

# Assessing Landscape Change in a Mining Area of the Peruvian Andes

A Case Study in The Yanacocha Mine, Cajamarca



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## ACRONYMS

AP	Aerial Photo
API	Aerial Photo Interpretation
GIS	Geographic Information system
GPS	Geographic Position System
LULC	Land use- Land cover
masl	meters above the sea level
MYSA	Mining Company Yanacocha SA
NGO	Non –governmental Organisation
RS	Remote Sensing
SA	<i>Sociedad Anónima</i> in Spanish, generally designates corporations
TIN	Triangulated irregular networks

## ABSTRACT

This study examines physical and perceived landscape change in a mining area in northern Peru. Mining conflicts between companies and local people have intensified; this highlights the necessity of a better understanding of environmental and social consequences of mining activities. Landscape studies could be relevant to understand such problematic. I aim to assess the landscape change in a mining area by (1) mapping the physical landscape change and (2) surveying the local landscape people's perception of the physical landscape change. I approach the material dimension through spatial-regional interpretation of diachronic aerial-photos to produce Land cover-Land use maps and to allow further temporal comparison towards change detection in a GIS environment. The mental dimension was surveyed through the analysis of semi-structured interviews of the people who were living in the area of the mine and who lives now on its surroundings. The material landscape analysis shows a change rate of 75% in seven years (1993-2000) in the whole study area; and of 52% in areas outside the mining facilities. This is mainly from the conversion of seminatural grassland into mining and sparse grassland. These results correlated positively with local people's perception of environmental transformations, as the dramatic reduction of basic livelihood resources such as grassland and water. Most informants report loss of practices, customs and identity. The study provides empirical and theoretical support to approaches combining GIS mapping and perception surveys in the study of landscape change.

## Preface

*This work reflects my strong interest, the mining activities and the possibilities to carry out this activity in a sustainable approach. Through my research I found one of the most interesting theories I have ever studied, landscape. I feel privileged to have been able to work in such topics. Now I would like to give thanks for help and support to:*

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# 1 INTRODUCTION

Mining is considered one of the most profitable and least environmentally friendly activities (Warhurst 1998, Bell et al. 2001, Miranda et al. 2003, Hester and Harrison 2004). Mountainous countries are rich in mineral deposits and, in large part, their economies are sustained by the exploitation of mineral resources (McMahon and Remy 2001, Miranda et al. 2003). Historically, conventional financial policies of companies, which focus on maximizing profit, have not been concerned with the environmental impacts of the mining process and hence harmed the surrounding milieu and the local people (Miranda et al. 2003, Kocagil and Eduardo 1996). Nowadays, the claim that mining is hazardous and dangerous for the environment and the local people is driving wide opinion currents from different sectors, in national and international levels, against the mining companies and their management methods (Warhurst 1998, McMahon and Remy 2001, Miranda et al. 2003, Hester and Harrison 2004). In spite of that, companies argue that they are investing enough effort, financial sources and new technology in order to avoid all possible environmental-social impacts (SNMPE 2004, Yanacocha 2004).

A better understanding of the environmental and social consequences of the mining activities is a necessity in this context, and *'landscape'* is a concept that comprises several relevant environmental and social variables. Therefore, with this thesis I will attempt to assess the landscape in an area under mining influence in Peru, focusing on the relations between the landscape changes and the development of the mining activities. In this introductory chapter, the background and research problem are introduced, followed by specifications of the objectives and research questions, and the presentation of the coming chapters.

## 1.1 Background

Mining is the process of extracting metallic or non-metallic mineral deposits from the Earth (Queens University 2005). This process consists in two basic phases and it is performed by two operation systems. The phases are extraction and processing; and in wider approaches these can include the previous steps of exploration and the further steps of closure. The two operation systems are surface or open-pit, and sub-surface or underground mining (Buchanan and Brenkley 1994, Toomik and Liblik 1998). Each mining phase in each operation system has the potential to cause negative consequences in the environment; furthermore, mining can generate large impacts, long after the closure of its operations (Toomik and Liblik 1998, Klukanova and Rapant 1999, Bell et al. 2001).

Mining operations imply the rearrangement of minerals within the Earth, and the use of dangerous and toxic chemical elements (Buchanan and Brenkley 1994, Toomik and Liblik 1998, Klukanova and Rapant 1999); both processes are able to provoke large-scale contamination. Moreover, the massive reallocation of materials results in considerable morphological changes (Cairns and Atkinson 1994, Toomik and Liblik 1998). The contamination of water, soil and air and the alteration of the geomorphology cause the degradation of soil, vegetation, wildlife and human conditions (Pentreath 1984, Klukanova and Rapant 1999, Bell et al. 2001), and produce drastic transformations of the landscape (Toomik and Liblik 1998).

The process of landscape change starts at the very beginning of the mining operation, with the construction of access roads and townships that could initiate unplanned human inhabitation and squatting. The construction of access roads has a negative influence on vegetation, wildlife and forest in the area (Buchanan and Brenkley 1994). Later, during the mining extraction and processing phases, surrounding areas are often dumped with rock waste, tailings and slime dams, creating zones of residues (Toomik and Liblik 1998). The deposits of coarse waste material are usually placed in heaps on the surface while liquid residues are placed in artificial lagoons for sewage treatment, or are drained off directly to the rivers and natural lagoons. These deposits not only sterilise land by covering valuable soil, but also often contain dangerous contaminant compounds (Pentreath 1994, Klukanova and Rapant 1999, Bell et al. 2001).

The amount of solid residues removed and deposited by mining operations creates new surface features of artificial origin such as waste heaps, ash plateaus, and depressions of various sizes formed after the extraction of bedrock (Toomik and Liblik 1998, Klukanova and Rapant 1999). The magnitude of this physical transfiguration of the surface results in the replacement of the approximate original contour (Buchanan and Brenkley 1994). The large changes in the geomorphology increase the possibilities for hazardous events such as landslides and inundations (Cairns and Atkinson 1994, Klukanova and Rapant 1999). In brief, the combination of physical and chemical transformations driven by mining operations could result in an unproductive, sterile and hazardous landscape.

## **1.2 Research Problem and Justification**

Mining is one of the most traditional and important economic activities in Peru. Historically, before Spanish rule, during Inca and Pre-Inca times, it was mainly dedicated to the ornamentation of the elite. During the Colonial period, due to a “gold-silver centred” policy, a period of great development in the exploration and exploitation of precious metals started. Later, in the Republic era, the exploitation of other minerals began, due to the increasing demand from Europe and North America. Nowadays, since 1990, the entrance of international companies has driven a boom of large scale mining activities (Glave and Kuramoto 2000, Tolmos 2000, Ministerio de Energía y Minas 2002) and Peru has become one of the world’s top ten producers of gold, silver, copper, zinc and lead (Ministerio de Energía y Minas 2002, SNMPE 2004).

Economically, mining represents about half of the country's export revenue, and one of the main sources of the governmental budget (Tolmos 2000, Ministerio de Energía y Minas 2002, SNMPE 2004). Nevertheless, this amount only stands for a small percentage of the national GDP (Gross Domestic Product) because of the weak connection of mining with other economic sectors, and its minimal influence in the labour market (Glave and Kuramoto 2000, Francke and Mendoza 2001). The necessities of the large mines are very much specialised and hence, they are supplied by high-tech companies from the capital of Lima and abroad (Glave and Kuramoto 2000); besides that, the use of high technology reduced the necessity of man

power, increasing the necessity of specialised knowledge. Evaluations of the influence of mining on the productive chain and on employment generation find that it only represents 4 to 5 % of the GDP and between 2 and 3% of the employment sector (Francke and Mendoza 2001).

Environmentally, mineral exploitation has caused great impacts in many areas of Peru, especially in the Andean area where most of the mining centres are located. The main impacts are related to pollution of the water, soil and air (Bech et al. 1997), and also, depending on the size of the mining centres and operation systems (open-pit or underground), to the transformation of productive “crop-grass” landscapes generated by agro-pastoralist activities in unproductive “barren ground” mining and post-mining landscapes (Glave and Kuramoto 2000, Pascó-Font et al. 2001).

The small capacity to produce employment, the scarce revenues that reach the local population and the awareness of the environmental damage and its negative consequences for the farmers and pastoralists is effectuating a negative vision and response to the mining activities by growing sectors of the society, mainly the local population (Glave and Kuramoto 2000, Pascó-Font et al. 2001, Bury 2004). These responses converted into protest actions of different kinds have been surfacing throughout the whole country. In some cases they contributed to the paralysis of the mining activities such as in Tambo Grande-Piura (north in Peru), where one large gold-mining operation was stopped by the opposition of the local organizations (Haarstad 2005). Also a gold exploration-operation in areas closer to the city of Cajamarca, in Cerro Quilish, was stopped after long-lasting protests of local communities. Currently, the antagonism toward mining continues in many areas of Peru, alongside buoyant mining activity and the several recent projects to exploit the abundant reserves of economically valuable metals.

These socially negative responses demand improvements in the mining sector, towards a better management that does not damage basic resources for livelihood, and that is accompanied by improvements in the allocation of revenues (Francke and Mendoza 2001, Pascó-Font et al. 2001); both are crucial for the future of this important Peruvian economic activity. A different management implies to improve the study, monitoring and treatment of the environmental and social consequences of mining activities. In this sense, studies of the different impacts of mining activity are very important to find out clear diagnostics and

further solutions. One of the studies that could collaborate with such an endeavour is the study of the *landscape* changes under the mining activities.

*Landscape* is a broad and complex concept. There are several definitions of different orientation that will be explained in the theory chapter, but in this thesis *Landscape* is understood as a study field which includes a material dimension, the “*result of interactions between a certain society, its cultural preferences, and the given physio-geographical conditions*” (Sporrong 1993, Lundberg and Handegaard 1996 in Lundberg 2002: 247) and a mental dimension based in perception and interpretation of such physical reality (Antrop 2000). This interpretation represents the value that individuals and societies give to their environment. As Meining (1979: 29) argued, landscape can “*tell us much about the values we hold and at the same time affect the quality of the lives we lead...*” In brief, the core of my objective is to attempt to understand how mining changes the landscape, using *Landscape* as an integrative concept that includes spatial materiality and the interpretation of it.

### 1.3 Objectives and Research questions

The overall objective of this study is to assess the landscape change in an area under influence of mining activities. The specific objectives and research questions are provided in the following table:

**Table 1-1 Specific Objectives and Research Questions**

Objective 1:	To assess the physical landscape change in a mining area and surroundings.
Research Question:	<i>What are the physical landscape changes?</i>
Objective 2:	To describe the local people’s perceptions of the landscape change.
Research Question:	<i>How is perceived the landscape change by the local people?</i>

## **1.4 The Structure of the thesis**

This thesis has seven chapters. The first chapter was the introduction. Chapter two is a description of the study area. Chapter three explains the theoretical foundation of this study, by reviewing and commenting on the literature on the landscape concept and the key methods that approach this dimension. Chapter four is a narration of how the research was conducted. It specifies the case study approach adopted for this study and how the applied methodology influences the analysis of the cases. Chapter five presents the result of the two research questions. Chapter six presents an analysis of the results discussing the quality of the sources and the suitability of the applied methods in relation with the research problem. In the last chapter the lessons learned from the analyses of the case studies are presented as conclusions, and recommendations for the improvement of landscape and mining studies and further research are provided.

## 2 STUDY AREA

In this chapter, I intend to describe the general characteristics of the setting of my study. In order to describe the main characteristics of the area, I will define the main aspects of the general context in the first subchapter, 2.1. This subsection is important in order to be familiar with the general conditions that will be useful to understand the particular characteristics of the study area. Then I will depict the location of my study area and describe the natural and social attributes of the area. Before I describe them, I have to emphasise that these attributes have been undergoing an active process of transformation since the starting of the mining activities, whose analysis is contained the coming sections<sup>1</sup>; therefore here only a brief description of the general natural and human characteristics of the research setting will be presented.

### 2.1 The Peruvian Andes

My research is addressed to the Andes as the regional context of this thesis; the Andes are a very important and decisive factor in the environment and the landscape of the western South-American continent. They are also the general field of research and my specific area is extended to some part of this territory, the area of the Yanacocha Mine Corporation (MYSA) in Cajamarca, Northern Peru.

The Andes are the longest and one of the most inhabited mountain chains in the world, extending through all the west of South-America along seven countries and more than 7000 kilometres and reaching elevations close to the 7000 masl (meters above the sea level) (Pulgar-Vidal 1996). On this range of altitudes the frequent cold climate of the mountains is compensated by the latitudinal tropical position generating milder conditions that favour the human presence in the region (Lumbreras 1974). Evidence shows human presence and management of the Andes territory that started very early (Lumbreras 1974, Preston *Unknown*

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<sup>1</sup> It will be analysed especially in chapter 5: Results.

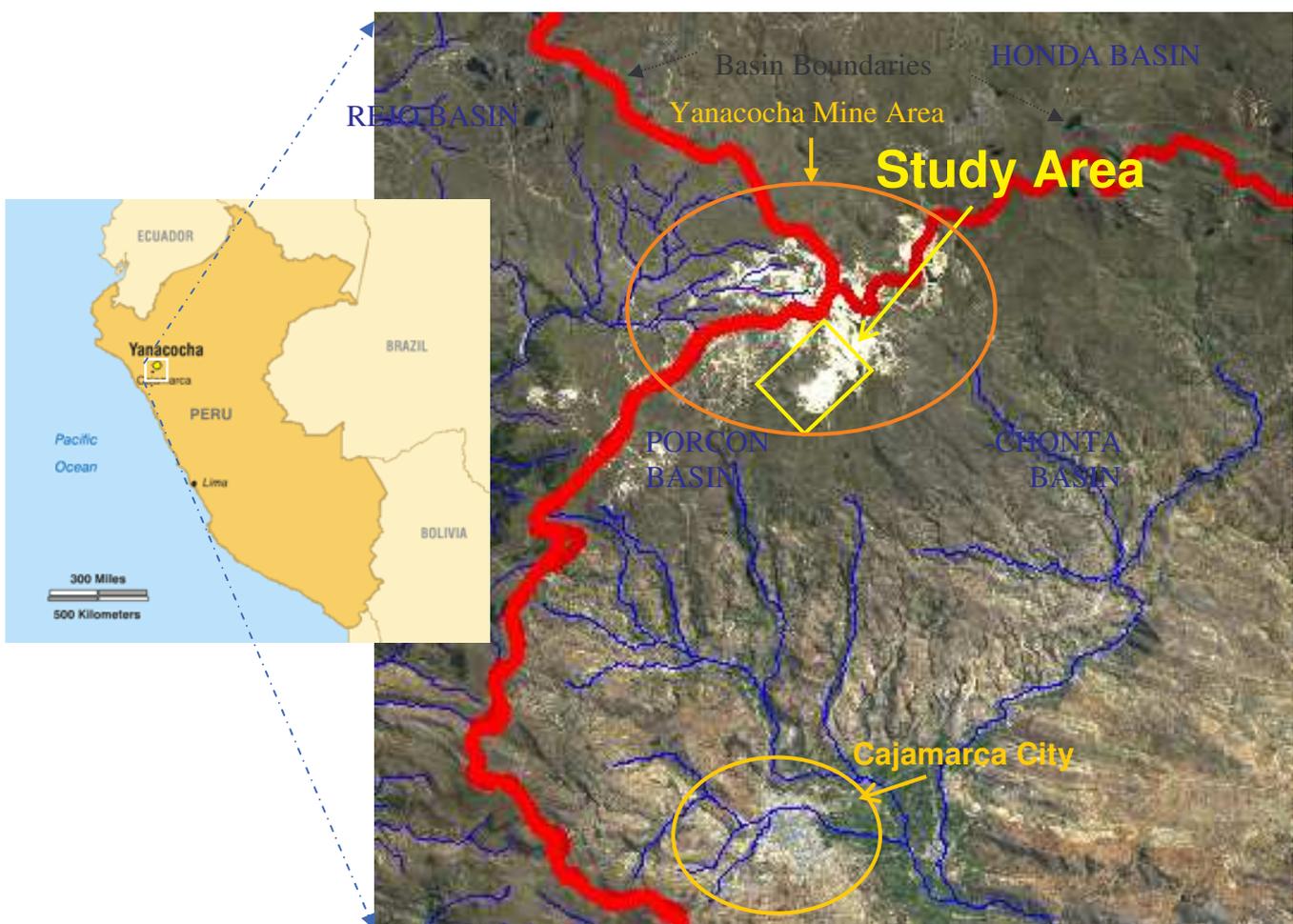
*date*, Young 1998). In fact, some of the oldest archaeological evidences of human presence in Peru were found in the Andes region (*i.e.* Paccaicasa, 2740 masl, 17500 BJ).

Physically, the Peruvian Andes are not regular. They represent a large area which goes through the whole territory of Peru, from the North to the South. Their characteristics vary according to their latitudinal position, their orientation east or west and mainly their particular altitude (Clapperton 1993). The Southern and Western Andes are drier and higher on average; in contrast, Northern and especially Eastern areas are less dry and lower. Higher areas are characterised by low temperatures and difficult conditions for the development of vegetation (Pulgar-Vidal 1996, Martinson 1997). Above 3500 masl, the presence of trees is scarce and grassland becomes the main feature of an area mainly resided and managed by herders (Preston *undated*, Pulgar-Vidal 1996, Young 1998). In these areas, nearly all of the great mining operations in Peru are situated; my study area corresponds to the north western-central Andes and pertains to the largest gold-mine in South America, the Yanacocha Mine Corporation.

