

University of Turku Department of Geography

Verónica Gálmez Márquez

THE ROLE OF NATIVE AGRICULTURAL KNOWLEDGE IN ENVIRONMENTAL
SUITABILITY ASSESSMENT FOR CROPPING SITE SELECTION
Case Study: The Matsigenka of the Timpia Native Community in Peruvian Amazonia

Master's Thesis

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ABSTRACT

I have analyzed the role of native agricultural knowledge in environmental suitability assessment for cropping site selection. In a Matsigenka ethnic group community of south-eastern Peruvian Amazonia, I evaluate the criteria native people utilize for selecting suitable sites where swidden agriculture is preferably practiced. It is then assessed how these agricultural suitability patterns correspond with the current regional instrument for land use planning (ecological-economic zoning) and with the edaphic properties of the study area. The data were acquired through interviews, field visits, soil sampling, physiographic measurements and satellite imagery analysis. After physical environmental characterization of the study area using digital elevation models and land cover analysis performed upon SPOT image supervised classification; open lands coverage was estimated in relation to distance from the community's external market. The results suggest that elevation, slope, vegetation, soil colour and texture are sufficient initial environmental indicators for discriminating suitable from non-suitable sites for cropping. Natives use a blend of traditional and modern criteria to select suitable sites for cropping. Suitable sites, represented by current open lands accounting for 0,59% of the community's territory, are naturally restricted to a small portion of the community. After correspondence of native cropping suitability classes and ecological-economic zones, half of the area considered as most suitable according to the native criteria are classified under the land-use planning instrument as zones for recuperation due to deforestation. Successful restorative practices, which are still to be locally accepted, should consider the concept of agrodiversity within gardens.

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1. INTRODUCTION

Land use planning in the tropical rainforest regions is a challenging exercise. Even more if adequate land use decisions are considered vital for the achievement of an optimum productivity and for the assurance of land sustainability. In these regions, land use planning is commonly carried out by regional authorities, but if successful results are targeted, a participatory approach should be considered. Moreover, it should strive to include the local environmental knowledge in its complex process (Bebbington 1991; Winklerprins 1999). This knowledge acquired through empirical practices is a consequence of the understanding gained from the environment's adaptive responses after human influence. And, if it is fused with the scientific basis of the natural environmental processes, the results in the field of land management become promising.

Most of the studies concerning the role that the traditional ecological knowledge plays in land use planning have focused on rural peasants, riverine farmers and colonial settlements. And due to external influences, their most common productive practice, swidden agriculture, resembles a mixture of both traditional and market-oriented approaches. Less research has been focused on the most traditional inhabitants of the Amazonian rainforests, who are still encountered living in a more scattered way, but whose settlement patterns are shifting to a more nucleated manner (Henrich 1997).

Reaching sufficient understanding on the natural environment the native Amazonians develop is of sum importance. Therefore, to obtain qualitative and quantitative information on the environment, remotely sensed data have been, so far, considered among the most efficient data sources if correctly interpreted. Remote sensing technologies have enabled the collection of environmental data where observations from the field are insufficient and where accessibility becomes a limiting factor for ground survey. This has been particularly demonstrated for the case of the Amazonian rainforests (Puhakka *et al* 1992; Tuomisto *et al* 1995; Mäki 2003; Thessler *et al* 2005; Toivonen *et al* 2007; Asner *et al* 2007). Remote sensing techniques have also been used for establishing connectivity patterns between the environment and anthropogenic influence. In particular, the identification of tropical forested areas where farming activities occur under shifting cultivation has increased attention (e.g. Carreiras *et al* 2006; Yemefack *et al* 2006; Sirén 2007; Sicat *et al* 2005).

Although several studies have successfully corresponded the traditional ecological knowledge with scientific facts, only few have emphasized the role that the local criteria play in discriminating the suitability of the sites for one kind of land use or another. In this study, I focus on the local agro-ecological knowledge that the population of a native Amazonian community has about the environment. I define native agricultural knowledge as the agro-ecological knowledge that native people have concerning the use of their lands for performing traditional agriculture. It is acquired through generations and perceived at a particular time. To call it native is a reference to the fact that it is the knowledge carried by the members of the native community under study, and it is not intended to be understood as a subordinate of formal science.

The overall objective of this study is to assess the environmental criteria used by the Matsigenka natives of the Timpia Community in the Peruvian Amazon region for the selection of the most suitable sites for farming activities. Moreover, it is intended to evaluate whether these agricultural suitability patterns match with the current regional instrument for land use planning. A comparative approach is used to find correspondences between the native agricultural knowledge and the scientific basis on the use of the lands for agricultural purposes. It is intended to reduce the gap between these two types of knowledge and to build up a more complete understanding of the land suitability for farming purposes.

The methods used in this research are both qualitative and quantitative. The primary data consists of interviews conducted within the Timpia community; as well of spatial data sources complemented with detailed fieldwork information. The secondary sources are chosen from previous studies within the land use planning arena.

To accomplish the research objectives, the study is methodologically divided into four sections:

- Prior to native agricultural knowledge assessment, a proper understanding of the natural environment must be reached. This is pursued by characterizing the study area's environment using spatial data sources such as: Satellite images, aerial photographs, digital elevation models, and thematic maps. The environmental information focuses on physiographic features, geology, soils and

land cover; and the interrelation between them. Moreover, as the current natural landscape is influenced by the evolution of the land-use patterns, exemplifications on land cover change are also addressed. The land cover analysis serves for the identification of sites where current farming activities are practiced.

- External factors considered potentially influential for the agricultural site suitability assessment are evaluated. For this purpose, it is aimed at quantifying the different land cover types in relation to the distance from the external market (community's nucleated settlement, rivers and tributaries). Consideration is taken whether these variables are included for the site suitability assessment.
- The suitability of the sites for farming purposes according to the natives' criteria is presented under two complementary approaches: (a) a quantitative environmental suitability assessment for the community as a whole, based on several environmental variables; and (b) a qualitative correspondence between soil features considered relevant by natives and soil characteristics derived from laboratory analysis. The inclusion of soil characteristics in the first approach is restricted by the fact that soils in the study area are heterogeneous, and the extrapolation of site-specific soil sampling results to the entire study area was not pursued. Therefore, the second qualitative approach is considered.
- A correspondence analysis is made between the site suitability for farming according to the native criteria, and the regional land use planning instrument (ecological-economic zoning). Similarities and/or disparities between the cropping suitability classes found upon native criteria, and the zoning's agricultural classes are aimed to be found in an areal basis.

2. LITERATURE REVIEW

2.1. *Soils in the tropics*

The tremendous variety in the terrestrial world's landforms is reflected in a diversity of geological processes that have occurred over millions of years, while more recent factors in the variation are biological processes and the influence of man. Similarly, within any landscape there is a wide range of soils resulting from a series of soil-forming factors. Combinations of these factors lead to the development of unique soil types, with a relatively predictable series of horizons that constitute the soil profile (Bardgett *et al* 2005). There are five main factors on which the nature of the soil profile at any particular place depend: (i) the physical and chemical characteristics of the parent material; (ii) the past and present climate; (iii) relief and hydrology; (iv) the length of time during which soil-forming processes have been active, and; (v) the ecosystem, including vegetation, fauna and the effects of human activities (Briggs *et al* 1997). These soil-forming factors operate in an interactive manner, but the predominance of one or two of them become evident at a particular location where soil develops.

Concerning the parent material, soils are formed from the weathering of either consolidated rock in situ or from unconsolidated deposits derived from erosion of consolidated rock that have been transported by water, ice, wind or gravity. And the mineralogical composition of these deposits varies tremendously (Bardgett *et al* 2005). Therefore, the parent material and landscape position greatly influence the morphological and chemical characteristics of the soils (Osher *et al* 1998). Furthermore, the inherent properties of the original material are of sum importance in the first stages of soil development; and the fact that mineralogical composition varies between different geological formations may be ecologically important. Indeed, understanding the way in which the soil characteristics vary with parent material and landforms provides a basis for posterior land management practices design (Osher *et al* 1998; Junge *et al* 2007).

