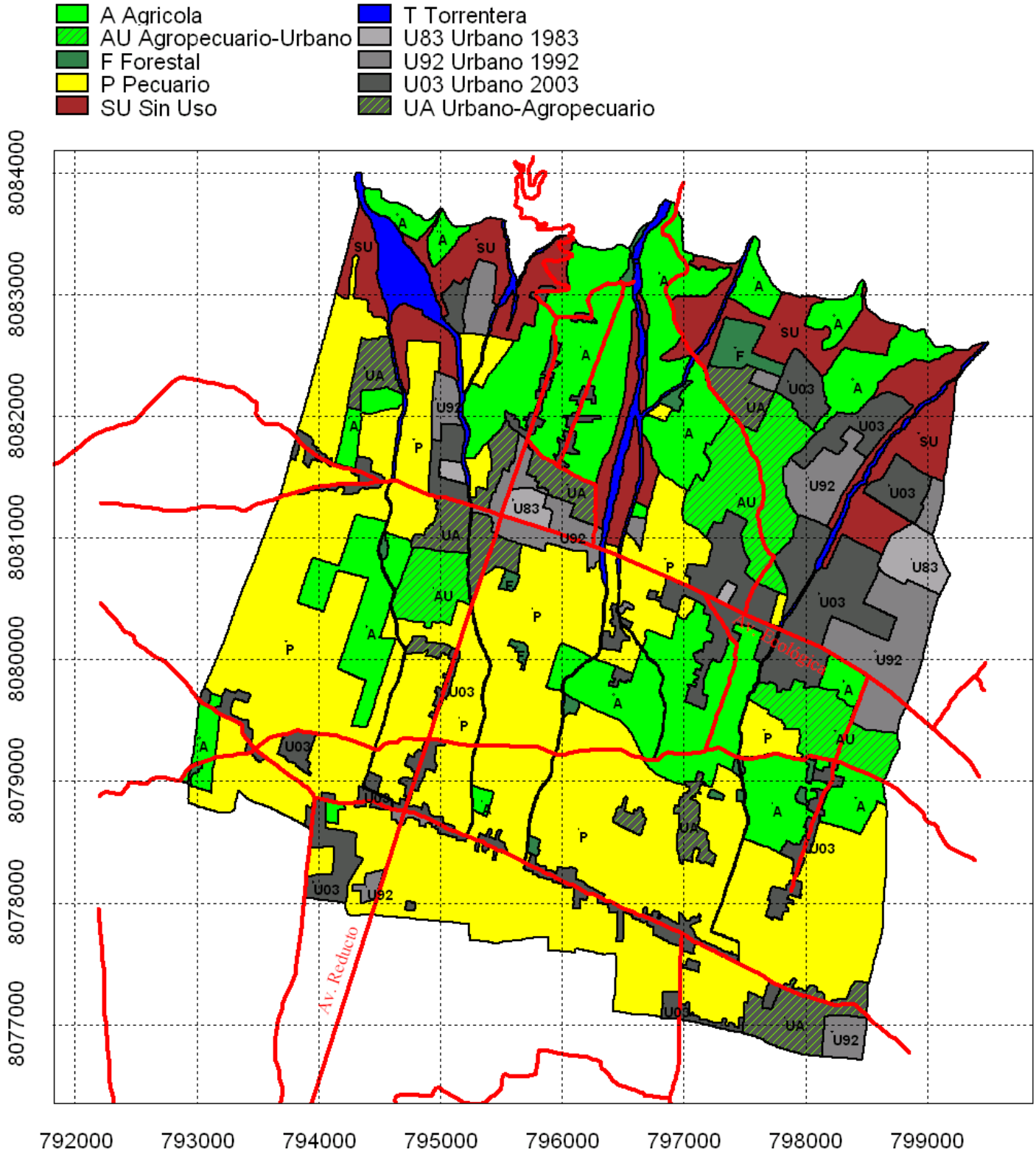
Table 14. Urban area growth rate in the period 1983-1992-2003

UNIVERSIDAD MAYOR DE SAN SIMON
CENTRO ANDINO PARA LA GESTION Y USO DEL AGUA
PROYECTO NEGOWAT

MAPA 7
CRECIMIENTO URBANO 1983-1992-2003
ZONA DE VALLE DEL MUNICIPIO DE TIQUIPAYA

Superficie: 3158 Ha Escala 1:50 000

Cochabamba, Octubre de 2003



7. CONCLUSIONS AND RECOMMENDATIONS

The results of the realized mapping show the development of a quick process of land use change in the valley area of Tiquipaya municipality:

- In 1983, it made up an absolutely agricultural zone with 47 % (1485 ha) of its area devoted to agricultural use, with the production of diverse crops like: potato, bean, vegetables and flowers. The livestock use area covered 34.5 % (1088 have) of the total study area.

- For 1992, the situation dramatically changed ending up with a prevailing cultivation of corn, oat and alfalfa for dairy cow feeding. This land use covered 50.9 % (1608 ha) of the total surface. The area devoted to crop production decreased to 26.5 % (838 ha).

- In 2003, the agriculture production continued being predominant, although it decreased its area, the livestock land use covered 41.4 % (1306 ha), and the agriculture land use covered 18.9 % (591 ha).

At farming system level, a process of reduction of the land use intensity has been developed. For the year 2003, the farming systems dedicated to the milking production with medium land use intensity were dominant. For that reason, these farmers cultivate mainly corn, alfalfa and oat, leaving off aside other crops like: potato, bean and several vegetables.

Regarding the urban area, between 1983 and 2003 a quickly and lawless process of urban area growth was developed. This growth was developed mainly at the expense of agricultural lands (agriculture use and livestock use). Among the years 1983 and 2003, the urban area was increased from 36 ha (1.1 %) in 1983, to 215 ha (6.8 %) in 1992, and 564 ha (17.9 %) for the year 2003, marking an increase of 529 ha in this 20 year period.

The land use change process has a tendency to settle down farming systems with intensive land use and medium land use intensity with more force; those are characterized by less water requirement and less manpower. Along the study, several hypotheses have been formulated around this change process, however this aspect is not considered in the present study. For that reason, it is recommended to outline a new study on the basis of the reached results, with the objective to analyze in deep this land use change process and to identify the most important factors that address this process.

BIBLIOGRAPHY

Duhamel, C. 1998. First approximation of a reference land use classification. Final Report. FAO, Land and Water Development Division. Land Use Program.

INE; MDSP; COSUDE; CID. 2000. Bolivia Un Mundo de Potencialidades, Atlas Estadístico de Municipios. Páginas 202, 204.

Instituto Nacional de Estadísticas de Bolivia. 2000. Datos de población por municipio. Disponible en *www.ine.gov.bo* (20 de noviembre de 2005).

FAO-UNEP. 2000. El futuro de Nuestra Tierra: Enfrentando el desafío. FAO-UNEP. Roma, 2000.

Saenz, M. 1997. Caracterización de la gestión de riego y producción familiar en la zona norte y central de Tiquipaya, Tesis de grado para optar el grado de Ingeniero Agrónomo. UMSS, FCAP. Cochabamba, Bolivia. Páginas 11 – 13.

SERINCO SRL. 1999. Plan de Desarrollo Municipal 1999 – 2003 del municipio de Tiquipaya. Cochabamba, Bolivia. Páginas 13 – 96.

Young, A. 1994. Towards and international classification of land use. Consultancy report to UNEP-FAO.