## **2.2 The Study Area**

The Yanacocha mine area (fig. 2.1) constitutes the most important area for gold deposit operations in Peru, and hosts the largest economically-viable gold resource-base of the country; it is also considered the most profitable gold mine in the world (Buenaventura 2006). MYSA is owned by the USA-based Newmont Mining Corporation (52%); the Peruvian Buenaventura SA (43%); and the World Bank's International Finance Corporation (5%). The Company operates an area of 160 km<sup>2</sup> in the north-east of the province of Cajamarca in the northern Peruvian Andes at latitude 7° south (Stratus 2004). The mine area lies approximately 15 km north of the city of Cajamarca at an elevation of approximately 4000 masl on the Continental Divide, separating streams that drain eastward to the Amazon Basin and subsequently to the Atlantic Ocean (in the Porcón-Chonta, and Honda basins) from those that drain westward to the Pacific Ocean (in the Rejo Basin).

My specific area of study, as shown in fig. 2.1, comprises 10 km<sup>2</sup> or 10000 Ha. of both operative sectors and non-operative mining sectors.<sup>1</sup> The area is located in the south of the mine area in the upper part of the Porcon-Chonta Basin (fig. 2.1), in the district of Cajamarca, province of Cajamarca. The election of this exact area as a sample of the whole Yanacocha came after a process; first, I attempted to cover the whole mining area and surroundings; but the extension of the mine, 160 km<sup>2</sup> and the difficulties to get authorisation to enter to the mine, turned this endeavour not feasible for the application of the methods. Second, I tried to find the closest villages to the mining centre, and I could find contacts in one of them, *Quishuar Corral*; this village was also reachable through a small road two hours far from Cajamarca City. The study area is located 2 km east from this village. Third, the exact position was determined by the area covered by the materials (Aerial Photos from 1993 and 2000) in whose analysis the landscape mapping is based.



## 2.1 The Study Area and their basins

<sup>1</sup> The operative areas represent the areas under mining activities.

## 2.3 Physical Characteristics

The study area is located between 3700 and 4200 masl. At these altitudes the morphology is characterised by a rugged surface, steep mountain slopes and gorges. These features were created, mainly in the Tertiary age, through the combination of new volcanic domes, successive weathering and extraordinary events of fluvial-glacial deposition. The domes formed the natural hills of the area and are the deposit of the valuable gold-mineral (Buenaventura 1992).

The volcanic sediments fragmented from the domes composed the main parent material of the soil. As it is shown in the soils horizons in fig. 2.2, above this volcanic high-acid material, the soil presents low-depths layers of Horizon A with a rich organic material surface or a B horizon characterised by accumulation of clay, iron, organic matter or aluminium (Diaz and Poma 1999, Stratus 2004). The horizon A contains a large source of viable seeds that can germinate and establish relatively quickly. Removal of the organic layer causes nutrient deficiency and susceptibility to erosion (Buenaventura 1992, Shepherd Miller et al. 1994).



2.2 Soil profiles in Chonta and Porcon Basins (Stratus 2004)

The climate of the study area is typical of tropical Andes regions, characterised by temperate to cold temperatures with large daily oscillations and a distinct rainy season (Pulgar-Vidal 1996, Martinson 1997). Conditions are often windy, especially at higher elevations. Rainfall is characterized by very distinct wet and dry seasons. The seasonal precipitation pattern in the study area presents a rainy season from October through April and a dry season from May to September. Precipitation data indicate that in general, average monthly precipitation is highest during February and March and lowest during July and August (Shepherd Miller et al. 1994). Correlations between precipitation and elevation are positive in the study area because of their location in the Atlantic side of the Continental Divide. In contrast, the correlation is negative on the Pacific side of the MYSA area (Stratus 2004).

The water resources consist of lakes, ponds, wetland/swamp areas and water streams. In the whole MYSA area, Stratus (2004) describes the presence of ten lakes for 2003, with an average of less than 0.5% watershed extent; these lakes are the origin of the tributaries of the Porcon-Chonta, Honda and Rejo watersheds. The study area is the origin of streams that drain to the Porcon or to the Chonta Basins (fig. 2.1); the streams originated on the west and north drainage to the Porcón Basin, which is composed of two major sub-watersheds, the Río Grande and the Río Porcón, that supply the drinking water for the city Cajamarca. The streams originated in the east drainage to the Río Chonta and correspond to the affluent of *Quebrada Rio Azufre*.<sup>1</sup>

## 2.4 Population and Economic Characteristics

Traditionally, the human population in the Peruvian Andes has not been concentrated in settlements. The difficult conditions, such as steep topography and availability of fertile soils (Dollfus 1981) for the human occupancy generated a transversal inhabitation, where different members of families occupied different ecological levels (according to altitude) to take advantage of a diversified production. In this appropriation model, the lower areas are dedicated to agricultural activities and the higher to pastoralist activities (Dollfus 1981,

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<sup>1</sup> *Quebradas* are the narrow and rough bottom of the route in which the occasional streams (mostly coming in the rain season, some of them are permanent) or current usually flow.

Rostworowski 1981). The villages are small where they exist, and settlement is usually in the form of dispersed houses in different locations along the watershed.

These characteristics were present also in the study area, which was used to carry out pastoralist activities of different livestock before the mining started, and yet, there is a mainly pastoralist-based economy in the sector outside the mine<sup>1</sup> (Bury 2004, Pascó-Font et al. 2001). The animal husbandry system is extensive, the use of the semi-natural rangeland is shared by people of the highland, and seasonally by shepherds of lower areas; besides the livestock breeding, there are also other secondary uses such as the collection of plants for medicinal use. There are no villages in the study area, the closest one is *Quishuar Corral*, with 31 families and 210 inhabitants, according to Yanacocha (2003).

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<sup>1</sup> Analysis of the land use changes inside and outside the mining area will be described in chapter 5.

### 3 THEORETICAL FRAMEWORK

The object of study of geography has been understood in many different ways. One of the main perspectives argued that geography deals with the relations between “*society and the natural environment*” (Peet 1998: 1). In the geographical tradition, *environment* is understood, by two opposing currents. On the one hand there is the current that considers the environment “real” regardless of individual conceptions of it, and on the other hand there is the position that considers the environment to be a reality only constituted in thought (Kitchin and Tate 2000). Among these opposite positions there have been intermediate views. These perspectives have called the environment *space*, *place*, *region* or *landscape* (Peet 1998). Nevertheless, the term *landscape* is widely used also outside the geography boundaries, it also a concept in science, art and daily life expressions; and with several conflicting meanings. Thus, a preceding survey of different *landscape* concepts is crucial to understand the approach I will use in this research. With this aim a historical overview of the term and the analysis of different concepts and methods will follow.

#### 3.1 History of the Concept

The term *landscape* is an association of two concepts, *land* and *scape*. The second word *scape* most likely refers to *shape* or *ship*, which means association and partnership (Spirn 1998). Therefore, according to this meaning, landscape is the shaping of the land, and/or to the association with the land by societies (Spirn 1998). The definition of landscape as a manmade land is more evident in the current Germanic languages such as in the German *Landschaft*, the Dutch *landschap* and the Norwegian *landskap*; in all of them, landscape is the land moulded by the human activities. Hence, the notion of “cultural landscape” is redundant, since all landscapes are cultural and an expression of the human imprint on the surface (Spirn 1998, Lundberg 2002). Nevertheless, the historical process of this expression’s usage has brought nuances of ambiguity to its definition.

Historically, *landscape* shows its first evidences in manuscripts written in Old German around the century IX A.D, with the use of *lantscap* or *landscapft* as a translation of the Latin *regio*

that signifies area, region, territory, district, country or zone (Tress and Tress 2001). Further evidence dated in the late Middle Ages shows the use of the term *lantschap* by the Dutch as “an administrative entity, a certain area, or ... as a synonym for land and one’s native country” (Tress and Tress 2001: 144). Probably, the semantic relation with *land* influences the additional use of the word, referring to the background scenery (commonly, a natural or agricultural area) of the painted portraits; and later, referring to the bare scenery as the main objective of the painting (Relph 1981, Tress and Tress 2001).

This kind of painting reached high popularity in the sixteenth and seventeenth century in all of Europe, and *landscape* started to be widely used as a denomination of the piece of art characterised for the painting of a natural scene with an aesthetic value (Relph 1981, Tress and Tress 2001). These paintings are considered as ideal representations of attractive sites, but they are also precise illustrations: “they were topographically accurate, depicting typical and often recognisable scene...this was a dramatic change, from implication and involvement to impersonal and precise representation” (Relph 1981: 26). It might be that the artists painted attractive land features as they saw it without particular intention to idealise. According to Kwa (2005), the current understanding of the depicted landscapes as idealistic representations, was created by the art critics of the twentieth century. Before, especially in the seventeenth century or early eighteenth century, the notion of real nature was closely linked to the paintings (Relph 1981, Kwa 2005). Landscapes were considered beautiful but at the same time real. In the context of a Post-Renaissance period that saw environment as a natural-pristine order opposed to a cultural-mundane order (Tress and Tress 2001), *landscape* was the expression of the magnificence of the nature, understood as part of the real world and not as part of the idealistic mind of the artist.

In the nineteenth century, the conception of landscape as a visual representation of the natural reality is taken by Alexander von Humboldt to introduce landscape as a scientific object. Humboldt (1769-1859), one of the founders of the modern geography and whose major endeavour was the attempt to find the universal laws and connections underlying each particular natural phenomenon (Peet 1998), saw in the works of the painters, expressions of natural events with the potentiality to be abstracted in an ecological unity that exposes the relations behind each observable scenery (Kwa 2005). The artist’s eye could find the general between the individual, “by the suppression of all unnecessary detail, the great masses are better seen, and the reasoning faculty is enabled to grasp all that might otherwise escape the

*limited range of the senses*” (Humboldt 1849-52, ‘*Cosmos*’ in Kwa 2005: 157). Humboldt, in his exploration journeys around the world, worked with painters to illustrate the nature, with the purpose to represent neither a plant nor a particular element, the focus was to find the composition, the masterpiece, the unity behind the image (Kwa 2005). This new concept of landscape as “*the total character of a region*” (Humboldt 1808 ‘*Ansichten der Natur*’ in Naveh and Lieberman 1994), instituted a physical and holistic understanding of the landscape that revolutionised the landscape studies.

After Humboldt, landscape was no longer considered only an aesthetic category or a painting genre; it is also a scientifically used concept. Manifestation of this new trend is the definition of the German geographer Rosenkrantz (1850) who considers landscapes as “*relative wholes, integrated local systems of factors comprising all kingdoms of nature*” (Schmithusen 1973 “*Was ist eine Landschaft?*” in Bastian 2001, Kwa 2005). The conception passes from the art to an exclusive natural-based dimension. Through this process, the concept of landscape expanded to sciences and especially to the physical geography (Tress et al. 2001, Kwa 2005).

Geographers, as Humboldt and Rosenkrantz, introduced *landscape* to the scientific lexicon and thus, opened the studies on this field, which soon became part of both, human and physical geography enquiry. In France, Vidal de la Blache (1845-1918) considered landscape as the physical domain that could be transformed by civilisation (Conzen 2001). For the German school, landscape is the manifest-visible phenomena that form a homogeneous area or region (Conzen 2001), and conditioned the evolution and capacity of the societies living in it (Peet 1998).

In reaction to the idea of a determinative environment, new studies focused on the moulding power of the civilization centring its attention in landscape as a cultural product (Peet 1998). In this line, Carl Sauer, in his essay, ‘*The morphology of landscape*’ (1925), considers landscape as “*an area made up of a distinct association of forms, both physical and cultural*” (Tress and Tress 2001: 145), remarking upon the influence of the culture processes as the central object of human geography (Peet 1998, Conzen 2001). The cultural landscape starts to be examined according its morphology and physiology, just as the visible phenomena of nature (Conzen 2001). In opposition to this increasing focus on landscape studies, Richard Hartshorne (1939) criticised the *landscape* concept as confusing and suggested its removal

from the geographical field in favour to the term *region* as “*unique combinations of characteristics in specific areas*” (Hartshorne 1939 in Peet 1998: 17).

In the same year, a physical geographer, Carl Troll (1939) instituted *Landscape Ecology* as “*the combination of the spatial, horizontal approach of geographers with the functional, vertical approach of ecologists*” (Farina 1997), thus starting one of the most prevalent currents of landscape studies. He developed this concept as part of his early work applying aerial photograph interpretations to studies of interactions between environment and vegetation. In this new branch, landscape is described as (a) as the result of the interrelation of natural and human factors, this could be recognisable in the (horizontal) analysis of the aerial photo; and the horizontal landscape determines the (vertical) ecological functionality (Bastian 2001, Tress and Tress 2001). In 1957, Dansereau considered landscape as the highest integrative level of environmental processes and relations (Naveh and Lieberman 1990); and Neef (1967) characterized landscape as a part of the Earth’s surface with a uniform structure and functional pattern and hence, similar ecological dynamic (Bastian 2001). This ‘spatial-ecologist’ perspective establishes the landscape concept in the area of the natural sciences, defining landscape as the sum of common spatial patterns which constituted a functional ecological unity. It bridged geography with sciences as ecology and biology and grounded the landscape concept on the natural science areas; *Landscape Ecology* perspective is still one of the more active areas of landscape studies.

In human geography, the panorama of the 50’s and the 60’s is dominated by the positivism that turns geography towards the objectivist science of man’s spatial organization in which environment is only approachable as a geometrical measurable space (Peet 1998). The focus is on the ‘space’ and the term landscape as one of the centres of the geographical inquiry is dislocated. In the 70’s, *humanistic geography* opposed to positivism the subjective perception of material phenomena; environment was considered “*as a series of locals in which people find themselves, live, have experiences, interpret, understand and find meaning*” (Peet 1998: 48), the space outside is worth for the meaning that they have inside the mind of people (Tuan 1977). This inductive appropriation of the surroundings made room for studies in which landscape was expressed as a human-internal reality and experience.

Later, post-structuralism and post-modernism strengthened the focus on the subjective qualities of landscape and the ways in which landscape was socially constructed. The

landscape concept was enlarged in order to "*allow for the incorporation of individual, imaginative and creative human experience into studies of the geographical environment*" (Cosgrove 1985 in Tress and Tress 2001: 146). The symbolic reading of the material-biological landscape was interpreted and analysed. Landscape exists outside of the mind, but it receives a meaning inside the mind of individual, who is conditioned by the cultural and social structures of each society (Tress and Tress 2001). The importance of the perception and how the material environment enriches the life of society was emphasised (Conzen 2001).

Influences of art history and aesthetic theory support this drive towards the subjective dimension (Conzen 2001). Landscape is a scenic object and the ultimate determinant of perception. Bourassa (1991) stressed the biological, cultural and personal modes of aesthetic experience and considers landscape to be a "particularly unwieldy aesthetic object. It is a messy mix of art, artefact and nature, and it is inextricably intertwined with our everyday, practical lives" (Tress and Tress 2001: 146).

Such historic perspectives all present different positions along the continuum of landscape as either material environment or as mental interpretation. The notion of landscape as an exact portrait of nature contributes to the Humboldt idea to use such a term in order to refer to the total abstraction of a visible area. Humboldt's concept was based on understanding landscape as a visual objective, which could be perceptible through its forms. This orientation influenced two strong currents inside human and physical geography. In the first, it became an expression of the human power to ascribe a determinate characteristic to the environment, creating boundaries and differencing areas (Cultural Geography School), in the second, physical geographers it was understood as a spatial form that will influence ecological processes (Landscape Ecology). Both notions of landscape had the material space as objectives, emphasising either the human imprint or its influence in ecology. This material centred approach was adjusted by researchers who were inspired by humanistic, post-structuralist and post-modernist geography and who consider the feeling, perception and interpretation of the landscape as or more important than the reality itself.

The few perspectives mentioned above do not give a complete picture of landscape research, but they attempt to identify the main areas of landscape research, especially inside the field of geography. They point out the existence of two different understandings of landscape, one that considers it as material entity and another that considers it as a mental dimension. The

debate between these approaches, the landscape as a materialistic objective reality or as a mental subjective perception, is one of the most highlighted aspects of the current landscape studies (Antrop 2000, Terkenli 2001, Tress and Tress 2001). In the following part I will write about the main positions in this debate.

### **3.2 Landscape as material concept**

As it was observed in the previous section, in most parts of the tradition of landscape research by geographers (Humboldt, *Cultural Geography* and *Landscape Ecology*), landscape is a material reality containing the natural phenomena and the human expression in it. The materialistic approach considers landscape as the tangible-material world where “*we can walk upon them, fly over them, recreate them or measure them*” (Tress and Tress 2001).

The material landscape studies could focus on its natural or cultural characteristics. Natural landscape could be divided as well into abiotic and biotic overlaying spheres. The abiotic, non-alive sphere is composed of the integration of landforms (geomorphology), geology/bedrocks, soil, water, air, and climate, which give the necessary conditions for the apparition and surviving of the (biotic) living components, consisting of flora, fauna and humans (Forman and Godron 1986). Above them, the societies mould and manage the natural landscape to develop their activities creating cities, buildings, roads, and dividing the land according their purposes (agriculture, herding, mining, industry and so forth), creating in this way, the cultural landscape (Naveh 1995).