Not only does the parent material play an important role in soil formation processes, but also the effects on soil development are largely due to temperature and precipitation, which vary considerably across climatic zones. These factors strongly govern the rates

of chemical reactions and the growth and activities of biota in soil-forming processes of mineral weathering and decomposition of organic matter (Bardgett *et al* 2005). In the humid tropics, pedogenesis is mostly controlled by the amount of rainfall and its seasonal distribution and topographic position, aside from altitude and lithology. High annual rainfall in these regions means that processes such as base leaching and clay translocation are commonplace and most soils have been formed by these processes (Reading *et al* 1995). Indeed, the rapid weathering and strong leaching differentiate the soil properties in the humid tropics (Briggs *et al* 1997). The soils of these regions are of particular interest, as they constitute one-third of the soils of the world and support more than three-quarters of the world population (Hartemink 2004). Therefore, a sufficient knowledge about their genesis, morphology, properties and distribution is required for a sustainable use of these soil resources.

Regarding tropical soils distribution and their edaphic characteristics, they have immense implications for the vegetation growth. In the lowland Amazonian rainforests, the edaphic differences are known to affect species distribution patterns in both inundated and non-inundated areas. And particularly, in Peruvian Amazonia, an important part of the ecological heterogeneity is linked with the variation in soils (Tuomisto *et al* 1995). Moreover, it has been demonstrated that plant groups, such as pteridophytes and Melastomes can be used as forest site type indicators, as the floristic patterns of these plants are highly correlated with soils and with other plant groups (Tuomisto *et al* 1995; Tuomisto *et al* 2003).

The allowance of comparison between the properties of the soils found in different regions requires the soils to be grouped in classes according to similar properties. Different systems of soil classification to group soils of similar properties in one class have been developed. Although many soil classification systems exist, two systems are widely used: The FAO/UNESCO soil classification and the United States Department of Agriculture Soil (USDA) Taxonomy.

The FAO Soil Classification, also known as the World Reference Base (WRB) for Soil Resources, has endeavoured to identify possible gaps and suggests adjustments for the 1988 Revised Legend of the Soil Map of the World. One of the main objectives of this reference base is to include some of the most recent pedological studies, while expanding the use of the system from an agricultural base to a broader environmental

one (FAO 2006). Moreover, it was not meant to replace national soil classification systems, but be a tool for a better correlation between national systems. The WRB Classification System is composed of 30 reference soil groups, such as *Cambisol* and *Regosol*. These soil groups are defined in terms of a specific combination of soil horizons, called the reference or diagnostic horizons. The key to the reference soil groups of the WRB classification system makes use of soil characteristics (e.g. colour, texture, and cation exchange capacity), soil properties (assemblages of soil characteristics), and horizons (pedological bodies) to describe and define the soil groups. In the USDA soil taxonomy, there are six categories: The first category, which is the Order, has 12 different classes; there are 64 Sub-orders, more than 300 Great groups, and more than 2400 Sub-groups. To distinguish the Orders, the markers left by the processes that occur in the soils are used. These processes must be in relation with the soil-forming factors. Examples of these orders are *Entisols* and *Inceptisols* (USDA 1999). Moreover, efforts have been made in establishing correspondences between the FAO and the USDA classification systems.

Under the WRB (FAO) classification system, one of the latest soil group incorporation is the one called *Anthrosols*. These are described as soils in which human activities have resulted in profound modification of their properties (FAO 2006). Indeed, the physical and chemical properties of the soils can be directly modified by human activities. In the tropics, one of the most common practices that could lead to modifications of the soil properties is the development of agriculture. In particular for the Amazon region, most of the constraints imposed by the soils on agricultural development are chemical, rather than physical, in nature (Sanchez 1982). According to the same author, the principal limitations of soils in the Amazon basin for agricultural purposes are: Phosphorus deficiency, aluminium toxicity, low potassium reserves, poor drainage, and low cation exchange capacity.

In addition to the soils acidity, it has been estimated that around 75% of the Amazon basin is characterized by the dominance of infertile soils; they are deep, well-drained, and red or yellowish. In contrast, when the soils are developed from alluvium, sediments or volcanic ash, they are richer in calcium, magnesium, and potassium; and they present slight to no acidity problems (Sanchez *et al* 1975). These poorly drained alluvial soils, but relatively highly fertile, are located mainly in floodplains. Additionally, aside from the soils low fertility, the lack of an appropriate soil

management technology becomes another limiting factor for agricultural development. It has been quantified that only about 6% of the Amazon basin has soils with no major limitations to agriculture (Sanchez *et al* 1982).

However, when food crop production is needed, it should logically concentrate first on the more fertile soils of the region. But the limited extent of such soils in the Amazon and the considerable flooding hazard indicate that major increases in food crop production are based on the dominant infertile soils (Sanchez 1982). When soils are used for crop production, the basic soil requirements of crop plants can be divided into: (i) internal requirements, which include soil moisture, soil aeration, natural soil fertility, effective soil depth, soil texture and stoniness, and soil toxicity; and (ii) external requirements, which refer to slope, topography, occurrence and depth of flooding and soil accessibility. For a specific crop, the lack of or a deficiency in a basic soil requirement becomes its limiting factor (FAO 1993). Aside from the soil requirements, other factors that influence crop production are: yield determining factors, such as light or temperature; and yield reducing factors, such as pests and weeds. However, there are certain crops and pasture species more tolerant than others to high levels of toxicity and low levels of available phosphorus, and other soil problems. Nevertheless, research carried out in the Amazon area of Peru and Brazil has shown an array of agricultural management options for humid tropical landscapes dominated by acid soils (Sanchez *et al* 1975; Sanchez *et al* 1983; Nicholaides *et al* 1985).

2.2. *Land use, land cover and land evaluation*

2.2.1. General aspects of land use, land cover and land evaluation

Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. It concerns the products and/or benefits obtained from the use of the land as well as the land management activities carried out by humans to produce those products and benefits. Land cover is the observed physical and biophysical cover on the earth's surface, including vegetation, man-made features, bare soil and water surface. It is dependant on the land use given at a certain moment in time, and therefore, subjected to sudden changes (FAO 1998). While land cover refers to the type of feature present on the surface of the earth,

the term land use relates to the human activity or economic function associated with a specific piece of land (Lillesand *et al* 2004). Based on the similarities of certain land features, several initiatives have attempted to establish land cover classification systems.

Among the most well-known land cover classification systems, the Global Land Cover Characteristics Database developed by the United States Geological Survey (USGS, 1992) is of relevant importance. This system is based on categories that can be reasonably interpreted from aerial or space imagery; recognizing, however, that some information cannot be derived from remote sensing data. This database was developed on a continent-by-continent basis. Another initiative led by the European Environment Agency is the Coordination of Information on the Environment (CORINE) Land Cover Database, which provides a pan-European inventory of biophysical land cover, using a homogenized 44-class nomenclature made available on a 250 by 250 grid database. Several other initiatives on a national level have been developed, but homogenization of the different land cover classes across countries usually becomes a limiting factor for a proper land cover class correspondence. Therefore, a well defined land use/land cover classification system facilitates the assessment for a particular use; that is to say, it simplifies the work of land evaluation.

By evaluating the condition of the lands, one may solve the doubts concerning the success and suitability of all these possible land uses. Land use actors may have different interests in the same piece of land: An indigenous farmer might be interested in achieving a sufficient crop production according to his calendar; a local organization might be interested in modernizing the traditional farming techniques; while other organizations may attempt to increase a farmer plot's yield with a certain crop. Land evaluation is defined as the assessment of land behaviour when it is used for a particular purpose, and it is a tool for land use planning. Moreover, it is defined as the process of predicting the potential use of the land on the basis of its attributes (Rossiter 1996). The evaluation of the lands takes into account the economic aspects of the proposed use, as well as its social consequences and its impacts on the environment (FAO 1976). Currently, there are several methodologies being used for land evaluation purposes. One of them is the land capability classification methodology, designed by United States Department of Agriculture, where soils are grouped depending on their capability to produce common cultivated crops. Alternatively, a more widely used methodology for land evaluation is the one designed by the Food and Agriculture Organization.

FAO recognizes certain principles that are fundamental to the methods that are employed in land evaluation, and they are as follows: i) land suitability depends on any particular use, and different kinds of land have different requirements; ii) land evaluation needs to compare what has been gained and lost according to the type of land and land use; iii) a multidisciplinary approach is pursued; iv) land evaluation should be made according to the socio-economic and physical context of the area under study; v) sustainability must be the base of a specified land use; and vi) benefits and inputs of more than a single land use type must be evaluated.

For the evaluation of land suitability, the spatial unit of analysis is the land mapping unit. The delineation of this unit should, ideally, be based on land qualities that have the most influence on the land uses under consideration. Thus, depending on the objectives of the evaluation, relevant core data sets may include soils, landform, climate, vegetation, and surface and/or groundwater reserves (George 2003). Therefore, land suitability can be understood as how well a land mapping unit matches the requirements of the land use type (Rossiter 1996). The suitability classification of the FAO framework for land evaluation is structured in four different categories: The Orders; named Suitable, and Non Suitable; with a conditional phase to be used when certain additional conditions must be met. The Orders are subdivided into Classes; which show different suitability degrees within Orders. Each Class, except the first one, is in turn divided into Subclasses; which reflect a kind of limitation (e.g. erosion, soil fertility and/or drainage). The number of Subclasses should be kept to a minimum necessary to distinguish land with significantly different management requirements. The last category in this hierarchical classification is represented by the Units. These are used at a farm planning level and are defined by differences in management requirements or production.

2.2.2. Ecological-Economic Zoning

The ecological-economic zoning is an alternative zoning version which integrates physical land resources elements with socio-economic factors and a wider range of land uses in zone definitions (FAO 1997). The zoning is prioritized in areas where economic development may clash with effective conservation of the natural resources, and in tropical rainforests regions, with primary forests in particular (Sombroek *et al* 2000).

The ecological- economic zoning has become an effective management tool for the land use planning in tropical countries, and it has gained special attention in the Amazon rainforests areas (e.g. OTCA 1994).

At a national level, the Peruvian Environmental National Council (CONAM) is the national authority body for the management of ecological-economic Zoning processes. This situation might vary during the course of 2008, as according to the Article 4b of the bill to create the Peruvian Ministry of the Environment and Natural Resources, one of its main objectives will be to promote and achieve land-use planning. Currently, CONAM defines this zoning as an instrument for information and planning, and for facilitating the land use decision making while avoiding land use conflicts. Moreover, this zoning is addressed in Article N°11 of the Organic Law for the Sustainable Use of Natural Resources. It is approved by the authority body to serve as a territorial ordering aid to avoid overlapping conflicts on land titling and improper land use, based on prioritized areas. Also, they are meant to reconcile the conservation national interests with the sustainable use of the natural resources. The zoning regulation instrument defines three different study scales: macro, meso and micro zoning. In this context, the macro-zoning is identified as a contributor for the elaboration and approval of policies and development of land use planning; from national, macro-regional and regional scales. Moreover, in order to become an effective tool, a participatory approach is core for the zoning elaboration.

Within the national level, regional initiatives for territorial ordering have been developed. In north-eastern Peru, an ecological-economic zoning was elaborated with the objective of facilitating the implementation of policies, projects and programmes oriented towards the sustainable development of the influence zones of the Iquitos-Nauta road (IIAP 2005). Additionally, in the department of Cusco, Peru; La Convencion Province elaborated an ecological-economic zoning with the aim of providing a guiding tool for the occupation and use of the territory. The zoning of this Province was developed by the Energy and Mining Ministry's Technical Group of Inter-institutional Coordination, jointly with the Province's Municipality and the Institute of meteorology and environment (IMA). In its elaboration, different land units were delineated according to the zoning planning development stage. Several thematic maps, such as geological, geomorphologic, physiographical, soil, climate, and hydrographical were used to delineate the integral land units. These units were then overlaid by vegetation

and socio-economic variables to generate the ecological-economic units. The criteria used for the assessment of these units included: productive aptitude, vulnerability, ecological value, urban-industrial aptitude, and environmental use conflicts. The ecological-economic zones were then obtained by overlaying the results of both of the sub models. Additionally, categories defined by law, such as the natural protected areas, and mining and logging concessions were also considered.

When planning a macro zoning for agricultural occupation, it requires proper information on the characteristics and the requirements of the different feasible land use types or livelihood systems. Special attention should be given to the combination of timber-oriented agroforestry and small holders' subsistence farming. And this may become patterned on the indigenous knowledge systems of land use (Sombroek *et al* 2000).

2.2.3. Land use and land cover change

Land cover changes are caused by natural processes and are due to anthropogenic influence. In the tropical rainforests, most of the human-induced land use/land cover change occurring in these areas is related to farming activities. In turn, these are commonly related to the practice of subsistence and/or incipient commercial agriculture or cattle ranching. In the Amazon region, within the forest based farming system (FAO 2001), most of the farmers make use of an agricultural system commonly known as "shifting" cultivation, "slash and burn" or "swidden" agriculture. The conversion of tropical rainforest to shifting cultivation leads to dynamic processes, acting on the spatial aggregation of various land use and land cover types (Yemefack *et al* 2006). Sanchez (1973) describes shifting cultivation in tropical America in the following way: "*small fields are cleared by axe and machete during periods of least rainfall and burned shortly before the first rains. Without removal of debris, crops are planted in holes dug with a digging stick...After the first or second harvest the fields are abandoned to tropical forest regrowth*". Specifically, the swidden-fallow agriculture practiced by most indigenous Amazonians is a multi-fallow cultivation system, whereby they cultivate fallow plots at all ages in various cropping combinations and sequences (Tschakert *et al* 2007).

Land use change due to agriculture starts by selecting a place where new gardens are felled either from primary forest or from secondary forest in old fallows, and soil fertility is improved by burning the felled trees and other plant materials (Ohl 2007). Because of the successional differences between swidden systems and cattle pastures, the latter requires at least twice the fallow time to regenerate an equal amount of biomass as swidden systems. Moreover, the success of post-fallow land reuse, both for pasture and agriculture, relies on the reaccumulation of biomass during fallows (Henrich 1997). Without sufficient biomass, burning and subsequent decay cannot release sufficient nutrients and organic matter in these otherwise poor soils; and over the long term, this process of land degradation transforms farms into “green deserts” containing only small, stunted secondary vegetation (Loker 1993).

Aside from farming and cattle raising, national policies concerning the extraction of energy resources in remote locations also favour land use change. In this respect, natural gas extractive and transportation activities are also considered as causing agents for a land use patterns shift. Accordingly, pipelines and camp sites need to be built and therefore forest corridors are opened. In Peru, the Camisea gas project, which consists of the exploitation of the natural gas reserves in Block 88 (*Cashiriari* and *San Martin* fields), is relevant in the context of this study. The gas and liquids transportation requires the opening of the forest and the maintenance of the pipelines' right of way.

2.3. *The use of remote sensing and GIS in environmental studies*

Remote sensing technologies have enabled the collection of environmental data where observations from the field are insufficient and where accessibility becomes a limiting factor for ground survey. The applications of remote sensing in environmental studies are virtually limitless, but one of the most common uses is related with the identification of the different land cover types on earth and their associated features. In this sense, while land cover can be directly interpreted from appropriate remote sensing images, information about human activity on the land (land use) cannot always be inferred directly from the land cover assessment (Lillesand *et al* 2004). To correctly interpret the targeted earth surface features, the principles of remote sensing must be well understood.

In principle, the sensors situated on airborne or spaceborn platforms acquire data about the way various earth surface features emit and reflect electromagnetic energy, and these data are analyzed to provide information about the resources under investigation. In remote sensing, the interest is centred in measuring the diffuse reflectance properties of terrain features. In this sense, the reflectance characteristics of earth surface features may be quantified by measuring the portion of incident energy that is reflected. This is measured as a function of wavelength, and is called spectral reflectance (Lillesand *et al* 2004). Additionally, to become efficient tools, the assumption must be that the spatial patterns captured by remote sensing represent the features of interest, of which land cover / land use could be estimated (Yemefack *et al* 2006). Moreover, when the tools offered by remote sensing are combined with geographic information systems, possibilities for a variety of spatial integration and analyses of different themes are offered. They become an effective tool to put site-specific models into a spatial context to examine important processes, identify important locations, and accommodate scenario analyses, even if land features occur in the least accessible locations (Mäki 2003; Vezina *et al* 2006).