Traditionally, studies of landscape have focused on either the natural or the cultural landscape. Regarding the natural landscape, some studies stress more the landscape as abiotic under the notion of “*landscape as morphology*”, composed mainly of morphological elements such as mounds, hills, mountains, cliffs, (Baker 1972, 1988, Baker & Butlin 1973, Langton 1988 in Lundberg 2002). Others, such as the *Landscape Ecology* followers, focus more in the landscape as physio-biological unit (Forman and Godron 1986, Farina 1997), emphasising more its ecological functionality. On the other side, the studies of cultural landscape focus on the landscape as a mainly cultural creation. The cultural expression is the

result of the mentality of a specific society and time, but exists outside it, “*as the tangible meeting point between nature and mind*” (Naveh 1995: 44).

In this sense, the influence of the human mind in the material landscape is understood as important, but the focus is on the tangible expression of this mentality. In this perspective, landscapes can be readable to understand the social structure that exists behind the physical reality; the landscape as the mirror of society and as the result of the relations of power inside the community (Forbes 2000). Current tendencies of landscape studies is to approach the whole landscape as a cultural entity (Terkenli 2001, Lundberg 2002), the etymological meaning of the term ‘*land-scape*’ as “*manmade land*”,<sup>1</sup> and new tendencies of ecological studies (outside the Clementsian paradigm) arguing against the conception of nature as opposite of culture, support this view.

The focus on either the natural or the cultural components of the material landscape does not imply that the other is not considered; it is a scientific consensus that both interact with each other. Yet naturalists claim the importance of the human processes where culturalists put emphasis on the natural conditions of the environment (Tress and Tress 2001). However, in the scientific praxis, researchers, considering their objectives and perspectives, emphasise more the natural or the cultural characteristics. In natural, cultural and intermediate positions, landscapes are considered complex integrative objects which are only feasible to be studied because their spatial dimension (Farina 1997) and because of that, can be classified, mapped and analysed.

### **3.3 Landscape as mental perception**

The use of *landscape* as a spatial–physical reality that is objective and tangible has not been the only meaning of this term, it has also been considered as an artistic-ideal representation of the world. In section 3.1, regarding the history of the landscape concept, I mentioned that the use of this term achieved popularisation in Europe, in the post-renaissance period as the artistic portraits of natural sceneries. Being an aesthetic concept, it entails a subjective valuation of the world, hence there is a mental qualification intrinsically related to the use of

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<sup>1</sup> In section 3.1 there is a more detailed analysis of the origin of the word *landscape*

landscape as artistic expression. Relph (1981: 23) asserts “*landscape was for long time an aesthetic concept that requires leisure and training to appreciate*”. The artistic representation can be realistic and without a particular intention of idealising a place (Kwa 2005), but the election of some areas as beautiful or with aesthetic values showed a subjective mental connotation (Tress and Tress 2001). Therefore, landscape can not be separated from the mental interpretation that determines which visual piece of the environment has sufficient artistic value to be considered as landscape. The aesthetic implicitness of the concept of landscape has been kept in the underground and off the scientific enquiry since the renaissance period. As Naveh and Lieberman (1990:3) claim, that the “*...landscape [concept] has undergone great changes, but the original visual-perceptual and aesthetic connotation has been adopted in literature and art, and is still used by many persons involved in landscape planning and designing. They are more concerned with scenic-aesthetic landscape perceptions than with its ecological evaluation*”.

The aesthetic value is only one part of the mental approach to the landscape. People perceive the physical landscape, and through reflection maintain feelings for the material environment symbols which exist in society (Tress and Tress 2001, Antrop 2005). These responses are variable; the same material landscape can give different individual and communal answers, and even variable in the same individual or community. A landscape is not composed of “*what lies before our eyes but what lies within our heads*” (Meinig 1979: 34). Facing a particular scene, each viewer incorporates their own socio-cultural-psychological characteristics into their approaches to landscape. “*I happen to think that it is useful to have a word which encompasses environments in terms of the way in which I experience them, and landscape seems eminently suitable*” (Relph 1981: 22). These interpretations of the material surroundings are also an important part of the landscape, as Tuan (1979: 90) said, “*nor does landscape mean simply a functional or legal unit such as farm or township... landscape is such an image, a construct of the mind and of feeling*”.

This does not mean that landscapes are only mental representations of the environment, but that these are as genuine as the material dimension. Landscape is “*a human idea, with a long and complicated cultural history which has led different human beings to conceive the natural world in very different ways*” (Cronon 1995 in Tress and Tress 2001: 146). The existence of this human inside is, of course, influenced by factors coming from the natural and cultural environment, from the material landscape. On one hand, the climate, morphology and other

natural phenomena influence the human mentality. On the other hand, the mentality generates a different approach that constantly recreates the material landscape. Our mental view of landscapes is a product of culture and culture creates material landscape (Naveh 1995). The human being constructs its landscape and receives constant feedback from it, in an active interchange, and “*landscapes as objective realities affect the lives of people*” (Meining 1979). The active interchange between material mind and the material world is one of the core complexities of the landscape concept.

The mental dimension of the landscape is constructed by sentimental and rational approaches. The rationality and the feeling are together in the interpretation of the landscape, “*landscape is a primarily aesthetic phenomenon, closer to the eyes than to the mind, more related to the heart, the soul, the moods than to the intellect*” (Hard 1970 in Bastian 2001: 758). Also Forman and Godron (1986: 5) assert that “*people have also feelings about landscapes. For example, what do you feel about the landscape you live in? beauty? pride of ownership? danger? belonging?*”. Hence, as Dramstad et al. (2001) argue, it is possible to affirm that people are influenced by a mixture of logic and emotion that incorporates aspects of landscape structure, biodiversity and cultural heritage.

This mixture of logical and emotions develop different interpretations of the material world. Each individual can “see” the landscape under different socially constructed “lenses” (Meining 1979). The relevant ways of interpreting a landscape can be denominated by scenery, resource and institution (Cosgrove and Daniels 1988 in Lundberg 2002) or even as nature, habitat, artefact, system, problem, wealth, ideology, history, place and aesthetic (Meining 1979). Lundberg (2002: 247) states that “*to the interpretation of landscape, practice, law and custom must be considered*”.

To have sentimental and rational approaches to the material landscape implies also an evaluation of the landscape: “*environmental attributes do not only determine perception, they also act as qualities, determining landscape evaluation; perception and evaluation are closely related*” (Coeterier 1996: 29). According Kaplan et al. (1989) the main attributes are the physical ones (spatial diversity, naturalism), land cover types (use), informational variables (coherence, order, legibility) and perception-based variables (openness, smoothness) (Lucio et al. 1996); Antrop (2000) considers three main attributes, the natural framework, the cultural inheritance and the aesthetically well-feeling; and economic values are also considered

important by the 'European Landscape Convention' (2000). Evidences of the combination of different attributes have been studied by Dramstad et al. (2001) who consider that biodiversity can be also important for cultural heritage and for human aesthetic appreciation. In contrast, there are other researches that consider ecological attributes historically incompatible with the cultural ones, stressing the importance of the aesthetic evaluation (Parson and Daniel 2002). Understanding the main mental attributes people give to the landscape is considered, nowadays, crucial for landscape planning and management (Coeterier 1995, Dramstad et al. 2001, Krausse 2001, Antrop 2005). The methods to deal with this landscape dimension will be outlined in the following section.

### **3.4 Landscape Methodologies**

In the previous sections, I introduced landscape as a concept which has a material dimension and a mental dimension. The *material landscape* is the natural-cultural environment and the *mental landscape* is the different feelings and rationalities that influence the interpretation of this material landscape.

The material dimension comprehends the natural environment formed by geomorphology, the water bodies, the air, the climate, the flora, the fauna and the processes that are interrelated with them. It evaluates the cultural environment as installations, infrastructure, the land use areas and the diverse expressions of human occupation on the natural physical terrestrial surface (Forman and Godron 1986, Farina 1998). The mental dimension interprets the material landscape as artefact, nature aesthetic object, institution, system, custom, institution, resource, practice, law, object of pride, instrument of power, ideology, place (Meining 1979, Tuan 1979, Daniels 1993). The scientific methodologies to deal with these dimensions vary depending on whether they were developed within the natural sciences, the social sciences, the humanities, the arts or other fields. Each discipline within these fields has developed their own traditional applications and concepts of the term and has successfully arrived at different methods to study landscapes (Terkentli 2001, Tress and Tress 2001). Dealing with all the methods that study such a complex and wide concept is beyond the scope of this thesis. Considering the objectives of my research, the aim of this section is only to outline the main

methods of landscape studies. I will first outline an approach to the methodology for the material landscape, and one for the mental landscape.

### **3.4.1 Methodology for the Material Landscape**

The material landscape is formed by a mixture of landforms, water bodies, atmospheric conditions and cultural expressions; all in interrelation, a complex reality which common characteristic is its spatial nature (Farina 1997). Therefore, to analyse landscape it is necessary to organize the reality spatially in groups or classes according to their similarities and differences (Farina 1997, Zee and Zonneveld 2001 in Garrido 2004). The classification is considered a methodological necessity in the analysis of the landscape (Forman and Godron 1986, Naveh and Lieberman 1990, Farina 1997). According Antrop (2000), the landscape classification follows three approaches: A *thematic approach*, which focuses on the analysis and interrelation of the different landscape components; a *regional approach*, studying the landscape as hierarchical units; and *landscape metrics*, which attempts to analyse the geometric characteristics of the landscape and its ecological functionality. I will consider each in turn.

The thematic approach analyses different landscape components separately and tries to make a synthesis (Antrop 2000). The result is a set of thematic maps that are analysed independently, and that are after connected to get the spatial classes of the landscape. Among the different thematic values to be considered is an emphasis on the roles of the climate, geomorphology (including underlying rocks and parent materials) and the ‘disturbance (ecological) factors’, especially human intervention (Forman and Godron 1986). Garrido (2004) claims the geopedologic, hidrologic and landcover themes as the most relevant for a landscape evaluation. Farina (1997) proposes an alternative combination in a hierarchical system where the themes physiotope (geology, aspect and slope rate), land use and humus forms can be joined. Geographic Information Systems (GIS) can be used in the process of combining the different thematic maps and data bases (Farina 1997, Garrido 2004).

In the regional approach, the spatial classes are taken from the landscape as a “whole”, directing homogeneities and differences without focusing on any theme in particular. This perspective takes into account that the relevant themes that could be considered in a landscape

study are too large to be studied individually and that landscape is always more than the sum of its elements (Naveh and Lieberman 1994, Antrop and Eetvelde 2000). Commonly, the different landscape classes are structured in different hierarchical levels according to the study objective. The result is a chorological classification of the area and the description of different landscape types (Mitchell 1973, Zonneveld 1995 in Antrop 2000). For the distribution of landscape units in chorological relations, Zonneveld (1972 in Naveh and Lieberman) proposed the following hierarchical levels of increasing size: The ‘*ecotope*’ (or set) as the smallest holistic land unit, characterised by homogeneity of at least one land attribute – namely: Atmosphere, vegetation, soil, rock, water (without non excessive variations in other attributes). Thereafter the ‘*land facet*’ (or ‘*microchore*’) is a combination of ecotopes, forming a pattern of spatial relationships and being strongly related to properties of at least one land attribute. Next is the ‘land system’ (or ‘*mesochore*’) as a combination of land facets. Finally, the ‘main landscape’ (or ‘*macrochore*’) is a combination of land systems in one geographical region. Aerial photos and satellite images are considered as important data sources in this approach (Forman and Godron 1986, Farina 1997). Currently, computer-based classifiers, mainly using remote sensed data such as satellite images, can automate the process diminishing time and standardising the analysis, but also can contribute towards extreme simplifications of landscape analysis (Devereux et al. 2004).

The landscape metrics approach refers to the quantitative characteristics of the landscape structure composed of patches, corridors and a background matrix (Antrop 2000, Bastian 2001, Lausch 2002). These metrics influence the functionality of the landscape and the physical spatial structure affecting the animals and plants (Forman and Godron 1986). Patches are the principal structural components of landscapes; they are the non linear surface area differing in appearance from its surroundings. Corridors are narrow strips of lands which differ from the matrix and facilitate the movements of organisms. Matrix is the overall structure (Forman and Godron 1986). These landscape elements vary in size, shape, number, type and configuration (Forman and Godron 1986, Farina 1998). The conceptual base is that the geometrical characteristics affect the flux of energy, the interaction between species and several ecological processes (Farina 1997). The edge of a patch for example is one of the most important characteristics to analyse diversity. It influences the energy entrance and distribution in the patch; thus, in the areas close to the edge of the patch there will be more energy because it has more open space (Forman and Godron 1986). Using metrics it is possible to get several quantitative analysis supported statistically. For example, Lausch and

Herzog (2002) studied the landscape transformation in a post mining area based on the number, size, shape and arrangement of patches of different land-use/land-cover types, choosing 16 metric indicators. Landscape metrics are widely used together with area statistics to quantify landscape structure and composition (Lausch 2001).

My research attempts to characterize the nature of the physical change, and then the perception of such change. In this sense, my first research question is *What are the physical landscape changes?* It deals with the mapping of spatial reality for which main methods were prior described. The selected method and its implementation will be explained in chapter 4, Methods.

### **3.4.2 Methodology for the Mental Landscape**

Attempts to understand the feelings, impressions and cognitive features that generate the mental landscape of societies and individuals are one of the most complex aspirations of landscape studies. In the section 3.1, I remarked that this view was opened within geography by the humanistic geographers as a reaction against the positivistic view of the world as geometrical space. In this field, landscape studies started to investigate the subjectivity of the individual with the aim to understand the landscape as it exists inside the human mind, the perception and interpretation of the physical reality.

There are two tendencies in the studies of society in relation to the environment. One that considers the human interpretation of the landscape as mainly qualitative research, and the other which claims that the perceptive expressions can be quantitative analysed; these approaches are used to deal with the complexity of the human perception, and correspond to different positions of understanding this object. For the quantitative researchers, science needs to be objective, and the landscape interpretation needs to be quantified to be scientifically comprehensible; in contrast, qualitative approaches highlight the uniqueness of the perception, the exceptionality of each individual sense of the world. In the latter, further generalisation is possible, but each individual position is properly scientifically relevant.

My research also attempts to uncover social responses to the geographical change produced by mining activities, thus the second research question is: *How are the physical*

*landscape changes caused by mining activities perceived by the local population?* The question addresses perception and understanding, and therefore, it is related to the uniqueness of the individual experiences facing the transformation of a pastoralist area in a mining one. Hence, the nature of my approach stressed the necessity in the use of qualitative methods as well.

Qualitative methods are the different procedures that focus on the view of individuals and groups as a product of their experiences, concerned “*with the understanding of social structures and individual experiences*” (Hay 2000: 3), the priority is going deeply into the study of an individual or a group to discover something behind them; instead of producing large amount of numerical data in cases that can not be generalized. The individual experiences, places and events that are considered are not necessarily representative or replicable. Hay (2000) considers three main types of qualitative research: The oral (primarily interview-based), the textual and the observational. The most widely used is the oral, consisting in semi-structured, open interviews, and oral histories; hence, mostly qualitative approaches are considered essentially ‘discourse-oriented’. The application of these methods will be addressed in chapter 4, methods.

### **3.5 The Landscape Change**

Landscape is material and mental, but is also a dynamic-temporal entity. Each element of the space we can see outside and lying ‘behind’ our eyes is plausible of change. The cultural shaping of nature represents a historic process in the context of a society mentality, and its technology and materials. But also, the human moulding of the landscape has been influenced by the natural characteristics of the area, i.e., the presence of agricultural terraces obeys the necessity of having crops in slopes. Landscape change is the expression of active natural-human interactions.

The main natural forces driving the landscape changes are, according Forman and Godron (1986) the geomorphologic processes in its interaction with the climate, the colonization patterns of organisms and the disturbances. In this line Antrop (2005) adds the influence of

the topography and the soil; moreover he concludes that strong disturbances as caused by avalanches or hurricanes can profoundly affect landscapes.

The human factor is considered the main performers of change, because “*the humans have always adapted their environment to better fit the changing societal needs, and thus reshaped the landscape*” (Antrop 2005: 24). The changes have been expanded according to the rate of growth of human populations, their consumption pattern and technological power (Naveh 2000). Nowadays, according Antrop (2000) the main human pressures on the landscape are housing, land as a production space, the networks of infrastructure, and recreation. Thus, tangible houses, agricultural land (or another production) and roads represent the human demands according a determinate culture and the socioeconomic, political, technological, informational, natural potentialities (Buergi et al. 2004).

There are several methods to study the process of change. To deal with a material map-able landscape (see 3.4.1) the most used method is the comparison of a sequence of maps of different years in a linear time base (Antrop 2000). Remote sensing data is considered a basic input to know the reality of each precise time and a GIS environment is widely used to overlap the different temporal maps (Jansen 2001).