When considering the tropical rainforests as hard to reach environments, remote sensing techniques increase the effectiveness of the studies performed in such regions. The latter despite the fact that optical remote sensing in the tropics has been hindered by the high frequency and extent of cloud cover (Westman *et al* 1989). Several studies concerning the use of remote sensing in the Amazon rainforests have focused on deforestation, land degradation and selective logging detection (e.g. Asner *et al* 2005; Souza *et al* 2005; Asner *et al* 2007). In a regional scale, remotely sensed data has been used in Western Amazonia to gain quantitative information on the environment. For instance, satellite imagery has been used to study the spatial distribution of the rivers, while establishing patterns of connectivity between populated centres within the region (Toivonen *et al* 2007). In a national level, remotely sensed data have been used to collect information on road construction and deforestation in the western part of the Amazon basin in Peru (Mäki *et al* 2001). Additionally, if a proper understanding of these heterogeneous environments is reached, it makes it possible for remote sensing and GIS methods to become core components for geo-ecological map production. Then, they can be used for illustrating the variability of the natural environment and the details of human activity (Kalliola *et al* 1998).

Remote sensing sources have gained grown interest in the field of Amazonian rainforests' vegetation classification. The reflectance patterns of the terrain features are determined by the physical properties of the vegetation and soil, and can therefore be used to identify different vegetation formations. Moreover, the structural differences of Amazonian lowland rainforests could only be anticipated due to their dissimilar spectral reflectance in satellite images (Tuomisto *et al* 1995). When remotely sensed data are used in vegetation mapping, the standard procedure is first to select and document representative sites in the field and classify these according to their vegetation characteristics. Thereafter, the entire image is classified using the field sites as training areas in a supervised classification procedure (Thessler *et al* 2005). Nevertheless, sufficient accuracy in primary *terra firme* forest types and secondary forest types classification is not easily reached, although successful examples can be addressed. For instance, in the Brazilian eastern Amazonia, successional forests were classified using spectral properties and ecological characteristics (Vieira *et al* 2003). It was concluded that successional status, as characterized by species composition, biomass, and distributions of heights and diameters become satisfactory means of stratifying these forests for characterization of spectral properties. In Peruvian Amazonia, successful classification results were obtained using floristically defined lowland tropical rainforests. This classification was then utilized to study wildlife habitat use in the same area (Salovaara *et al* 2005).

Remote sensing initiatives for identifying and classifying areas where swidden cultivation practices take place in tropical rainforest have recently increased. In southern Cameroon, the spatial segregation of land use and land cover types under shifting agriculture were related to Landsat ETM data (Yemefack *et al* 2006). Moreover, Carreiras *et al* (2006) assessed the extent of agriculture/pasture and secondary succession forest in the Brazilian Legal Amazon using data from the Spot Vegetation satellite image. In an indigenous community of the Ecuadorian lowland rainforests, Landsat images were used to quantify the land use change caused by swidden cultivation, while differentiating agricultural fields and young fallows from old-growth forests (Siren 2007).

Livelihoods based on agriculture are tightly linked with and dependent on the environment. If a proper understanding of the environment is reached through remote sensing, it also becomes a manner for exploring human activities patterns. The role that

these images play in mapping land use and land cover have demonstrated to provide efficient results if data gathered from the field is combined with local knowledge on the environment (Yemefack *et al* 2006).

2.4. *Native Knowledge and Native Agricultural Knowledge*

Several synonymous terms are commonly found in the literature to refer to the cultural background that local people have concerning the use of the land they occupy. Terms such as indigenous knowledge, traditional knowledge, indigenous agricultural knowledge, and so forth are used to define this type of knowledge. Bebbington (1991) refers to it as a body of knowledge which is built up through experimentation and put into practice by locals at any one time. It is also defined as a complexity of practices and decisions that local people make (Oudwater *et al* 2003). Moreover, Grenier (1998) describes the indigenous knowledge as the unique, local knowledge existing within and developed around specific conditions of women and men indigenous to a particular area.

The main difference between native agricultural knowledge and formal agricultural science is that the former concentrates on adaptation of knowledge, and is less formal in both its social organization and its research methods (Biggs *et al* 1981). The rationale for studying local knowledge about the environment is that most progress towards sustainable land management will derive from the synergy of local and scientific knowledge. If this is accepted, then integrating or relating the two knowledge systems is a central issue (Payton *et al* 2003). Concerning local knowledge on soils, a participatory methodological approach was developed integrating Latin-American and African experiences to identify and classify local indicators of soil quality. A correspondence with soil quality technical indicators was found, and it facilitated the integration of local and technical knowledge about soils and their management (Barrios *et al* 2006).

Studies concerning the traditional ecological knowledge have mostly focused on the use of the lands. And most of these studies have been carried out in African and Asian countries. In this respect, Cools *et al* (2003) developed an approach to integrate the knowledge of both farmers and land resources experts to promote adoption of new land use systems in north-western Syria. Moreover, Zurayk *et al* (2001) carried out a land

capability classification and land use analysis in a region of Lebanon using the indigenous knowledge as one of the information sources for this classification. In Rwanda, Steiner (1998) studied the farmers' perception of soil suitability for cropping practices. Studies concerning the traditional knowledge of farmers in Latin America have mostly focused on soils and their suitability for different land uses. Barrios *et al* (2003), when studying the Orinoco floodplain farmers from Venezuela and the hillside farmers from Honduras concluded that there is a consistent rational basis to the use of local indicators of soil quality and their relation to improve soil management. Additionally, Salovaara (2005), when studying the *Ribereños* people (non-indigenous rural peasantry of Peruvian Amazonia), found a clear correspondence between the peasants traditional forest classification and a floristic classification produced by using systematically collected botanical data. It was shown that these peasants have clear preferences for certain forest types when selecting sites for slash and burn agriculture and hunting. Also, indigenous knowledge has been tested to be a useful source of information to differentiate vegetation types as well as plant species composition (i.e. habitat classification) (e.g. Shepard *et al* 2001; Hernandez *et al* 2006).

Local soil knowledge is an important source of information when designing sustainable land management strategies. And the importance of participatory approaches for the capture of such knowledge is being more and more valued. When studying the local soil knowledge, there are three dimensions that can be explored: (i) listing the criteria people use to describe their soils, and how these criteria are used to make land use decisions; (ii) correlating local soil classification with western soil classifications; and (iii) incorporating local soil knowledge into development issues and land use planning (Winklerprins 1999).

Several criteria are applied when local farmers refer to the description of the soils present in their lands. Saito (2006), when studying farmers in Laos determined that the soil colour was the most important descriptor of the soils. Moreover, Oudwater *et al* (2003) stated that for most farmers, the surface texture is the most important criteria taken into account to discriminate soil classes. In a study on Ethiopian farmers, Erkossa *et al* (2003) conclude that soil colour, texture and its position in the landscape were important criterion for farmers to evaluate their soils. Ohl *et al* (2007) carried out research on the swidden agricultural practices of two native communities of Matsigenka ethnia inside the Manu National Park in Peru. They identified that the soils' local names

varied according to their physiographic location, and that colour, texture and drainage properties influenced the way in which a soil type was named. Moreover, Johnson (1983), while studying the soils in the *Shimaa* native community of ethnia Matsigenka, also in Peru, identified that soil hardness was probably more important than soil fertility when selecting a site for farming purposes.

3. THE STUDY AREA

3.1. General characteristics

The study area lies within the boundaries of the Timpia Native Community; which is politically situated in the District of Echarate, Province La Convencion, Department Cusco, Peru (Fig 1). The main hamlet of the Timpia Native Community is located in the following UTM coordinates: 737146.100mE, 8663467.000mN. The nearest most important river is the Urubamba, and the community straddles this river. The most important tributary is the Timpia, which gives its name to the community. The total extension of the study area is 36 621, 95 ha (Plan Maestro SNM 2007), and according to the 2007 community's population record, the number of families reaches 167, including 10 families belonging to the Timpia annexed lands. The estimated number of inhabitants in 2003 was 628 inhabitants (communal census), while in 2006 the estimation rose to 800 (Plan Maestro SNM 2007). The native community of Timpia obtained its legal status when registered in 1974, and it was granted a land title in 1983.