Landscape change means to know the past and several methods from different perspectives, quantitative and qualitative methods (see 3.4.2) can be used with this aim. Lundberg (2005) for example, as part of an extensive research project on landscape change in Hystadmarkjo (Norway), presents the results of the implementation of several methods such as historic-geographic materials (documents) analysis, place-name studies, aerial photo interpretation, vegetation mapping and GIS, transects, gradient analysis, plot analysis, multivariate data analysis, dendrocronology, soil analysis, cartography and map analysis, and finally interviews.

Knowledge of the landscape change and the historical causes that form the present are crucial to improve the planning and management of the landscapes. A better understanding of the different processes that result in the current mining-influenced landscape and the significance of this landscape for the local people could be important in order to improve integral mining management.

In this project I aim to integrate quantitative and qualitative methods; quantitative to deal with the physical landscape change and qualitative to address the local's people perception of such change.

## 4 METHODS

### 4.1 Introduction

The research design consists of a problem, objectives and the methods to reach these objectives. The problem I deal with is related to the necessity of independent research on the mining impacts in Peru, in a context where the main actors have extremely different opinions regarding them. In this sense, an evaluation of the landscape changes could give representative information on these impacts, besides giving information on the actors' perception of them. Hence, the objective of my research is *to assess the landscape change of an area under influence of mining activities*; as it was analysed in the chapter 3, landscape studies use several methods, which will be selected according to my scientific position and its relevance to the case study.

Before describing the methodological process carried out in this project, some points about my understanding of Methods is called for. I understand Methods as the set of rules or procedures employed to arrive at my objective. The rules concern how to approach and represent reality. There are two ways of reasoning behind all methods. The *deductive* goes from general principles to specific cases, starting of a theory and then narrowing it down in order to propose a hypothesis to be tested in a case(s). The *inductive* goes from observation toward generalizations and theories, starting from specific cases towards general conclusions. It is also named 'observational' (Miller 1991). In my research, I have worked from the observation of a selected case to the conclusions, in a bottom-up way. My observation has been led by the objectives and research questions; my study of the problem does not start of the proposal of a model, it uses different techniques of landscape studies to answer the research questions.

The process of choosing the proper techniques needs be attentive towards the discipline of geography where the research is grounded. As it was referred in the chapter 3, landscape theories and methods are parts of the geographical tradition and are parts of the debate between the understanding of the world as a real or as mental (Kitchin and Tate 2000). As it was outlined in the mentioned section, I consider *landscape* to comprise the material and the mental dimensions of the reality, the reality that my research deals is *the landscape change in*

*a mining-influenced area* in their spatial and mental dimensions, and through the methods I have to represent this reality. The task to comprehend landscape as physical and mental reality raises different challenges. First, the problem of dealing with a physical reality whose analysis would require the acknowledgment of the environment as real, and second, a perspective of acknowledging perception and interpretation of the environment as well. All of these approaches makes it complicated to find a singular methodological approach, and drove me to the use of both qualitative and quantitative methods to generate data and to complement the findings.

## **4.2 Selection of Case Study**

The research question that leads my research addressed the landscape changes in a mining area. My approach has to choose a representative case among the different mining areas of Peru. At the time of the research, between 2004 and 2006, Yanacocha Mine (MYSA) seemed to be one of the most interesting because of the dimension of the operation and the controversies about their environmental, economical and social impacts, expressed in the active resistance to the mining project by significant sectors of the local population.

The amount of production and the high grade of the mineral make Yanacocha one of the larger and more profitable mineral ventures in South America. Environmentally, it is claimed that Yanacocha SA pollutes rivers and soil, which affects the livestock and the local population. Furthermore, since the mining is located in the highest part of four watersheds, it is argued that it affects the quality and quantity of the resource water in the downstream basin area, including the city of Cajamarca. The people of the area claim that the negative influence of the water resource and the diminishing of the land in use, strongly affect their livelihood standards sustained in agro-pastoralist activities. These claims have been expressed in social outrage such as direct clashes between local groups in one side, and the security of the mining company and the police, on the other side. There is a general context of conflict and distrust, especially between the company and the local people.

For all these characteristics and for the scope of my research I consider this case study representative and stimulant.

### 4.3 Situated Knowledge and Biases

I believe the subjectivity is latent in all knowledge and the insertion of the personal characteristics of the researcher on his/her research is unavoidable. I think the issue is not to make claims about the objectivity of the research, but instead it is important to emphasise that the researcher is affected by her or his situated knowledge made up by its background and previous personal experiences (Dowling 2005). Awareness of this situated knowledge is important as well to have a constant reflexion of how it can affect the research process. The choice of the topic is not casual; as a part of the research process, I have to be aware of my own background, because the choice of methods, analysis and hence, the results are definitely influenced by my personal and academic state.

As part of my situated knowledge, some personal description is important; first, my research has an initial motivation to attempt to give my project some significance in relation with my country. A relevant topic is mining and the impact of mining in the environment, then I found that mining impacts were important for me because my family history. I was born in an agricultural area in the middle of Peru, the Valley of Mantaro, an area strongly influenced by mining activities. My grandfather, father and other members of my family, as many members of the local population were working for mining companies localised in higher areas of the Mantaro basin. This activity permitted a diversification of the economic activities in the area, through the combination of mining salaries and traditional agro-pastoralist production, improving the economies of the families, and opening new opportunities. For example, my father could afford higher studies thanks to his seasonal work in the mines. Nevertheless, the environmental damage in the area is significant and obvious. The fauna in the Mantaro River has disappeared; in areas closer to the mining centres, there are large heaps of mining waste uncovered by vegetation and totally unproductive; and, many lakes are completely or partially buried by mineral and toxic residues. My family migrated to the capital, Lima, when I was child. Still, since my family kept its connection with our hometown through seasonal visits, in my child perception the degradation of the sceneries, and also the aggressive smell of the mining cities (due of the smoke of the refineries) built a very negative vision of the mining. When I grew and learned more about the region, I realised that the mining had not only had negative impacts. As I wrote before, the economic mining impact in my town's area was

positive. Then, some of my situated knowledge is partially based in these two influences, an emotional perception of a mining as a “destructive” activity and a more rational vision of the importance of the mining for my family’s economy, as well as the regional and national economy.

The concern in landscape appeared in my interest for knowing and applying new technologies to environmental studies. In these studies, new technologies such as GIS and the use of Remote Sensing (RS) data had a strong influence on my research. The possibilities to catch images of reality and the potentialities to use diachronic aerial photos or satellite images, as documents of the change, determined my approach to landscape studies. In dealing with such topic, I discovered that social perspectives are crucial to understand the landscape, and it drove my attention to qualitative methods, which approaches I consider relevant in my research.

It is claimed that study of the own background is relevant in all the steps of the methodological process, and as researcher I deal with an object that I decided because I have a topic and a personality and subjective interests. As mentioned, I have become interested in mining for personal reasons. My background motivates my research problem, and the following steps of the research. The methodology was influenced by my studies in geography and my personal identification with the importance of the spatial data registered by remote sensing and studied through GIS methodologies. The spatial information served as a platform to find one of the most holistic and confronted topics, landscape studies. They guided me to the importance of the perception of the physical reality. And it coincided with my previous recognition of the importance of the information from local people. It is an important resource that should be central to research, because the local people who live in a region have often known the area for a long time and have witnessed the transformation of their surroundings.

Then, the whole process has to be described to face these two parts of the research, the spatial information analysis and the perception examination. In both there are daily decisions to be made, and answers to the conditions that create the research environment. As researcher I am dealing with a reality changed by natural and human forces, and at the same time, I have also been driven those same forces.

## 4.4 Data Collection

Data are not available as a finished product. Data collection is a constant decision making process that highlights certain aspects of the reality and interprets it, hence, in the process of collection; data can be said to be “produced”. The researcher observes, names, and conceptualises the events in reality. However, the researcher should be careful in trying to impose her or his own concepts on reality. It was one of my motives to include the subjective interpretation of the landscape; a rocky surface could seem unproductive for myself but could have different meaning for the local population. Thus, the collection of secondary resources such as aerial photos, maps and documents was accompanied by the interviews and field observation with local people.

Lima was the first site for the fieldwork. In Lima lives a third of the Peruvian population and it is the location of the headquarters of the main national agencies and ministries. One of the first tasks was to find spatial information in the format of aerial photos. The agency that carried out this task is the SAN, (National Aero-photographic Service), an entity of the Aerial Force, which main task is the aerial photography of the Peruvian territory. Here it was possible to find the photos of the area for the years 1993 and 2000.

As part of the field work consisted in visiting the study area, Yanacocha mine, on the highlands in northern Peru and to observe and sample the area where the mine carried out their activities and to talk to the people that have lived or used the areas of the mine, a pass into the mining camp or/and in the closer villages were required. In order to get this, a system of contacts needed to be build. To get to know the company, I tried to contact them through the different email addresses that they post on their web-pages without results, the opportunity came through the support of one of my professors in Peru who carried out projects with academics from the faculty of mining engineering; they introduced me and assured the independence of my project to the management area of MYSA. It was a decisive support to get access into the installations of the mining company. To contact to the local communities, the most important was to find the local people organisations and NGOs that carried activities in the area; I found one NGO helpful and it permitted my contact with local people.

Due to these contacts, I could carry out the fieldwork in the study area. MYSA managers gave me the authorisation to enter into the mine facilities and talk to their staff of the area of environment, but it was not possible to realise a detailed observation inside the mine. The size of the operations and the strict rules of the security system did not allow me to go freely through the mine area. Still, I visited the mine area on guided tours on three occasions. My approach to the local population was through a local NGO. This support was crucial, because the conflict between the local people and the mine made the peasants extremely suspicious of outsiders. But fortunately through the NGO I met one of the local leaders; he was decisive in the development of the research. He introduced me to relevant informants, and backed by him, I could be accepted in the different villages, especially in the village of Quishuar Corral that was near to the study area, besides having his support as guide and informant. The process of interaction with the people will be described in subchapter 4.6.

#### **4.5 Landscape Mapping: Towards a spatial-temporal analysis**

In chapter 3, I defined the concept of material landscape as the physical attributes which common characteristic is its spatial nature (Farina 1997). Thus, the analysis of the material landscape is based in its spatial classification according similarities and differences (Forman and Godron 1986, Naveh and Lieberman 1990, Farina 1997). There are three main classification systems:<sup>1</sup> Thematic, Regional and Metrics (Antrop 2000). In this research I will use the second approach that considered landscape as a complex “whole”, which *“is more than the sum of its composing parts... indicating that all elements in the spatial structure of the landscape are related to each other and form one complex system”* (Antrop and Eetvelde 1998: 43-44). In turn, my interpretation of the landscape will try to establish the general structural characteristics of the landscape, and the process of applying this methodology will be described in the following section.

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<sup>1</sup> Description of each classification system in pages 24-26.

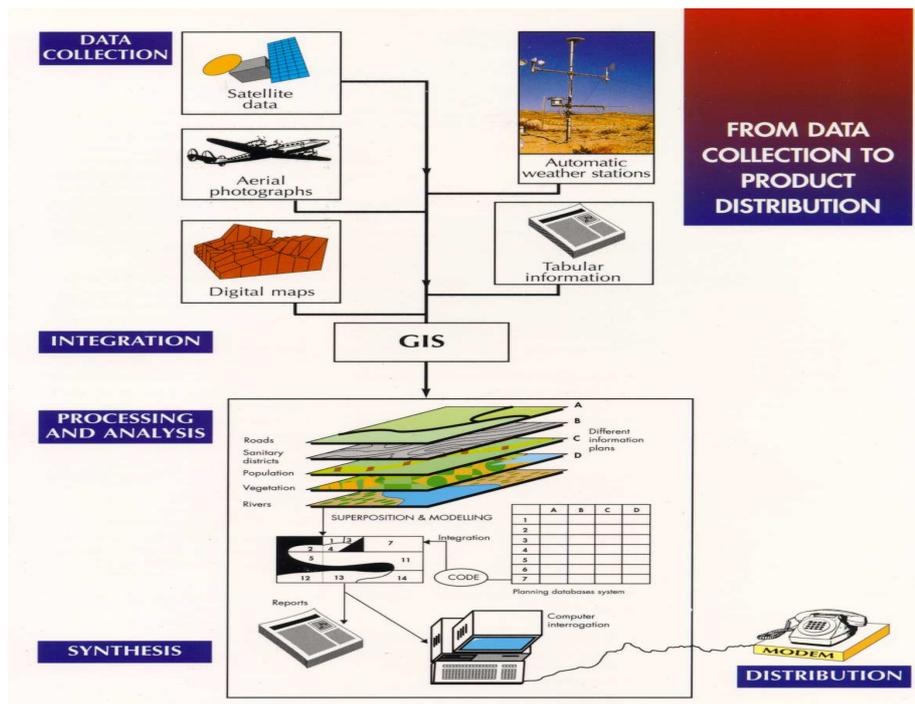
#### **4.5.1 Classifying Space and Mapping**

The first step is to organise reality, to find the categories that are relevant for our research, keeping in mind that they are abstractions able to reflect only a segment of the complex reality (Palacios 2004). Categories are the containers where I place my observation and give a meaning to the reality, and this process is decisively influenced by my *situated knowledge* (as I addressed in section 4.3), and in the main, the research objectives. My objective is to find spatial categories that are relevant to the particular studied landscape, a mining area in the northern Peruvian highlands. These spatial categories representations are visualised in maps.

*“Maps are graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes or events in the human world”* (Edson 1997 in Buckel 2004). Maps are very important spatial sources because they model and organize spatial reality according to some characteristics or themes (Antrop 1998, Palacios 2004). Each map represents a subjective ordering of the spatial reality. Maps visualize the spatial characteristics of the environment, but also communicate the perception of the map makers (Palacios 2004). My output, the landscapes maps, will not be an exception, since they represent landscape categories according to both actual reality and my own interpretation of such reality. The mapping will be carried out using GIS and Remote Sensing.

#### **4.5.2 The Role of the GIS and Remote Sensing (RS) in Landscape Studies**

The large amount of geographic data that can be considered important for Landscape studies makes GIS a powerful instrument in these studies. Geographic Information Systems (GIS) are computer-based systems for the storage, retrieval, manipulation, analysis, and display of any information that can be located on earth (Aronoff 1991, By and Kainz 2001, Longley et al. 2001). Localisation on earth in a computer system can be referred to as “geo-referentially”. Figure 4.1 depicts the basic characteristics of the GIS use, first, the collection of different types of spatial information, its integration in a GIS Data Base, and second, the further processing and analysis of the data on base to their location in order to produce a final synthesis. GIS also permits the analysis of spatial information in time. In my case study GIS was used to map the landscape throughout different years and to analyse the diachronic changes.



4.1 Basic Characteristic of the GIS (By and Kainz 2001)

Figure 4.1 shows that among the main sources of spatial information are remote-sensed data such as satellite images and aerial photographs. Remote sensing is considered the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Jansen 2001). In landscape studies, this type of information is considered very relevant, especially in *regional*<sup>1</sup> classification analysis, because each image can give a total overview of the surface characteristics of an area.

My research is based in Aero-Photo Interpretation (API). Interpretation of other remote sensing data as satellite images were not considered as an input for landscape mapping because they are generally in low resolution. It is agreed that remote sensing data must be available in a sufficiently high spatial resolution to capture important features such as linearity, which is indispensable for the evaluation of a landscape pattern (Lausch and Herzog 2002). For a similar case study, the landscape change in a open pit mining area, researchers recommended a spatial resolution of less than five meters (Lausch and Herzog 2002). In consequence, knowing most of the available satellite images such as Landsat and Aster have

<sup>1</sup> See subchapter 3.4.1

no less than 15m (per pixel) of spatial resolution, the main source of spatial information will come from Aerial Photos (AP), which, being a no-digital data, resolution depend upon of the scanning process and of the scale of the photo. Other spatial data that complement the API will be outlined in the following subsection.

**4.5.3 Materials**

The spatial analysis of the landscape change needs relevant spatial data of at least two stages in time to determine the positive and negative alterations from one time to the other. The spatial data is the data representative of values regarding a particular phenomenon, and its spatial location which could be relevant for the analysis of the data (By de and Kainz 2001, Longley et al. 2003). The main data was collected during field work, from June to August 2006. The ancillary data was collected from different sources, mostly in the field. The main data sources are:

**Table 4-1 Materials**

<b>Data</b>	<b>Year</b>	<b>Characteristics</b>
Aerial Photos	1993, 2000	Various
Digital National Chart		Based in scale 1:100 000
National Chart		Scale 1: 100 000
GPS observation points	2005	Description Land cover
Ground Photos	2005	Ground, scenery
Field Notes	2005	Various

**4.5.4 Mapping**

The process of mapping the landscape is divided in two steps, Pre- classification and Classification. Additionally a complementary technique to visualise three-dimensionally the area is also described. Different methods and techniques have been used in all this process. The software used was ArcGIS 9.1.

## Pre-classification

The *Pre-classification* consists in the preparation of the data before the final categorisation. The material base was the aerial photos of 1993 and 2000. It is considered that comparison of diachronic data sets needs to take into consideration the conditions of the data generation. One important condition of the study area is the large difference between the seasonal precipitations. Hence, during the dry season, most vegetation is extremely reduced due to drought; in contrast during the rainy season, all vegetation types are growing and vegetation patterns are better detected. Table 4-2 shows the four considerations of data selection: Scale, date, time and clouds coverage; these characteristics are similar in the two AP sets; therefore, the comparison is pertinent; both APs correspond to the drought season.