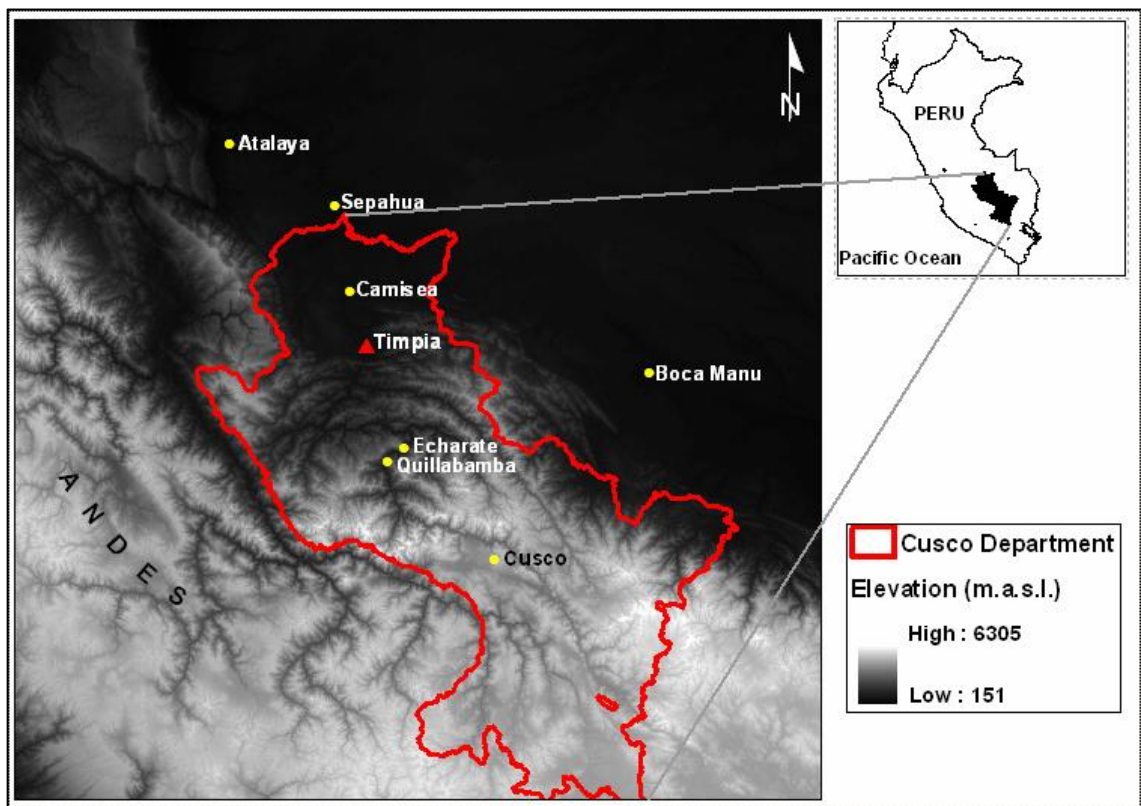


Figure 1: Topographical location of the study area (Timpia Native Community) in south-eastern Peru. Refer to figure 2 for the detailed boundaries of the community and its hydrographical network.

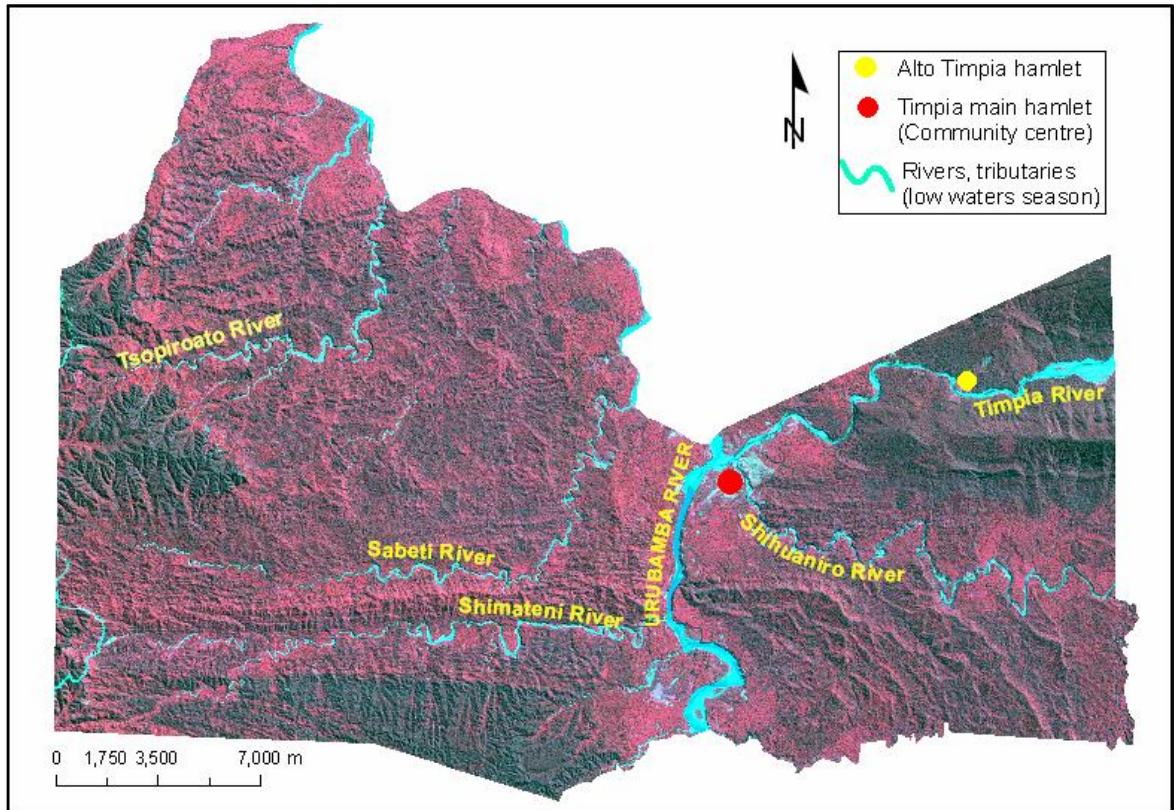


Figure 2: Study area delimited by the political boundaries of the Timpia native community

Although the study area of the present research is limited by the boundaries of the Timpia native community (according to its political limits), most of the following geologic, hydrographical and geomorphologic descriptions are made in reference to the Lower Urubamba region, where the community lies, as most of the literature refers to this region as the basic unit for characterization.

3.2. Geology

From the tectonic-structural perspective, the Peruvian Amazon region includes the upper foothill or Sub-Andean Zone (300-2000 m.a.s.l.) and the floodplain (< 300 m.a.s.l.). The former one situated along the eastern Andean border, and whose fault system regulates the geologic evolution of the main western Amazon basins (Räsänen *et al* 1987). Foreland dynamics have resulted in a *terra firme* composed of late Tertiary alluvium and younger alluvial terraces and plains (Räsänen *et al* 1990).

The Sub-Andean Zone includes those areas subjected to tectonic activities during the Upper Tertiary and Quaternary, between the eastern Andean chain westward and the Brazilian craton eastward. Moreover, the sedimentary deposits of the Sub-Andean zone represent the western part of the Cenozoic foreland basin, mainly filled with detritic continental sediments (Dumont 1992). According to the same author, while the western part of this foreland basin was uplifted as a consequence of the tectonics of the Tertiary, originating the current Sub-Andean hills; the eastern part continued to subside until the upper Miocene. This tectonic phase of the upper Miocene generated the Subandean Thrust and Fold Belt (STFB). Then, the structural framework of the Sub-Andean Zone consists of the STFB, which outcrops mostly in the Upper Foothills; and a second zone, namely the Subandean Tilted Block Zone (STBZ), which is concentrated mainly in the Lower Foothills (Dumont 1992). Most of the Lower Urubamba region is considered as belonging to the STFB, although a small portion of it is located in the STBZ. Within this region, the limit between the STFB and the STBZ is set by a major fault situated northward the Camisea river (Figure 3). And most of the native communities of the Lower Urubamba region (and the study area) are located in the STFB.