**Table 4-2 Aerial Photo Characteristics**

Characteristics	AP 1993	AP 2000
Scale	1: 15000	1: 17000
Date	4 June 1993	16 August 2000
Time	0930-1000	0930-1000
Clouds Percentage	0%	0%

The process to bring the APs into to a GIS environment starts with the scanning of the AP in a resolution of 300 dpi in format \*.bmp. Then, the 1993 AP was aligned with real world coordinates taken from the (digital) national cart (1:100000) files. The AP 2000 was geo-referenced using AP 1993 as a base, due to the fact that many of the geographic attributes observable in the National Cart has been changed in the last years by the mining operations.

## Classification

The *Classification* is based in *visual interpretation*. Human vision has the ability to organise and differentiate the different features it can recognise in an AP through the recognition of their shape, size, pattern, tone or hue, texture, geographic or topographic site and associations between features and identified objects (Lillesand and Kiefer 1994 in Jansen 2001).

The idea is to recognise different groups according to these elements, and draw the boundaries between them resulting in a vector-type map. This interpretation typically results in a thematic *Land cover* (LC) map (Antrop and Eetvelde 1998). Also, Farina (1998) and Lausch (2002) considered the identification of LC and *Land Use* (LU) is crucial to identify landscape categories. The Land Cover is considered “*something that covers the ground*” (Webster 1998 cited in Lund 1999: 115), the ground includes vegetation, water, ice, bare rock or sand surfaces and human constructions; the elements of physical environment that cover the land surface. Frequently LC categories are associated to Land Use, which refers to the employment of an area (Lund 1999) by cropping, pasturing, mining and others. In the practice, LU and LC categories are difficult to be separated, as in the case of secondary forests that have the same characteristics of orchards; in other cases the land uses of the same grassland cover can have mixed and variable benefits at the same time such as livestock breeding, collection of medicinal plants or fuel (Palacios 2004); moreover, the human use (LU) shapes the cover (LC), producing in many cases an indissoluble and unnecessary differentiation. In conclusion I will consider the theme Land Use-Land Cover LULC as my categorisation of the landscape.

The mapping process based in the visual interpretation of aerial photos, is supported by the information collected in the field. According to Wester and Oliver 2001, the aim of recording field data is to produce information in order to attach a meaning to the underlying data. Thus, the APs were attached to the field observation, it was carried out using a hand-held *Geographic Positioning System* (GPS) and a field notebook, at certain points photographs were taken; in many cases I asked local people about the uses and names of specific features and their information was crucial to define the landscape types. Still, the synthesis of all these information was leaded by my own understanding of the adequacy of the categories to represent the material landscape; as Antrop et Eetvelde 1998 argued the (material) landscape is as an objective reality, in whose classification there are subjective aspects to consider.

The landscape was categorised into eight basic landscape categories, the significance of each category is explained in the next chapter: seminatural grassland, sparse grassland, cultivated land (including hay and crops), mining, lakes/ponds, roads, rivers and buildings. It is crucial to give the same classes, and to attach the same meaning to them in my two temporal maps, to allow semantic inter-operability and further comparison.

### **Three Dimensional Mapping**

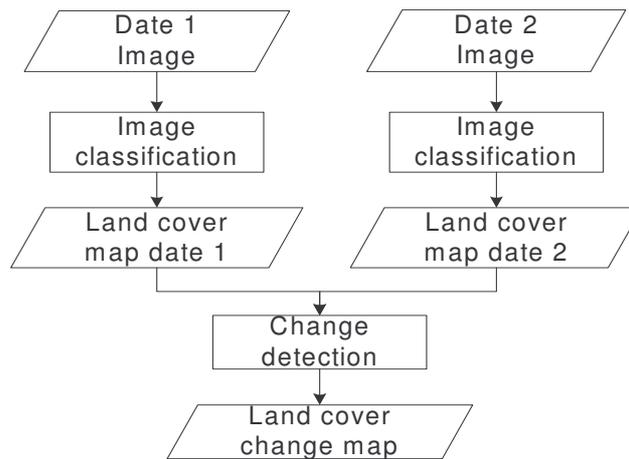
A relevant characteristic of the landscape in mountainous areas is the topography. In contrast to lowlands, the slope heterogeneity of highlands is larger and it has a strong influence in the vegetation and human use, hence, the topography is important in the representation of mountain landscape (Haberling and Hurni 2002) . New tools of exploration and presentation of spatio-temporal data have opened new perspectives in the visualization of the topography (Schmid 2001) and enhanced their capacity to represent possible morphological changes (Haberling and Hurni 2002).

Triangulated irregular networks (TIN) is one of the techniques to implement digital terrain models. They are built from a set of locations for which there is an elevation. Each point can be viewed as a point in three-dimensional (3D) space. From these points it is possible to construct a mosaic made by triangles (By and Kainz 2001). This mosaic illustrates 3D representation of an area. I used TINs to make 3D representation of landscape for each year. For 1993, I used the contour lines of each 50m of the digital national cart. For the year 2000, regarding the mining area whose topography has changed, I used elevation points taken in fieldwork and other points I assumed from the stereographic analysis, hence the result of the TIN 2000, will not be totally accurate; nevertheless, the importance to find and display possible morphologic changes makes the effort appropriate for the thesis objectives.

#### **4.5.5 Change Detection**

The objective of the spatio-temporal analysis is to identify differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multi-temporal data sets (By 2001). In the previous section the landscape maps from different dates are classified and labelled, then, the area of change could be extracted through the comparison of the classification results. Figure 4.2 shows the general process of change detection.

The comparison of the areas was made using and illustration the variation in the areas; also, to detect the change from one class to other, a GIS operation of overlapping was performed using ArcGIS 9.1\_ Spatial Analysis in Raster-Calculator. The results are described in chapter 5.



## 4.2 Change Detection Process

## 4.6 Interviews and Participatory Observation

The material landscape generates a variety of feelings, impressions and cognitive readings pertained to each individual but through socially constructed lenses (Meining 1979). My methods attempt to address this variety of feelings and impressions towards the understanding of how the local people perceive the landscape change; as it was referred in section 3.4.2 my approach try to find this information in the uniqueness of the individual experiences.

In my study I want to understand the perceptions of the local population, thus there is a need to find the adequate informants for the study. Qualitative methods are considered intensive because it is more important the case selection and the participants than the number of cases (Bradshaw and Stratford 2000). For my research, the relevant individual is those who were living, were making active use of the area where the mining company Yanacocha currently operates or are living in the neighbouring areas. These are the individuals who know the area better and are the long time users of the territory and of the available resources, and who have deep relations with the area in transformation. The purpose of informants' selection is directed at finding two groups, the people who have been in this area most of their lives and the people who is living in closer areas to the mining area, at the present time. The first group knows more about how was the area before the mining started, and how it has changed in the beginning; the second, is in direct contact with the transformation processes that are being produced by the mining, nowadays.

As mentioned in the previous section called “Study Area” in chapter 2, the Andean population does not live necessarily in villages. In the current mining area, some dispersed houses with families were dedicated to pastoralist activities. Some of them have family relations and land possessions in areas downstream of the study area, and many of them live in these areas now. Others do not have land in other areas, or have for other reasons migrated to the main city, Cajamarca. Finding this population was not easy because they are dispersed randomly throughout different areas, and because the tense situation between mining company and local population made the locals suspicious to “outsiders”. As it was referred, it was fundamental to have a local contact. The list of key-informants is presented in the following table.

**Table 4-3 List of Informants**

General		Place of Residence		Main Relation with the Mining Operations Area	
Informant	Work	Before Mining	Mining	Before Mining	Mining
Informant 5	Peasant	Village Tual	Village Tual	Temporary Herding	Cleaning of Canal that comes from mine area
Informant 6	Peasant	San Jose (Now Mine)	Village Tual	Residence and Work	Cleaning of Canal that comes from mine area
Informant 7	Peasant/ Shepherd	Quishuar Corral	Quishuar Corral	Temporary Herding	Temporary labour for MYSA/Neighbour
Informant 8	Shepherd	Quishuar Corral	Quishuar Corral	Temporary Herding	Neighbour
Informant 9	Peasant	Quishuar Corral	Quishuar Corral	Temporary Herding	Neighbour
Informant 10	Peasants (Group)	Los Alisos	Los Alisos	Cleaning of Canal	Nothing
Informant 11	Peasant	Huambocancha Alta	Huambocancha Alta	Temporary Herding	Cleaning of Canal that comes from mine area
Informant 12	Small merchant	Maqui-Maqui (Now Mine)	Cajamarca City	Residence and Work	Nothing
Informant 13	Unemployed	Maqui-Maqui (Now Mine)	Cajamarca City	Residence and Work	Nothing
Informant 14	Unemployed	Maqui-Maqui (Now Mine)	Cajamarca City	Residence and Work	Nothing

While interacting with people, the researcher needs to take into consideration some aspects of the complexity of the social interactions. In the social interaction the researcher can not separate him or herself from the subject of the research (Winchester 2000). The only way to be constantly aware of this process and of the role of subjectivity is through reflexivity, constant critical reflexivity about what I do to answer my research objectives. The objective was to collect information from the local population, so the important task was to try to understand how the local population categorized me and how that could affect the information. In the social process the *roles* and *status* I have in the informants' eyes could significantly affect the information I gathered.

*Status* refers to the role that you assume in the society in the mind of your informants. The role expectations that you can evoke in the informants can yield a biased answer. Since the beginning I tried to stress that my position in fieldwork was as a student, and for instance, to diminish my power position. I think, in my case, it was also important to come from another Andean area, to have similar physical features and to know the general costumes and traditions to be accepted as student, and on this then, obtain trustworthiness and rapport with the local people.

The method applied was semi-structured interviews. This technique employs an interview guide<sup>1</sup> that is organized by the researcher through flexible questioning (Dunn 2000). This kind of interview structure focuses on the main topics that are considered important for the researcher. Each person's information can be different and independently relevant, but in order to find out comparable answers certain aspects are addressed. The use of structured interviews was not carried out because I decided that asking the same questions in the same order to each informant would not help going deeply into the aspects I considered important to answer my research questions. As outlined before, interviewing is not simply put into practice as a straight forward methodology to obtain the information in the form of words from the "studied" people. It involves a power relation and an encounter between two subjectivities (Fontana and Frey 2003), and each subjectivity is influenced by its personal and cultural background. Information will be different according how people perceive the researcher, and the role that the researcher has in their view.

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<sup>1</sup> See Appendix

Most interviews were realised in the informal context of the daily activities of the people, such as walking to clean the canal, washing clothes or taking the animals to the grassland. After introduction and some conversation, I asked if I could write down the answers assuring strict anonymity. Normally I did not ask the names of the informants, as I considered that important in the context of the tense situation between local people and the mining company. Often the interviewee elaborated very extensively on some topics that were outside the question addressed. The interviewees addressed areas that were most important for them to raise, which was probably due to the described tense situation where the parties tried to emphasize their specific positions and opinions. At the same time, it was important to write a field journal of the main impressions and observations related to the research. It applies to give a context to the interviewees' answers.

Having collected the data through mapping, interviews and participant-observation, I used the results of the map analysis to identify the main physic landscape changes, and the interviews-observation to explain the changes and to understand the consequences of the landscape change in the perceptions of people. The triangulation of spatial analysis, participant-observation, and interviewing was necessary to explain and interpret the process of landscape change and their consequences.

## 5 RESULTS

### 5.1 The Landscape Change (Objective 1: To assess the physical landscape change)

#### 5.1.1 Landscape Categories

All categorizations are attempts to organize reality, to make it comparable, to represent a model, a simplification of the reality. These categories are used to classify the two sequences. Based in observation and ancillary data, as it is explained in chapter 4, Methods; I found the following categories as relevant: semi-natural grassland, sparse grass, cultivated land, mining area, lakes/ponds, rivers, roads and local buildings (Table 5.1). The description and significance of each category will be described in this section.

**Table 5-1 Categories of landscape elements**

Zonal	Linear structures	Small point elements
Seminatural Grassland	Rivers	Buildings
Sparse Grassland	Roads	
Cultivated Land		
Lake/Pond		
Mining		

#### **Semi-natural Grassland:**

Since I arrived to the study area I could recognize, everywhere, dense stands of bunch grasses including fescue (*Festuca spp.*), needle grass (*Stipa spp.*), bluegrass (*Poa spp.*), and mainly, reed bent grass (*Calamagrostis sp.*), forming tufts that according to Stratus (2004) can occupy 0.25 to 0.75 m<sup>2</sup> in basal area and reach 1 m in height if not burned or grazed. It is possible to find these bunches together with small patches of shrubs like *Werneria nubigena* and *Isostes sp.* (Sanchez et al. 1993), and patches of marshes, springs, and other areas with poor drainage usually dominated by sedges and rushes (Bazan et al. 1995). In the northern Peruvian

highlands, where my study area is situated, these bunches (and the region where they grow), go by the name *jalca* or *ichu*. In the central and south of Peru similar vegetation it is called barely *ichu*.

According to Pulgar-Vidal (1996) *ichu* is the dominant vegetation between 3500 and 4500 masl. At this altitude, only slow growing species are adapted to low-nutrient availability, resistance to desiccation, and cold temperature. The native species rely on the storage of nutrients in large root structures and the accumulation of organic matter in surface soils for their development and survival. The root systems allow storage and internal cycling of nitrogen in an environment where rates of mineralization and nitrification in soils are low. In addition, the root structure provides access to deep soil water during the dry season (Neotropical 2006).

The *jalca* formations of northern Peru have supported pastoral residents for over 3,000 years (Rostworowski 1981). This long term use of the area has influenced the dominance of grassland (Young 1998) through the common practice of grass-burning in these areas, avoiding a possible transition to other vegetation types. Mostly perennial, the *jalca* or *ichu* covers the land almost completely (fig. 5.1), with very little bare ground composed usually by rock, becoming the main source for the sustenance of the livestock and hence the primal resource for the mainly pastoralist-based economy of the high uplands. Among the most important forage grasses are *Bromus spp.*, *Calamagrostis spp.*, *Festuca spp.*, *Muhlenbergia spp.*, *Nasella spp.*, *Poa spp.*, and *Stipa spp.* (Bazan et al. 1995).



### 5.1 Seminatural grassland is the dominant cover in areas between 3500 and 4500 masl.

## Sparse Grassland

The highlands are covered mainly by semi-natural grass vegetation as it was described in the previous category, but in some areas the vegetation cover is reduced to a mix of grass and rocks, or grass and barren ground. The approximated grass cover percentage lies between 30 and 70. The factors of minor grass cover in certain areas are natural and human; the main natural factors are the steep topography that facilitates erosion and the loss of fertile soil, together with human factors as overgrazing and mining. The main species are also *Festuca spp.*, *Stipa spp.*, *Poa spp.*, and mainly, *Calamagrostis spp.*



### 5.2 Sparse Grassland in areas around mining

## Cultivated land

Cultivated land is the ground that has been prepared to raise hay or crops. Mostly it is used with the first purpose. The cultivated forage species are *Vicia atropupurea*, Rye grasses – *Ecotipo caj* and *Ingles arias*, *Pactylis glomerata* and different types of *Trifolium spp.* (Adefor *Unknown date*). The Rye grasses are most commonly grazed on (Informants 5, 8 and 10). Besides that, sometimes small-temporary plots are used for the cultivation of food products resistant to frost damage, such as potatoes (*Solanum tuberosum*) and other tubers such as oca (*Oxalis tuberosa*), mashua (*Tropaeolum tuberosum*) and olluco (*Ullucus tuberosus*), which usually are intercropped among themselves.



**5.3 The more abundant cultivated hay is known as Rye grass.**

### **Mining area**

The area where MYSA carries out its operations is characterized by barren ground with some patches of water, grassland and buildings. MYSA removes 70,000 tons of material daily (Ingetec 2003), which produces new features in the terrain. The main features in the mining landscape are the open-pit, the leaching pads and the waste dumps, these features are possible to be seen in the three-dimensional representation of 2000 (fig...).

The *open-pits* are the areas of extraction of the earth material; this procedure involves the excavation and extraction of important volumes of clearing materials. Original superficial water of the area is controlled by the use of derivation channels, the entrance of underground waters is controlled by pumping wells and the slopes of the edges are partially cement-protected against the erosion (Stratus 2004, Ingetec 2003, Yanacocha 2006). The extracted material with valuable mineral goes to the pads, the rest to the waste dumps.

The *leaching pads* are the heaps where material with value is deposited to be leached. This procedure implies the process of agglomeration of the very fine particles with valuable minerals (gold derived). The first step is the deposition of the material in layers on leaching fields previously conformed and waterproofed. Next, the layers are irrigated with a sodium cyanide solution that is applied by means of installed networks of irrigation on each layer. Then, the rich solution that has filtered through the layers, drains to derivation channels and

flows to storage wells from where it is pumped to a plant of metallurgical processes (Ingetec 2003, Yanacocha 2006). MYSA has the largest pad of the world (Stratus 2004).



#### **5.4 Mining facilities: pit (below), waste dumps (left) and pads (right)**

The *waste dumps* are the heaps of the non apt material for metal extraction, previous separation in materials potentially generating acidity, and potentially non-acidity generating materials. Materials with potential acidity generation are encapsulated with layers of non-generating acidity material such as clay, to isolate them of the subsoil and the atmospheric water and oxygen (Ingetec 2003, Yanacocha 2006).