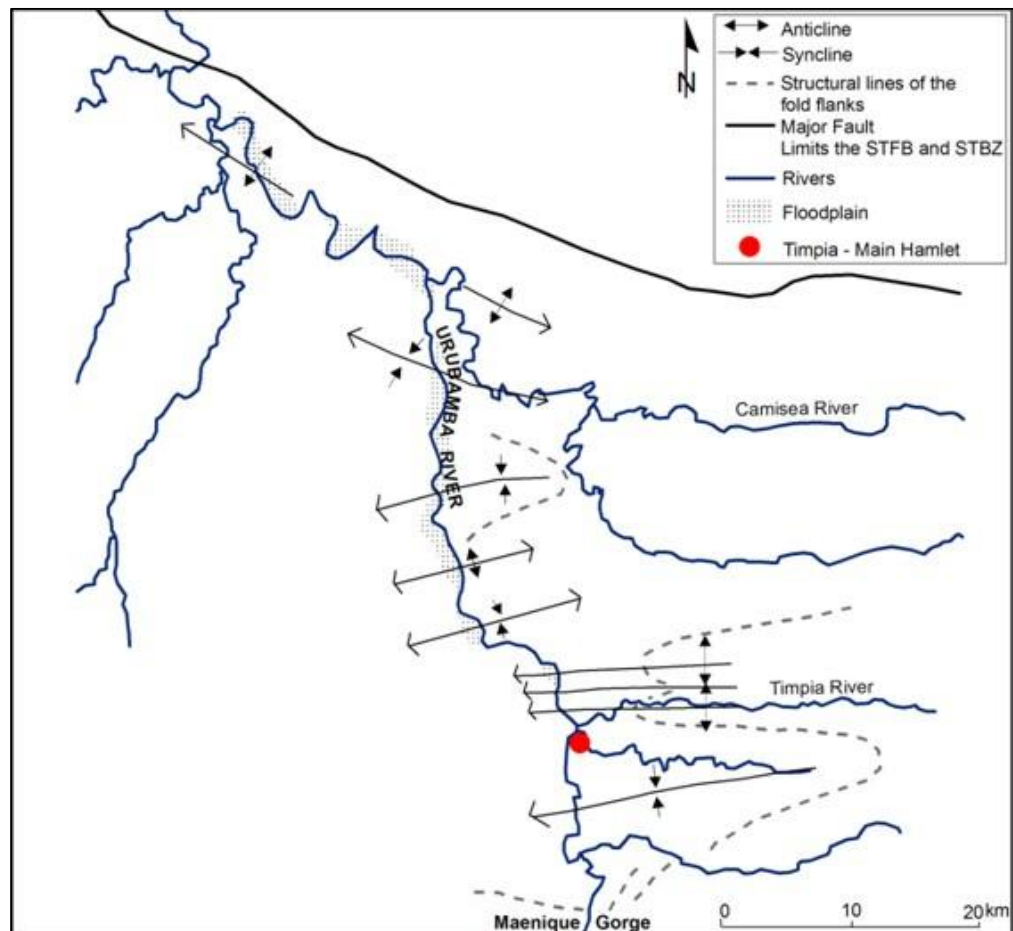


Figure 3: Structural croquis of the Lower Urubamba Region (redrawn after Dumont 1992)

Within the Timpia native community, sediments of different geological ages outcrop. The geologic frame of the study area corresponds to a sequence of sedimentary rocks of marine and continental origin (ONERN 1987). According to INGEMMET (2003) and Núñez del Prado *et al* (2006), there are nine lithostratigraphic units present in the community (figure 4 and table 1): The oldest formation outcropping is the so called *Río Tambo* formation (0,21% of the study area), which is overlaid by the *Grupo Oriente* formation. It is lithologically constituted by whitish quartzitic sandstones with intercalations of red-brownish mudstones and dark grey siltstones. The *Chonta* formation consists of shale and calcareous siltstones, with interstratifications of sandstones, marls and grey calishes. *Vivian* is an extreme formation composed by white brownish quartzitic sandstones with thin intercalations of dark shale and siltstones. It transitionally overlies the *Chonta* formation and gradationally underlies the series of “red layers” of the Tertiary. The *Yahuarango* formation is constituted by continental sequences with some marine influence. This series presents conglomerates with rounded pebbles, thick intercalations of red luthites interstratified with grey and red siltstones, with iron concretions, plant detritus and some layers of sandstones. Moreover, it is the most extended in the community. The *Chambira* formation presents red silty luthites, with intercalations of grey massive sandstones and red luthite partings. It is the second most extended in the area. These two units constitute around 65% of the study area.

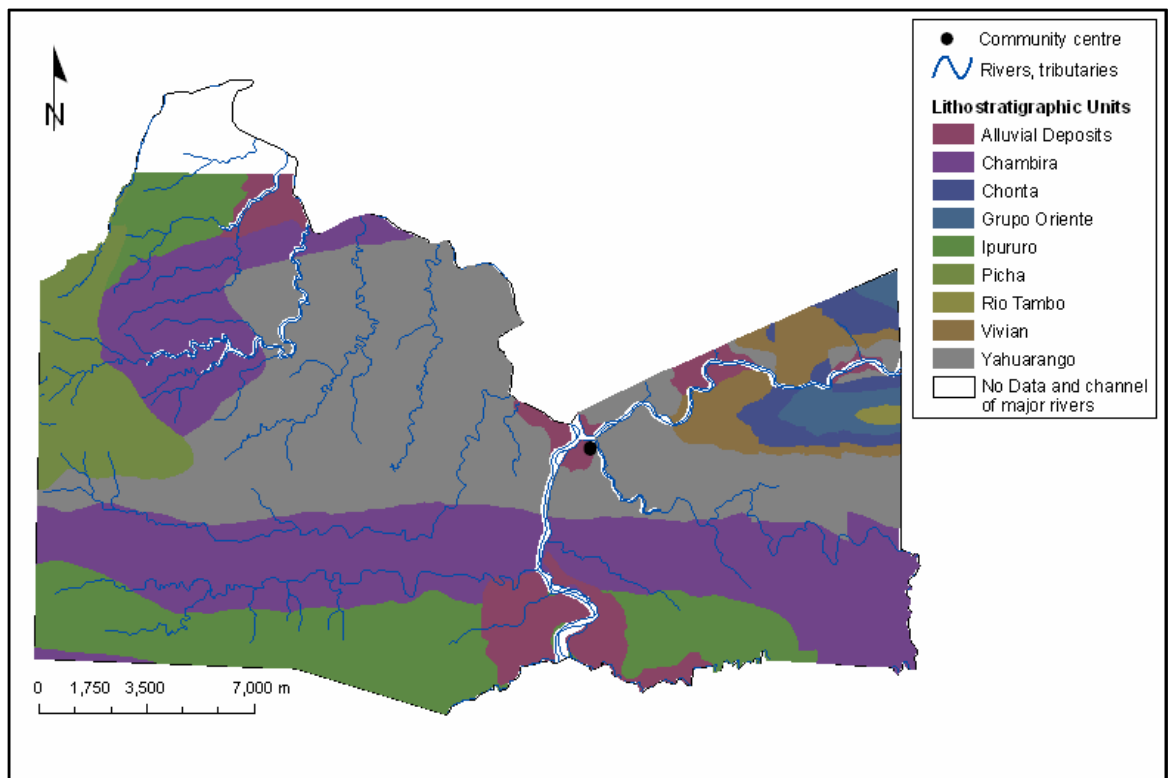


Figure 4: Lithostratigraphic Units present in the study area.

The lithology of the *Ipururo* formation shows horizons of partly silty red shale, as well as banks of sandstone with lenticular concentrations of hard quartzitic sandstones, and layers of conglomerated isolated pebbles, with some shale partings. The sedimentation environment could have been fluvio-continental. The *Picha* formation is constituted by quartzitic boulders, metamorphics and intrusives, joined together by a clayey-sandy matrix with calcareous cement. It is interpreted as a depositional environment of alluvial fans. Finally, the alluvial deposits include loose or weak consolidated materials of heterogeneous nature, which were eroded, transported and deposited by fluvial currents; or which originated by the in situ weathering of the pre-existent rocks; thick materials predominate in these deposits (gravel, pebbles).

Table 1: Lithostratigraphic units present in the study area

Lithostratigraphic Unit	System	Era	Basin	Area in the community (ha)	Area in the community (%)
Río Tambo	Permian	Paleozoic	Eastern ridge- sub-andean belt	74,7	0,21
Grupo Oriente	Cretaceous	Mesozoic	Sub-Andean	534,1	1,50
Chonta	Cretaceous	Mesozoic	Sub-Andean	762,6	2,15
Vivian	Cretaceous	Mesozoic	Sub-andean	1201	3,38
Yahuarango	Paleogene	Cenozoic	Amazon – Madre de Dios	11850	33,37
Chambira	Neogene	Cenozoic	Amazon – Madre de Dios	10920	30,75
Ipururo	Neogene	Cenozoic	Amazon – Madre de Dios	5817	16,38
Picha	Neogene	Cenozoic	Amazon Plain	2261	6,37
Alluvial deposits	Quaternary	Cenozoic		2090	5,88

Source: INGEMMET 2003. Areal information: This study

3.3. Hydrography and Geomorphology

Hydrographically, the Urubamba River is one of the Lower Urubamba Region landscape's major shaping agents. The Urubamba River, with a length of 149 km and watershed coverage of 3286 km², flows from the oriental ridge towards the north through the *Maenique* gorge (Fig 3). From its origin to the gorge, the river is narrow (Fig 5); thereafter it widens while low and flooded shores prevail. According to Dumont (1992), data from paleocurrent show a south-north main drainage direction in the upper section of the Urubamba River; which could be interpreted as a constant drainage direction previous to the folding and uplifting of the region.

The dynamics of the meandering Urubamba River play an important role, as the migration of the river can strongly modify the current floodplain. While the channel migration processes of several Amazonian lowland rivers maintain large floodplain forest areas in successional stages, larger-scale fluvial processes induced by active tectonics further modify vast tracts of intra floodbasinal area, and thus introduce present floodplain dynamics in new areas (Kalliola *et al* 1992). This in turn can contribute to changes in landscape ecology and land use patterns (Pärssinen *et al* 1996), especially near urban and rural centres, which are so highly dependent on the rivers for their livelihood (Kalliola *et al* 1992).

Specifically, for the Timpia native community, the Urubamba River constitutes the most important communication and transportation means, as well as the main access route to the external market. The same occurs for most of the other native communities and colonial settlements situated in the Lower Urubamba Region. Moreover, it constitutes a paramount axle for the north-south integration of the Peruvian Amazon region (INRENA 2004). Aside from the Urubamba River, several other rivers and tributaries are considered important for transportation and communication within the boundaries of the Timpia native community (Fig 2). In this sense, the Timpia river and the Shihuaniro River are navigable (solely by canoes or motorized canoes) even during the low waters season, but other tributaries of the Urubamba River, such as the Shimateni, the Impomeriari, and the Sabeti, among others, become non-navigable during this season.



Figures 5: Urubamba River section – Maenique Gorge (Photographs: Verónica Gálmez, 2007)

As a consequence of the processes that mould the forms of the land's surface, the geomorphology of the Lower Urubamba Region is varied. Three distinctive major

physiographic units can be identified: (i) the alluvial unit, originated from deposition of sediments from the erosive action of the rivers; occurring along the main rivers. And abrupt escarpments bordering the rivers typically limit its extent; (ii) the hill unit, which dominates the region, stretching across 70% of the Lower Urubamba Region. The steep sloping hills originated from tectonic and orogenic events, and were shaped by erosive processes; and (iii) the mountainous unit, concentrated in the southern portion of this region and formed by tectonic processes dating from the Jurassic and Cretaceous periods (Alonso *et al* 2001). According to Dumont (1992), the high terraces occurring along the lower section of the Urubamba River reach a height of 100 metres above the bottom of the valley; while the average terrace height is approximately 30 metres.

3.4. Soils

The soils of the Lower Urubamba region have basically two origins: (i) Soils derived from alluvial materials, and (ii) soils derived from in-situ weathering of the Tertiary materials (INRENA 2004). In this respect, Alonso *et al* (2001), recognize two primary soil classes according to the US Soil Taxonomy: the Entisols and the Ultisols; the former class occurring only on alluvial beaches, being young, sandy and yellowish with minor epipedon development. The Ultisols are deep, red or yellow, with low natural fertility and poor physical properties. Accumulations of humified organic matter in the surface layer are always present, but minimally so, throughout the study area. For the purposes of the regional ecological-economic macro-zoning, and specifically within the Timpia native community boundaries, the Institute of Meteorology and the Environment (IMA) recognizes four major soil classes, namely: *Sepahua*, *Saniriato*, *Cheni-Sepahua*, and *Mainjo Miscelaneo*. The characteristics of these soil classes are depicted in table 2, and their distribution within the community are shown in figure 6.

Table 2: Four major soil types as defined by the Institute of Meteorology and the Environment (2005).
Elaborated for land use planning purposes

		<i>Major Soil Types</i>			
		Sepahua	Saniriato	Mainjo Miscelaneo	Cheni Sepahua
Soil characteristics	US Soil Taxonomy equivalent	Inceptisol	Entisol	Entisol	Inceptisol
	FAO equivalent	Cambisol	Regosol	Regosol	Cambisol
	Depth	Moderately deep to deep	Superficial to moderately deep	Superficial to moderately deep	Moderately deep to deep
	Origin	Sub recent alluvial sediments or residual claystone materials	Coluvio-alluvial deposits and residual materials of luthites and sandstone	Coluvio-alluvial deposits or alluvial subrecent and old sediments	Sub recent and old alluvial sediments; claystone, sandstone and luthite residual materials
	Profile	ABC	AC	AC	A; A,B,C
	Texture	Moderately fine to fine	Medium to fine	Moderately coarse to moderately fine	Moderately coarse (sandy loam) to fine
	pH	Very strongly acid to strongly acid	Neutral to extremely acid	Extremely to very acid	Neutral to extremely acid
	Colour	Brown, reddish brown and dark yellowish brown	Brown to reddish brown	Brown to strong brown, sometimes yellowish brown and dark yellowish brown	Yellowish red with brown tonalities.
	Natural drainage	Good to excessive	Good to excessive	Good to excessive	Good to excessive
	Fertility of the superficial layer	Medium (Organic matter content)	Low to medium	Low	Medium
CIC	High	High	Low to very low	High to low	
Base saturation	High (more than 50% by ammonium acetate)	High	Low to high	Low to High	
Slope	15 - 50%	15 - 50%	15-25% and more than 50%	0-4% and 4-15%	

Source: IMA 2005

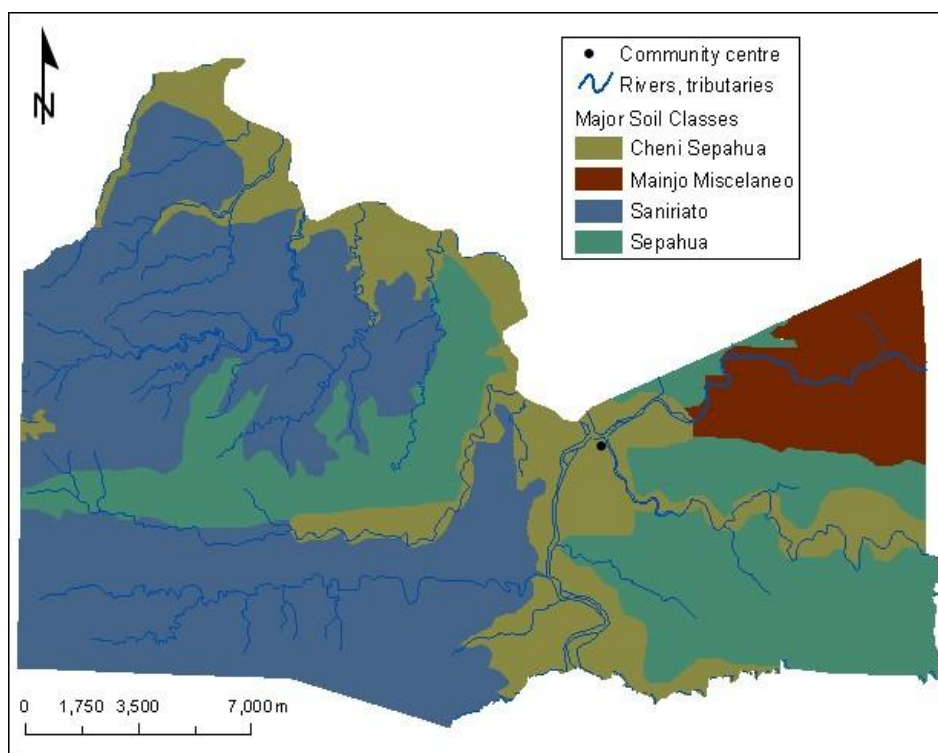


Figure 6: Major soil classes in the study area

According to their location, ONERN (1987) has classified the soils of Timpia as being deep, with incipient development and by abundant pebbles with lithic material conformed by claystone. They have a medium to moderate fine texture, good drainage, and low pH in the alluvial terraces. In the hilly landscape, soil depth is set as superficial to very superficial, with a moderate fine to fine texture, and low pH.