## Lake/ Pond (Water Body)

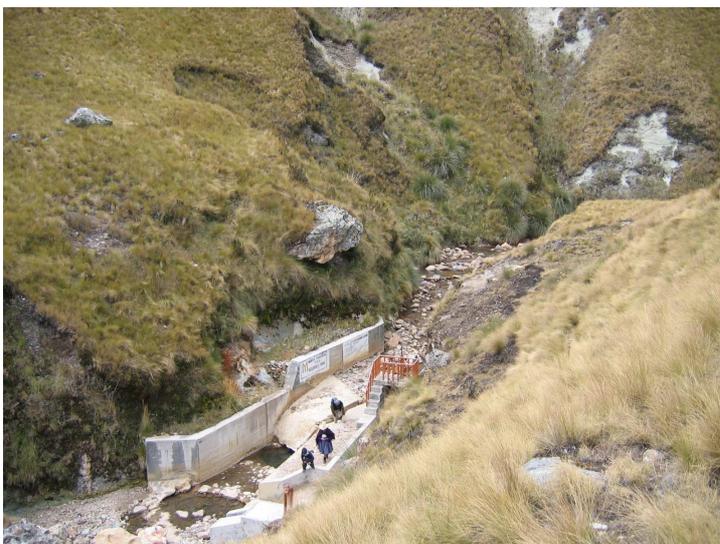
Lake and Ponds are bodies of water surrounded by land. In this group I consider all the bodies of water excepting rivers and groves. In the area there are water-bodies of different size and volume, from lakes to small ponds (locally named as *ojos de agua* or water's eyes). Figure...



**5.5 Pond close to mining area.**

## Rivers

Under this name I include the natural waterways. The study area is the origin of several waterways correspondent to gorges or ravines. I include them in this category.



**5.6 The waterways on the highlands are gorges or ravines.**

## Roads

I consider the ways used for motor transportation as roads.



**5.7 Road between Tual and Cince.**

## Buildings

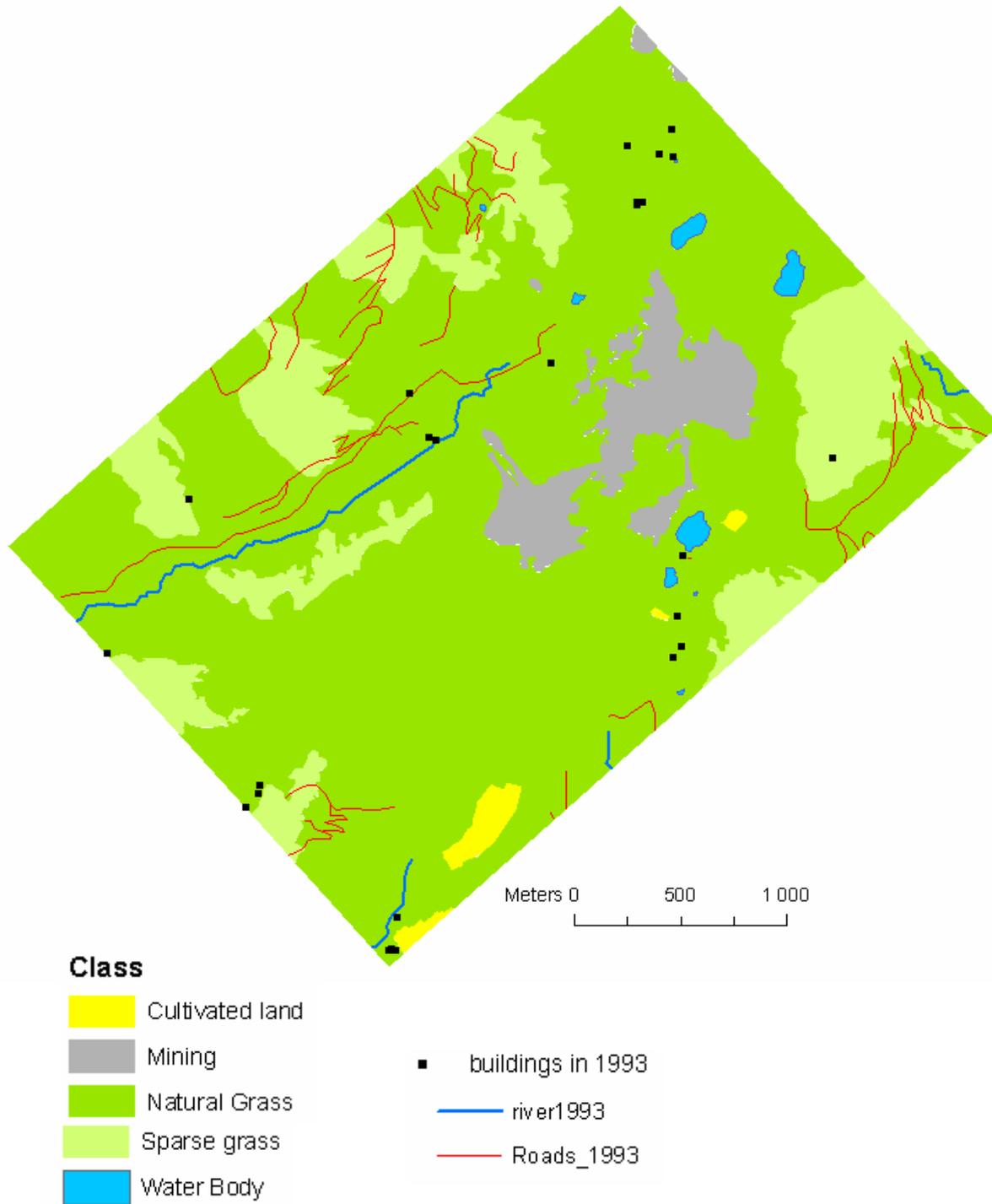
The buildings category corresponds to the human settlement. The characteristics of the buildings are very differentiable, from small small huts made by stones and plastic to big houses.



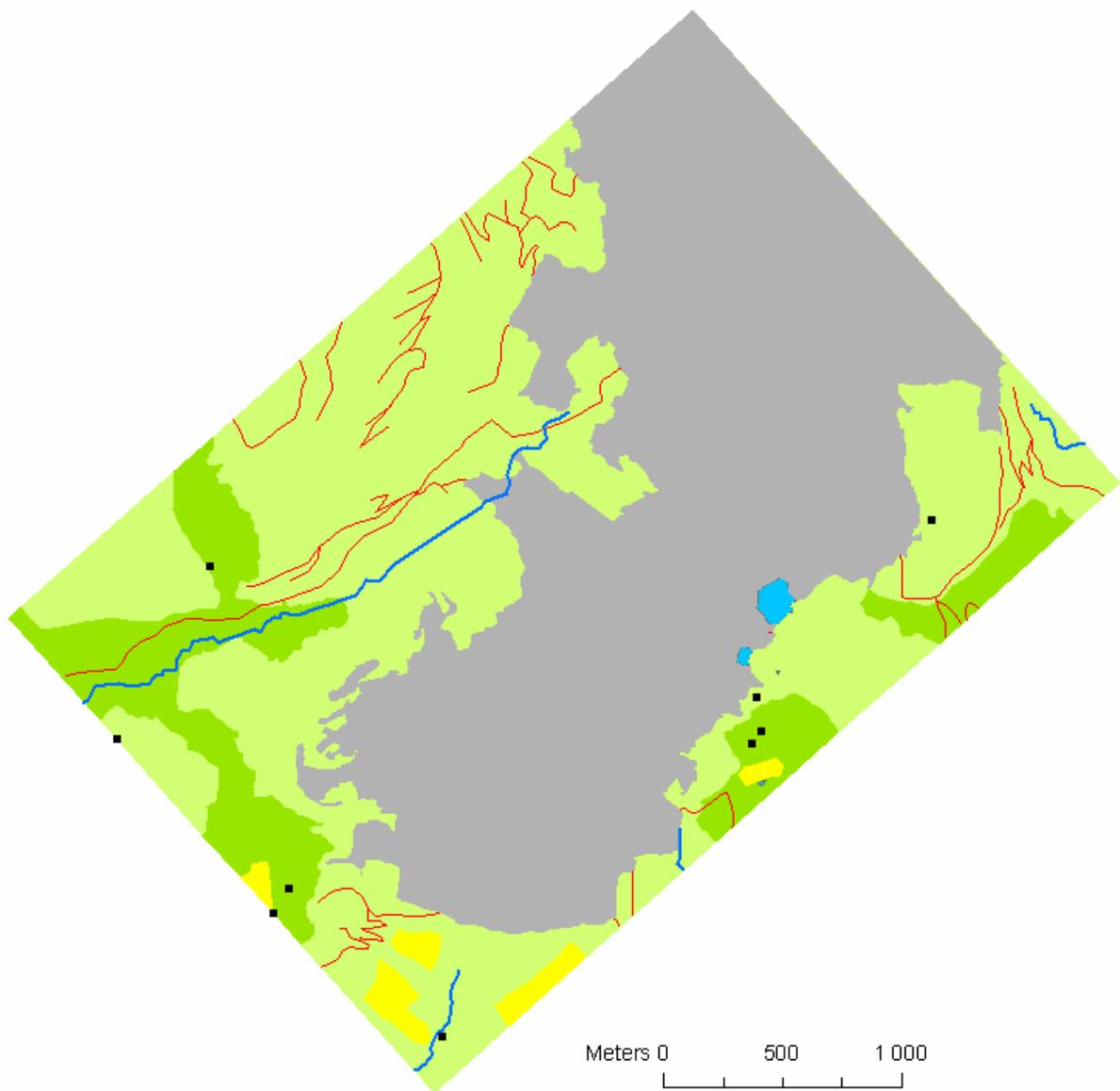
**5.8 Hut and new house in area of Quichuar Corral.**

## 5.1.2 Comparison of Landscapes

The result of the *regional* classification approach is depicted in this section. First, I will describe the results of each year, and then explain the main trends based upon tables and graphics. Figures 5.9 and 5.10 shows the LULC 1993 and 2000.



### 5.9 Land Use –Land Cover in 1993



**Class**

 Cultivated land

 Mining

 Natural Grass

 Sparse grass

 Water Body

 buildings in 2000

 river2000

 Roads\_2000

**5.10 Land Use- Land Cover in 2000**

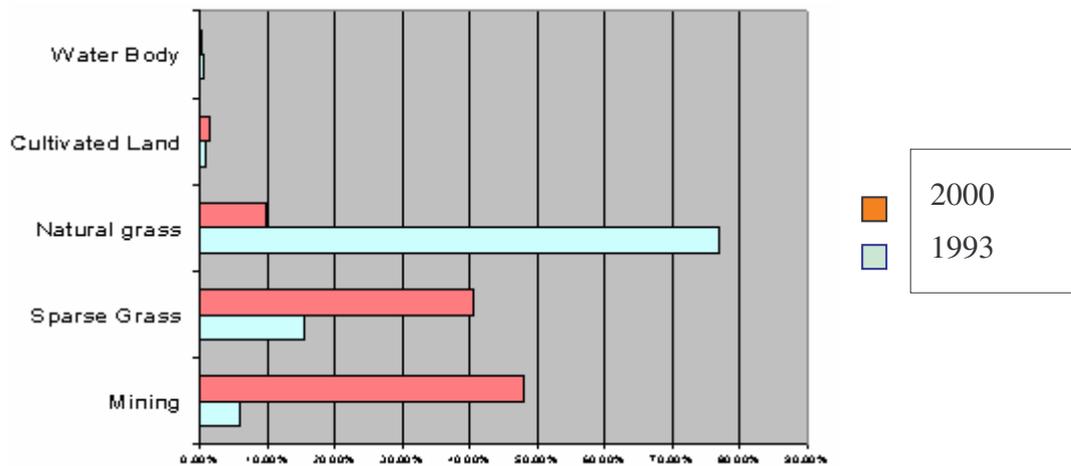
Figure 5.9 presents the landscape in 1993. The main characteristic is the presence of abundant semi-natural grassland (77%), extended for the whole area. There are also large patches of sparse grassland mainly in the highly eroded steep areas on the mountain hillsides, and portions of cultivated land (0.9%), in the low elevation areas of the south west. Where moisture accumulates, there are some patches of cultivated land. Those lands classified into the lakes/ponds class are mainly in the East. Most of buildings are along the rivers, and one road that connects the area goes parallel to the river Encajon. However most of the roads do not connect with the outside, instead they have dense presence, as it is observable in the east; probably they serve to the exploration and preparation of the mining facilities. The mining area is completely bare of vegetation, and at that year, 1993, the mining area was in preparatory stage, representing only 6% of the total area.

The map of 2000 (fig. 5.10) illustrates that half of the study area is covered by mining (48%), which takes up the east area completely. Sparse grassland is also a dominant feature (41%), covering all the area around the mine and the north of the area. Semi-natural grassland is displayed by a continuous patch along the river of the north and small patches in the west and south that cover only 10%. Most of buildings are displayed closer to the cultivated land in the southwest. There are two lakes in the south. The concentration of the roads goes to the hilly lands north of river Encajon.

As can be seen from a comparative visualisation of the maps, the landscapes from 1993 and 2000 are very different. A quantitative examination of the categories areas is displayed in table 5-2 and figure 5.11.

**Table 5-2 Landscape areas 1993 and 2000**

Zonal Land Cover	Percentage_1993	Percentage_2000	Difference
Seminatural grassland	77.13%	9.76%	-67.37%
Mining	5.81%	47.98%	42.17%
Sparse Grassland	15.59%	40.66%	25.07%
Cultivated Land	0.89%	1.35%	0.46%
Lakes/Ponds (Water Body)	0.58%	0.25%	-0.33%



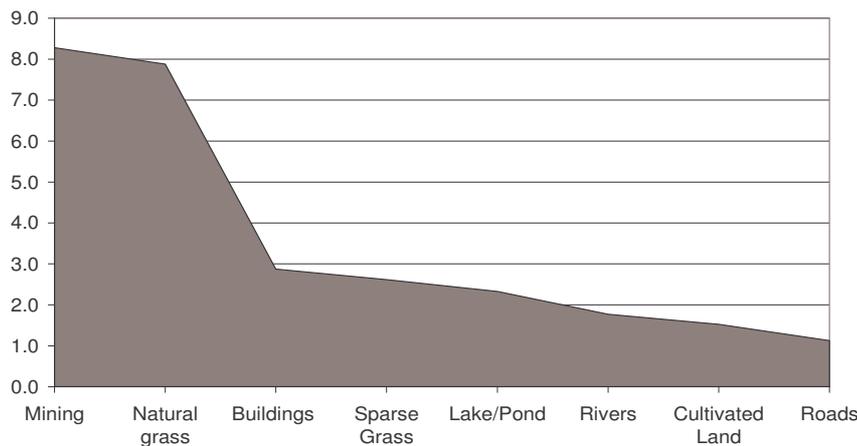
### 5.11 Quantitative comparison between the zone categories 1993 and 2000

Table 5-2 and Figure 5.11 illustrate a great variation during a period of only seven years. The natural grassland disappeared in 67% of the whole area; mining increased in 42%, sparse grassland increased also in 25%, cultivated land in 0.5% and lakes/ponds are reduced in 0.33% of the area. These results are representative but they do not illustrate the non-zonal categories such as roads, rivers and buildings, and the proportional significance of the landscape change in each category. Changes of small categories as lake/ponds are difficult to identify. In the next table and figure it is possible to identify this characteristic better.

**Table 5-3 Change Proportion**

Zonal Land Cover	1993 (Ha.)	2000 (Ha.)	Change Proportion	Trend
Mining	60.3636	499.7652	8.28	Increasing
Seminatural Grassland	800.8196	101.6232	7.88	Decreasing
Sparse Grassland	161.8304	423.4688	2.62	Increasing
Lake/Pond	6.0256	2.5924	2.32	Decreasing
Cultivated land	9.2436	14.0776	1.52	Increasing
<b>Linear Structures</b>	<b>1993 (m.)</b>	<b>2000 (m.)</b>		
Rivers	6691	3779	1.77	Decreasing
Roads	17567	15571	1.13	Decreasing
<b>Point Elements</b>	<b>1993 (Units)</b>	<b>2000 (Units)</b>		
Buildings	23	8	2.88	Decreasing

CHANGE PROPORTION



### 5.12 Change proportion per each category

Table 5-3 and figure 5.12 illustrate that the largest propositional change has been made in the category of mining, which has increased its 1993 size by eight times; but also the semi-natural grassland has changed eight times, though in inverse proportion. Proportional changes of other classes are not so dramatic but they are still important: Buildings occupy a third of their previous area, sparse grassland occupy three times more, lakes/ ponds and rivers reduced their extension twice, cultivated land and roads changed less than once, cultivated land increased and the length of roads diminished.

A small quantitative analysis displayed huge changes in seven years, being characterised specially for a total and proportional reduction of the semi-natural grassland and increase of the mining area. However these results are important, they do not show the nature of the evolution of one class to another; to know which categories have become an area of mining, sparse grassland or other categories, it is necessary to overlap the areas. The result is presented in the next section.

### 5.1.3 Categories Change

Table 5-4 shows the table resulted for the overlapping of LULC maps.

**Table 5-4 Categories Change 1993-2000**

Category	Area_ha	Percentage	Change/Stability
Seminatural Grassland to Mining	403.24	38.84	Change
Seminatural Grass to Sparse Grassland	291.26	28.06	Change
Sparse Grassland to Sparse Grassland	124.55	12.00	Stability
Seminatural Grassland to Seminatural Grassland	91.80	8.84	Stability
Mining to Mining	60.32	5.81	Stability
Sparse Grassland to Mining	28.12	2.71	Change
Seminatural Grassland to Cultivated Land	13.91	1.34	Change
Sparse Grassland to Seminatural Grassland	9.12	0.88	Change
Cultivated Land to Sparse Grassland	5.67	0.55	Change
Lake/Pond to Mining	3.75	0.36	Change
Cultivated Land to Mining	3.57	0.34	Change
Lake/Pond to Water Body	2.06	0.20	Stability
Seminatural Grassland to Water body	0.52	0.05	Change
Lake/Pond to Sparse Grassland	0.20	0.02	Change
Mining to Sparse Grassland	0.04	0.00	Change
Lake/Pond to Seminatural Grassland	0.01	0.00	Change

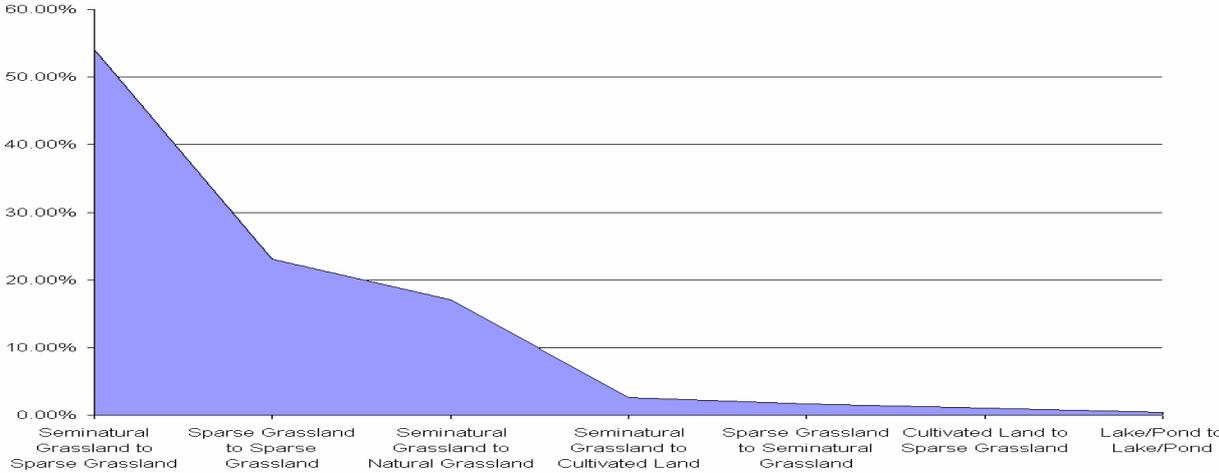
As seen in the table 5-4 the main category of change has been the transformation of semi-natural grassland in mining area, 39%, and sparse grassland, 28% of the total. The other

percentages are more moderate; sparse grassland converted into mining accounts for 3%, natural grassland into cultivated land for 1.5%. The other categories changes account for less than 1%. The result shows 73 % of change for the whole area in 7 years, and only 27% of stability.

Another interesting quantitative analysis is related with the area outside the mining. Table 5-5 and figure 5.13 shows the main change characteristics on this area- This area represents half of the study area, this area is not directly affected by the mining cover, but it present also large changes. The most significant is the transformation of seminatural grassland in sparse grassland. Figure 5.13 illustrates that it represents more than 50% of the area outside mining. The change rate is of 52% and 48% of stability.

**Table 5-5 LULC Change Outside Mining Area**

Class	Area_ha	Percentage	Change/Stability
Seminatural Grassland to Sparse Grassland	291.26	28.06	Change
Sparse Grassland to Sparse Grassland	124.55	12.00	Stability
Seminatural Grassland to Seminatural Grassland	91.80	8.84	Stability
Seminatural Grassland to Cultivated Land	13.91	1.34	Change
Sparse Grassland to Natural Grassland	9.12	0.88	Change
Cultivated Land to Sparse Grassland	5.67	0.55	Change
Lake/Pond to Lake/Pond	2.06	0.20	Stability
Seminatural Grassland to Lake/Pond	0.52	0.05	Change
Lake/Pond to Sparse Grassland	0.20	0.02	Change

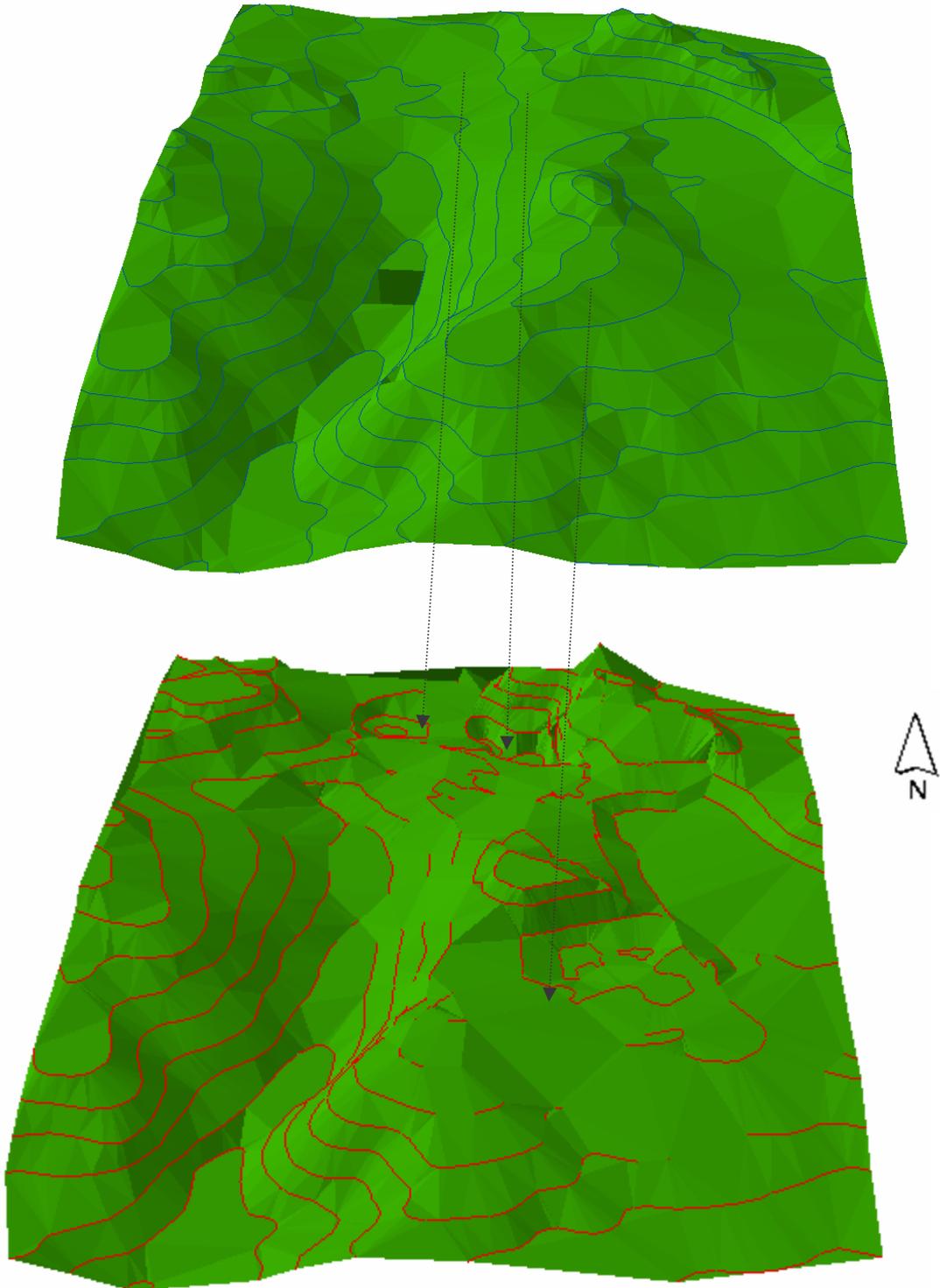


**5.13 LULC Change 1993-2000 (Percentage only Outside Mining Area)**

A general conclusion of this analysis is that mining is the main force of change, producing a huge transformation in the area. However, this analysis does not explain the morphological change of the area. In the section 5.1 it was described that mining facilities change the morphology as well, visualisation of this change will be displayed in section 5.1.4.

#### **5.1.4 The Three-Dimensional Maps**

Most of human activities do not change the landscape as much as mining does; the extraction of large masses of earth materials changed the morphology of the study area. To address the possible changes in a spatial analysis, effort has been made to sketch contour lines and to create a TIN 3D-image to have an overview of the landscape change. In figures 5.14 it is possible to see the drastic change in the mining area, the most notable is the creation of pits in part of the hills. The perception of these landscape changes will be described in the next section.



THE CREATION OF OPEN-PITS IS A RELEVANT CHANGE OF THE STUDY AREA

#### 5.14 3D representation landscapes 1993 and 2000

## 5.2 Perceptions of the Landscape Change (Objective 2 :To describe the local people's perceptions)

Landscape as a mental dimension is built on the basis of feelings and reasons. To address this dimension I consider important to approach the pre-mining period, and from this point direct to the mining period, the changes and their imprint on the area and on the people.

### 5.2.1 The Pre-mining Landscape

The mining activities transformed a pastoralist area with a low population density, an organization system, a social structure and a particular interaction and interpretation of the landscape. In the coming paragraphs I will try to reconstruct the landscape before the mining through the memories of people who were living in that area.

Yanacocha owns the property of approximately 160 km<sup>2</sup> (Stratus 2004). Information about the number of families that lived in this area varies from 40, 50 (Informant 6 and 12) to 100 families (Informant 13), even the number raises to 400 (Informant 14). It means a control over 40 to 400s hectares per family on average.

This area was always used for livestock pasture, since pre-hispanic time (Bury 2004). In the 1950s and 1960s, under the system of private *haciendas*<sup>1</sup>, it supported the intensive grazing of a large amount of livestock, especially sheep; “*I participate, together with other kids, in the herding of a flock of more than 10000 merinos*”<sup>2</sup> (Informant 6). After the Agrarian Reform in the 1970s, the change of the property brought a less intensified use of the land by the new landholders, who were people that lived in the area, in dispersed houses near the numerous springs and ponds, and mostly as shepherds of the landlords. Due to the low population density, the new landholders received a large number of hectares per family. This gave access

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<sup>1</sup> *Hacienda* was a system of large land-holdings pertaining to an only landlord or family. Mostly, the landlord had also the control of the people who lives and worked in the *haciendas*.

<sup>2</sup> Sheep *Merino* is consider one of the complete types of sheep for his fine-abundant wool and intermediate size.

to the most important resource, which constitutes the base of the livelihood activities, the natural capital composed of land and water resources (Bury 2004).

The wide access to land and water in these areas permitted the prospering of an extensive animal-husbandry activity. This has been the main use of these areas and together with the social connections among the population of lower areas; facilitated the interchange of animals for agricultural products, and allowed the access of products across different altitudinal production zones. Also, the constant availability of the resources such as grassland and water permitted the use of these areas for the grazing of livestock from lower areas in the dry season, and mainly in periods of drought. (Informants 5 y 6)

The number of livestock that grazed in the area is unknown, but according to the people who were living in the area...*“there were large amounts of livestock, especially sheep, from 200 to 300 per family; cattle from 100 to 500 per family. The total amount of alpacas (Lama pacos) was probably around 300; horses, mules and donkeys, from 100 to 200; pigs, 300 to 400 and the smallest fraction, goats, from 20 to 30 in the whole area”* (Informants 5, 6, 12, 13 y 14). *“When SENASA (National Service for Agrarian Health) came to vaccinate the cattle, there was not space for anything else”* (Informant 12). Though the number of animals could be exaggerated in the memories of the informants (if there is an average of 250 cattle and 100 families, it will give only 0.64 ha per each cow), the reference of the large livestock number was a common pattern of the people’s discourses and indicator of the importance of animal husbandry for their use of the space and construction of the landscape.

The husbandry system was characterized by the active herding of some stock, while others as the pig flocks were living by their own in the large plateaus *“the pigs were like wild animals, they were dangerous and lived in groups in the caverns”* (Informant 5). In general, the livestock raising was practiced in an extensive manner with little input and almost without, the cultivation of fodder crops. The feeding method constitutes an extensive exploitation of natural grazing lands entailing moves over varying distances, *“I have been walking days and days with the herds, I have made all the (mining) area by foot or horse”* (Informant 6); and in some cases, the cultivation of fodder crops to supplement herd nutrition, mainly for milk cattle *“the cattle with only “jalca” can not produce milk”* (Informant 13). Flocks from different families mixed also under the conduction of groups of shepherds; and in this way the different families opened and consolidated social relations *“I did not know other people*

*until I started to shepherd,...I had a great time with the other kids*” (Informant 6). The shepherds were mostly young members of the large family. The main incomes came from sheep selling, *“from time to time, merchants from the city, came to buy animals”* (Informant 14) and the weekly trade of cheese in the lower areas *“Each Sunday we used to go to Combayo to sell cheese in the market”* (Informant 13).

The extensive system of animal husbandry was possible due to an abundance of natural grassland in the area, *“the pastures never were a problem, even in the driest periods were pasture and water were sufficient”* (Informant 12). Because these tussocks were too hard to be eaten by the animals, a traditional method was to burn them before each rainy season to permit the growing of palatable grass, *“in order to have a new green pasture, each year it was necessary to burn the jalca”* (Informant 5, 7 and 13). Another types of grassland was the pasture that grew in the plain areas and wet areas, mainly dominated by clover (*Trifolium spp.*), *“closer to the water and plain, there was not jalca, it was called “mermes””* (Informant 14).

The *ichu* was not only used as forage; it was also, dried and used as construction material to solidify the mud’s bricks known as *adobes*, to make the roofs of the houses and as material for mattresses. It was a merchandise to be sold in the city to the bricks factories. Nowadays, this system of bricks fabrication is only used in the rural areas. *“We went to the city carrying the straws in mules and donkeys; it was an income when we were in necessity”* (Informant 5).

Other associated benefits of this vegetation were environmental: *“the jalca is excellent to protect the steep areas form erosion”* (Informant 5), and it was also used as a last resource in difficult times: *“the jalca was very important as food in time of dearth or famine”* (Informant 8); or as fuel-wood for cooking and heating, especially small shrubs. For medicinal treatment it was also used: *“there was a person who knew about medicinal plants, like a doctor. The plants were the cure system, in extreme cases it was necessary to go to the city”* (Informant 12). Also a few trees such as quinauales (*Polylepis racemosa*), and quishuares (*Buddleia incana*) were growing in that area, but they were planted by the people to have better fuelwood.

The wildlife was mostly located in the steep sites of the hills and in rocky areas characterised by difficult access and sparse grass cover. On these areas the pasture grows with difficulty,

and according to the informants it was the habitat of the main wildlife species, “*in the rocks it was possible to find numerous species of wildlife as vizcachas, (Lagidium peruvianum), deers (Hippocamelus antisensis) and foxes (Pseudalopex culpaeus)*” (Informants 13 and 14).

The water resources were referred to as abundant by my informants “...*even in the driest periods we had enough ... water*” (Informant 12), “*there were hundreds of “ojos de agua” (small ponds), the water was of good quality*” (Informant 6). The water use is described as follows: “*The water for house living was one exclusive pond while others were reserved for washing and others for the animals*” (Informant 12). “*Some ponds and lakes have movement “it runs”, this is an important characteristic for the good quality of the water*” (Informant 6), even some have medical properties “*because their minerals are good for the pest*” (Informant 14).

The landscape that exists in the memories of the local people changed when MYSA started its operations in 1992.

## **5.2.2 The Mining Period**

The MYSA district<sup>1</sup> has some historic antecedents of mining activity, beginning with extensive pre-Inca and Inca mining of cinnabar, and continuing during Spanish colonization. After a long period without any mining activities, between 1968 and 1973 exploration of base metal potential was made by a Japanese company and St. Joe Minerals (USA). BRGM (*Bureau de recherches géologiques et minières*, France) followed up the exploration and found a small gold resource. In 1983, Newmont joint ventured the property and focussed exploration on the gold potential (Stratus 2004). These historic events were not significant to my informants, only one referred “*first, the Japaneses came, they brought big machines (probably for drilling), but suddenly they left*” (Informant 5). Local people started to notice the upraising of the mining activities when in 1990 and 1991, land dealers started to buy the

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<sup>1</sup> It refers to the whole property of Yanacocha SA that extends by an area of 160 Km<sup>2</sup>

land, the process of change of the land tenure was the first before the mining facilities preparation<sup>1</sup>.

After getting the land property of the area, the mining operations started in 1992 with the preparation of the facilities<sup>2</sup> in the area of Carachugo<sup>3</sup>, the production began in the last months of the next year, the first bar of gold was produced on August 17, 1993 (Newmont 2005). Since then, the mine has continued to expand. The Construction of the Maqui Maqui facilities began in July 1994 and mining started in October 1994. The third mine, San José Sur, began operation in 1996, and the fourth mine, Cerro Yanacocha, began project operations in December 1997. Production began at the fifth mine, La Quinoa, in September 2001 and at the sixth mine, Cerro Negro, in 2004 (Stratus 2004, Atkins et al. 2005), and currently continued in expansion.

In order to prepare the terrain for the mining facilities, one of the first actions were the demolishing of the peasants buildings, corrals another human construction...*“when we were leaving, I saw already the caterpillars started to wreck my house”* (Informant 6). At the same time, MYSA’s caterpillars started to remove the top-soil with all the vegetation above, storing them for further process of re-vegetation (Ingetec 2003, Stratus 2004). At that time, the grassland and cultivated land did not exist anymore.

After removing the topsoil and after the whole area had been exposed, was when the heaviest part of the mine process started: the development of the pits, leaching pads and waste dumps. The procedure of open-pit extraction of the mineral implies the excavation and extraction of important volumes of clearing materials using explosives. For the people who remained and the people of the neighbouring areas, the explosives were related to the death of animals and destruction of the wildlife...*“I saw many sheep and alpacas dying all around ...there were so many deaths that even the foxes did not want to eat them”* (Informant 12), *“all the vizcachas were blown up, there were only rests of them all around”* (Informant 13).

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<sup>1</sup> The process of changing of land tenure was very fast, and many local people claims to be obligated and cheated by the intermediaries of the mining. The ex-owners of the MYSA area considered themselves as one of the most affected by the mining, the produced possible biases of it were described in the section 4.

<sup>2</sup> See details in section 5.1

<sup>3</sup> Carachugo pertains to the part of the MYSA mining district that corresponds to the study area of this thesis.

The explosives and the intense use of big machinery opened the process of massive reallocation of material and the change of the morphology. The perception of this morphological process is alluded as... *“all the areas I used to go do not exist any more... the pampas (plateaus) are heaps and the hills are holes”* (Informant 6), *“even the names does not have sense anymore, we used to call this area “Pampa Larga” (Large Plateau), there is not plateau anymore”* (Informant 11).

Water is one of the issues where people have stronger opinions about change. All informants complain about the quality, but mostly the quantity of the water, *“there were so much water before in comparison to now, we never had any problem with water, now we are “fregados” (ruined)”* (Informant 10), *“before the ponds were never dry, even in the dry season; now they are mostly dry”* (Informant 9), *“what we are going to do without water?”* (Informant 7), *“before I could drink the water directly”* (informant 8), and some of them questioning the future, *“now we have water because the mining pump some water from the underground to compensate us, but what we are going to do when Yanacocha will leave?”* (Informant 6).

People who live outside the mining area do not feel only affected by the water quantity and quality, there is also a claim about the sediments blowing from the mining area and its consequences on the pastures...*“the dust covers everything, the animals do not want to eat these bunches”* (Informant 7), *“when the wind comes from this side, in the afternoons, there is only dust all around”* (Informant 8).

Another large change in areas outside the mining is the opening of roads, the new roads are opening the economy system of all the area to the general system. Due to the high demand of milk, the new roads that connect the different parts of the mine with Cajamarca city are being used for milky trucks to gather the production of the villages and take them to the factories of the city. Besides, this is the only constant system of public transport in the zone. The impact is that most of people are trying to cultivate pasture in order to have better forage for their cows, *“The truck comes everyday, I live mainly from my cows”* (Informant 11).

### 5.3 Summary of Results

*What are the physical landscape changes?*

- There are large changes, but the general total change of the area is at a rate of 75%.
- The largest proportional changes have been in mining and seminatural grassland, which have increased and decreased respectively eight times from 1993 to 2000.
- The main physical change is the transformation of seminatural grassland into mining
- The change outside the mining area reaches 52%, therefore not all the landscape change is caused by the increasing of mining area.
- The main physical change outside the mine is the transformation of seminatural grassland in sparse grassland.

*How is the landscape change perceived by the local people?*

- The pre-mining area is remembered as a land with a great availability of resources such as grassland and water; where grassland permitted the sustenance of large numbers of livestock.
- The irruption of the mining is seen as a violent process that has caused the death of animals and total transformation of the area.
- The change has provoked a shortage of water resources, and the degradation of grassland.
- The construction of roads has accommodated easier access to the city and the connection to the regional market mainly for milk selling.
- The change has provoked the loss of the sustenance for people who used to live in the area and the reduction of the main resources for people of the areas surrounding the mine.

## **6 DISCUSSION**

Chapter six presents an analysis of the results discussing the quality of the sources, the suitability of the applied methods and the analysis of correlation of the results.

### **6.1 Discussing the employed methods**

#### **6.1.1 Discussing the methods for spatio-temporal analysis**

Since I relied on map layers, an evaluation of the data quality and the methods employed to produce them will be carried out. Burrough and McDonnell (1998) suggest as important criteria to evaluate data quality: actuality, completeness, consistency, accessibility, accuracy and precision (also related to raster map resolution and the degree of detail) and sources of errors caused by data entry and manipulation. Some points of these criteria will be applied to the evaluation of my main data source: Two diachronic data-sets of aerial photos.

Following these criteria, I will analyse the challenge to incorporate aerial photos (AP) information in a digital platform. First, I consider aerial photos to be actual materials to support spatial analysis, as they show the stage of one area in a raw format, without attached interpretation, which could give some source of error. The scale is another important characteristic in relation to data quality; the large scales of the aerial photographs (1:15000 and 1: 17000) made feasible by scanning and the production of a detailed digital data set with a high resolution that allows identification of small real features such as houses.

One sensitiv part of the methodology after digitizing is georeferencing. The APs were referenced in relation to the national cart (1:100 000). This scale challenged the finding of concordant features in the APs, whose scale was larger. It could affect the quality of the georeferencing; referencing is a crucial process because it creates problems in further stages of data integration to other sources. In this case, I consider that the referencing was good enough according to the scope of the project and because no other spatial sources, apart of APs, were integrated in the analysis.

There are several methods to classify the landscape, and I chose the *regional*, which usually applies LULC classification by *Visual Interpretation*. Subjectivity of the interpreter necessarily affects the classification; to reduce it, I tried to incorporate other categorisation sources and the definition of what I want to represent in each category.

In the process of interpretation, the identification of categories, buildings and cultivated land was difficult. To find out buildings, stereoscopic visualisation was necessary; to differentiate cultivated hay of grassland, since hays are sometimes small patches between the grassland and the tones are very similar, I was guided by the rectangular shape of the cultivated lands.

One of the main methods to assert the quality of LULC mapping is the accuracy assessment with “ground truthing” data. Standardised processes of land classification used a system of sampling and collection of ground truthing in the field to get the accuracy of the classification. Before the field, I prepared a stratified random sampling for ground control, but I could not carry it out in the field because I did not get authorisation to enter the mine area to use the GPS there, as it was necessary. To deal with this challenge, I took diverse GPS points in different ground classes, noted descriptions and took pictures of them. This information was very useful in the process of interpretation.

The change detection method is challenged by the fact that errors in each individual classification map are propagated into the change map. In addition, though the technique of overlapping is simple, it is difficult to produce a comparable map easy to be visualised. These points were addressed explaining the categorisation system and visualising the rates of change by graphics and tables more than by maps.

In general I consider the methods addressed to the material landscape representation consistent and relevant.

### **6.1.2 Discussing the methods for perception surveying**

The main data are the local people's answers; these discourses are very sensible and vary according to different constraints of social relations such as gender, race, age; the methods to deal with such source of inconsistencies are based in the constant reflection of the research process and other qualitative methodology practices. They were depicted in chapter 4, but it is important to make clear that my purpose here is to open some reflections on the main potential biases on my application of these practices.

I consider the main source of bias to these results was sustained by the atmosphere of antagonism that exists, nowadays, in Cajamarca; between, mainly, local rural people and the mine. Since I considered only the information of one side in my research, the whole social picture is not illustrated. This heavy atmosphere affected the responses of the people in two ways; first, it reduced the trust on researchers; second, it made the discourses strongly influenced by narratives and counter-narratives. For many local people, everything related to the mine was completely negative (though for many of the mine officers I met, it was completely the opposite). I tried to diminish this bias source by not addressing directly for perceptions; instead, I asked for more "factual" information (see interview template, appendix 1); and through this way, to find the interviewee's perception of the pre mining landscape and the mining processes afterwards.

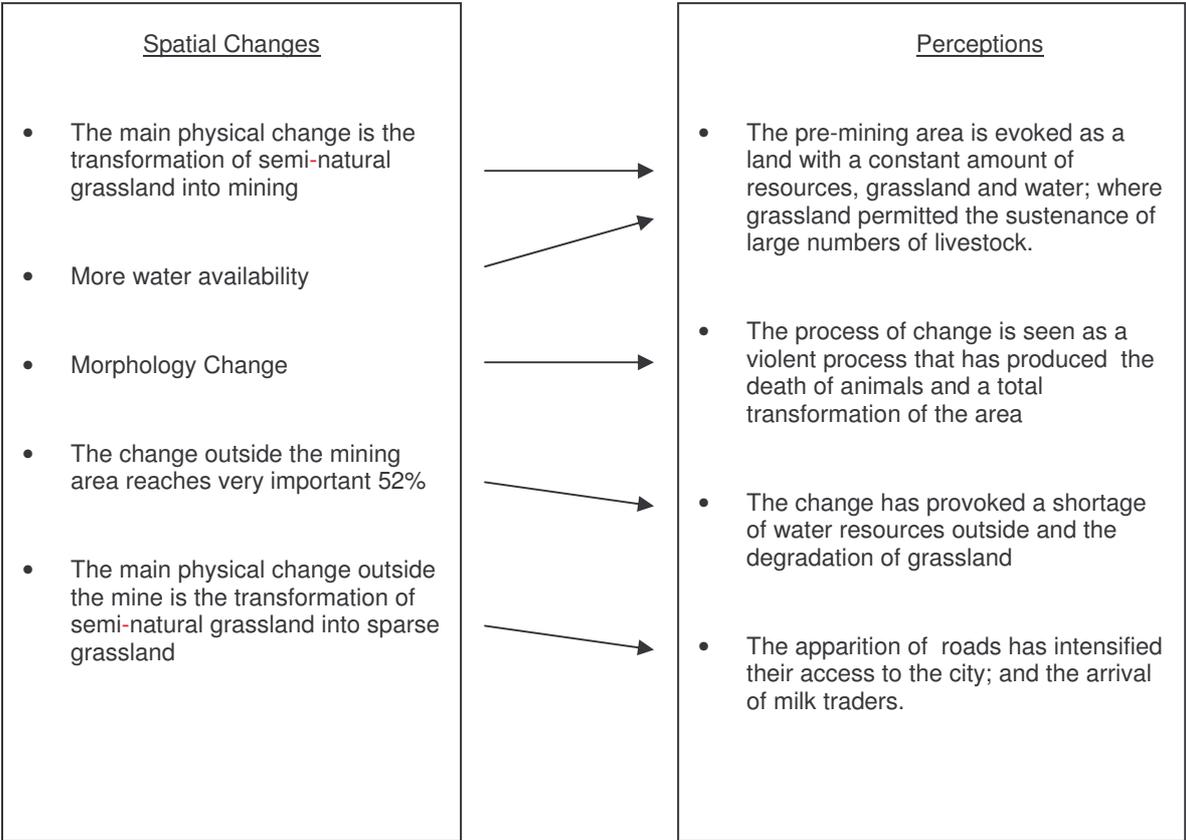
## **6.2 Relation between Spatial Changes and their Perception**

Landscape theory points out the significance to consider the two dimensions, material and mental, of the landscape and their interrelation. In the theory chapter it was outlined that material landscape researchers claim the importance of social-mental process on the shaping of the physical reality; while mental landscape researchers do not neglect the existence of the physic environment; but neither one group nor the other attempts an integral study of the two dimensions of the landscape.

My objective is not to fulfil such a great endeavour; my objective is barely to try to understand, in an empirical way, the landscape changes considering both sides as important. Then, comparing the two outputs, it is possible to find the main results are complemented to

each other. In fact, in general, the spatial analysis changes where corroborated by the people's perception, and vice versa. As it was outlined in the previous chapter the people's reconstruction of the pre-mining landscape shows a land with a great availability of grassland and water which could sustain large amounts of livestock, besides other several uses of this area i.e. medicinal plants or fuel collection; it can be corroborated with the spatial representation of 1993 that shows an area covered dominantly by grassland, with a high number of lakes and ponds.

Regarding their vision of the current reality, people claimed that mining has brought the shortage and pollution of water, the degradation-pollution of grassland and vegetation by sediments that are wind-spread deposited, coming from mining areas; and the morphological change of the landscape; my spatio-temporal analysis shows that in effect, morphology has changed, the semi-natural grassland has become sparse and there is a large reduction of lakes, ponds and rivers; but these analysis can not say anything about the perception of pollution. The main related outputs are shown in the next figure:



**6.1 Comparison of results**

Though, these results are evidences of a previous land with a great availability of resources, especially water; I consider that other information sources besides LULC interpretation and people's perceptions, such as precipitation rate or soil fertility are called for to give strong conclusions about the productivity of the landscape.

Methodologically, I think spatial change detection can generate a more complete view of the perception as well, and support the analysis. Most informants give attributes to their landscapes, landscapes of the past as plenty of resources versus current degraded landscapes; these conclusions are supported by the quantitative results. And people's perceptions are very useful to inform the process of change, spatial analysis is a comparison of two times, but without information about the transition and context that witnesses could give. Additionally, it shows the pertinence to consider quantitative and qualitative methods together in the study of the landscape.

My empirical outputs make me believe that *resource* (and resource changes) is a crucial concept to study landscapes in a social-environmental perspective. As Cosgrove and Daniels 1998 (in Lundberg 2002) asserted, interpreting a landscape can be denominated by scenery, *resource* and institution. In fact, the interpretation that local people made of the landscape is strongly related to the usage they give to it, as a land of resources. All the informants addressed the great availability of water and grass in the areas where the mine exists nowadays; the view of landscape as a *resource* is a relevant characteristic to relate the material and mental landscape according to my analysis.

### **6.3 Summary of Discussion**

The validity of the results is discussed through the assessment of the methods and materials employed in this research; and by the analysis of the correlation between the two groups of results. The assessment of the spatial methods show as main sources of biases the geo-referencing and categorisation, which can produce error propagation in further steps. The assessment of the qualitative method process shows the use of narratives and counter-narratives as the main source of bias in a situation of antagonism where each group wants to stress their position.

The comparison between the two groups of results depict that there exists a strong correlation between them towards the evidence of a dramatic change that has limited basic resources as grassland and water; and challenges the people living in the surroundings. Furthermore, to know the process that drives the spatial-analysis, qualitative information can play a crucial role; on the other hand, to enrich and give a ground to the perspectives, material studies are relevant. Theoretical implications of my results point out there are possibilities to integrate material and mental dimensions of landscape by the use of quantitative and qualitative methods. And one of the attributes that could be given fruitful assessments of landscape are resources.

## 7 CONCLUSIONS

In this final section it will be determined if the objectives were answered. In this sense, my general objective was to assess the landscape change of an area under influence of mining activities integrating their physical and mental attributes. This general objective was divided into two specific ones.

The first objective was to develop a spatial-temporal analysis of the physical attributes of a mining-influenced landscape. This objective could be broken down into two sections; how to map this landscape in the space; and secondly, how to map this landscape in the time. In the first, a holistic-regional method was elected based in the interpretation of diachronic aerial-photos sets towards the land cover mapping and their three-dimensional visualisation. In the second, the land cover maps are compared and overlapped to find out the landscape trend. The results displayed a previous landscape map mostly covered by seminatural grassland and then, a recent landscape mostly covered by mined land. The main trends are the change of the seminatural grassland in mining and sparse grassland; the second trend, addressed degradation of the area outside the mining, and as a probable influence of this activity.

The second objective was to survey the local people's interpretation of the landscape change. Under their perspectives, the pre-mining area appeared as an area rich in rangeland, water and hence, abundant livestock. It stressed that the influence of the landscape change in the people livelihood outside the mining is considerable and negative, a change, that according to them, has diminished the resources of grassland and water, and peril the pastoralist economy based in such resources.

These two results, material and mental, correlated mostly to each other: they show that grassland and water has diminished. The analyses of these results, together, find that landscape mapping and perception can be complementing methods. A theoretical outcome is the legitimacy of combining quantitative and qualitative methods in the study of landscape.

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## APPENDIXES

### GUIDE FRAMEWORK FOR SEMI-STRUCTURED INTERVIEWS

The guide framework focus consists in the following topics:

*(The leading questions are open)*

○ **Yanacocha area before the mine:**

How was Yanacocha before the mining?

*(Try to get information on)*

- Livelihood
- Number of houses, people
- Vegetation
- Uses of vegetation
- Economic activities in the area
- Cattle
- Crops
- Water sources

○ **Mining Begins**

How was the mining apparition?

- Time
- Activities
- Presence

○ **Yanacocha area nowadays**

How is the area and surroundings nowadays?

○ **Personal changes produced by the Mine**

What are your activities nowadays?

- Housing
- Work
- Personal: family, life