3.5. *Climate, ecology and vegetation*

In the Lower Urubamba region, the mean annual temperature is 25 °C, with monthly variations of ± 4 °C. In areas where the altitude exceeds 1000 m.a.s.l., the mean annual temperature diminishes approximately 0, 7 °C every 100 m of altitude increase. The mean annual precipitation averages about 3000 mm, distributed along a year with two marked seasons: The dry season occurring between the months of May and October; and the rainy season between the months of November and April. According to Holdridge's ecological classification, the life zone of this area is considered to be classified as Very Humid-PreMontane Transitional Tropical forest (ONERN 1987; CEDIA 2007).

In terms of vegetation, Alonso *et al* (2001) have identifies three different habitats in the non-flooded *terra firme* forest of this region: (i) *terra firme* forests, (ii) riverine terrace forest (not affected by seasonal flooding), and (iii) mixed upland forest. Common to all three habitats was the prevalence of the family Leguminosae, the most specious family. The same authors have also mentioned that abundance of trees with a dbh of more than 10 cm was higher in the riverine terrace forest habitat, where there is a strong domination of *Senefeldera inclinata* (Euphorbiaceae). Some important species in this forest type included *Cedrelinga catenaeformis* (Mimosaceae), *Pourouma minor* (Cecropiaceae) and *Tocoyena sp.* (Rubiaceae).

The *terra firme* forest is characterized by the presence of the palm *Iriartea deltoidea* (Arecaceae). Diversity is higher than at the riverine terrace forests, but lower than at the mixed upland habitat. According to the Megantoni National Sanctuary Rapid Biological Inventory made by The Field Museum in collaboration with other institutions (Vriesendorp *et al* 2004), clumps of *Tessaria integrifolia* (Asteraceae), *Gynerium sagittatum* (Poaceae), and *Calliandra angustifolia* (Mimosaceae), grow closest to the river, followed by an overstory of *Ochroma pyramidale* (Bombacaceae), *Cecropia*

multiflora (Cecropiaceae), and *Triplaris americana* (Polygonaceae), as well as *Jacaranda copaia* (Bignoniaceae) and *Erythrina* sp (Fabaceae).

Concerning the colonizing vegetation in primary succession floodplains, the persistence of the initial plant assemblage is controlled by the evolution of fluvial landforms; while only a few species among the set of colonists are significant in later forest succession. These include *Gynerium sagittatum* and *Tessaria integrifolia*, which resist moderate flood damage and resprout after burial (Kalliola *et al* 1991).

Guadua sarcocarpa (Poaceae) locally known as “kapiroshi” bamboo, presents easily defined characteristics. In reference to the forest structure, it occupies an alternate co-dominance, and in places where it is likely to be dominant, it reaches 80% of the whole forest density (ONERN 1987). Satellite images of the lower Urubamba area reveal that the distribution of bamboo is not patchy. Rather, it covers extensive areas but is completely absent from other zones. The transition from bamboo forest to non-bamboo forest is strikingly abrupt, and the number of tree species is higher in non-bamboo forests (Alonso *et al* 2001). When this bamboo dominates an open forest, it presents a dense shell of leaves at the mid-canopy level, resulting in higher reflectance in the near and middle infrared optical bands compared with typical Amazon primary forest (Nelson *et al* 2005). Also, the same authors mention that within each spatially continuous population of *Guadua* sp, covering tens of hundreds of square kilometres, all genets reproduce and die synchronously; while life cycle is around 30 years.

According to Griscom *et al* (2003), the bamboo dominated forests are *terra firme* forests characterized by a mosaic of (i) forest stands without bamboo with heterogeneous forest structure, and (ii) stands of trees scattered within a canopy dominated by a single species of native arborescent bamboos. The ecology of bamboo dominated forests is still fairly understood. In this sense, Vidalenc (2000) states that substrates where bamboo is excluded have more leached upper soil horizons, higher sand content, and probably higher percolation (on plateaus this means year-round stream flow and clear water streams). Griscom *et al* (2003) and Nelson *et al* (2001) agree that bamboo presence inhibits tree recruitment into larger size classes; and that this inhibition, in association with wind disturbance causing tree blow-downs, may explain the occurrence of this forest type without catastrophic disturbance.

The Nature Conservancy (2004), identified and selected three different plant communities' representative areas (with their names in Matsigenka) for an inventory process: (i) "Kapiromashi" (bamboo), when referring to the lower mountain slopes of the areas situated between 650 and 1200 m.a.s.l.; (ii) "Katarompanaki" (Clusia), when referring to middle-elevation tablelands between 1350 and 2000 m.a.s.l.; and (iii) "Tinkanari" (fern), making reference to the middle-elevation slopes in lands with an elevation between 2100 and 2400 m.a.s.l. They grant the landscape heterogeneity of the area to the rugged and varied topography, microclimatic changes along elevation gradients, disturbance from landslides, and dramatic, small-scale variation in substrate.

3.6. *Human settlement*

Indigenous peoples have lived in the rainforests of the Amazonian region for a long time, probably thousands of years. They were once more numerous and occupied more of the region than they do today (Dufour 1990). One of those indigenous Amazonian groups is the Matsigenka or Machiguenga ethnic group. The Matsigenka are an Arawakan-speaking group who inhabit the south-eastern part of Peru; extending from the upper and lower Urubamba region in Cusco, to the Manu National Park in Madre de Dios. Their territory, with an extension of nearly one million hectares, has always been considered of difficult accessibility (Plan Maestro del SNM 2007). Historically, the Matsigenka have been semi-nomadic cassava farmers, hunters and gatherers living in widely dispersed settlements throughout the headwaters of the Urubamba, Alto Madre de Dios and Manu Rivers (Johnson 2003). The highest concentration of Matsigenka people is located in the Urubamba basin; while a small amount of them is situated in the Manu basin. In 1993 the Peruvian census registered 8679 Matsigenka inhabitants, and according to the Information System on Native Communities of the Peruvian Amazon (2007), the total population is approximately 9540 inhabitants.

The Matsigenka, known as "Antis" by the Incas, and traditionally composed of extensive families with kinship relations; had a dispersed and migrant settlement pattern. But nowadays they live in a more nucleated and sedentary manner in their indigenous lands (Plan Maestro del SNM 2007). Aside from hunting, fishing, and gathering; poultry is also currently considered in their economic structure. Native people are shifting from livestock farming to poultry raising, as they view domesticated animals as an important source of additional income (Henrich 1997).

The main productive activities of these native people are developed in an economy of self-consumption or subsistence; with an increasing participation in a market economy. This merchandizing process progressively alters the settlement patterns, labour allocation, resource consumption, and land use (Henrich 1997). The farming system, considered strictly from the standpoint of quantity of food energy produced, is by far a household's most important source of food. Matsigenka gardens are remarkably productive and guarantee that starvation is a distant, perhaps insignificant, danger. Garden production is complex and dynamic, a flow of gradual transformation from first clearing to final abandonment of a garden (Johnson 2003).

Traditionally, they have used their native knowledge to select lands suitable for the establishment of their gardens or "chacras"; and practiced swidden agriculture using traditional techniques with long periods of fallow. The length of such could depend on several factors; such as the type of prior crop, field size, household access to labour and primary forests (Coomes 2000). Traditional swidden agriculture, still practiced in many Matsigenka communities, enables the forest to slowly regenerate after several years of fallow. The Matsigenka cultivate manioc, maize, plantains and bananas, and a large variety of minor root crops, fruits, medicinal plants and other useful species, averaging in all more than 64 different plant species (Ohl *et al* 2007). The variety of crops cultivated in slash and burn gardens supply most of the Matsigenka caloric intake (Henrich 1997). Solely the manioc yield approximates 10 metric tones per hectare (CEDIA 2007). Lately, increasing attention is given to the cultivation of cash crops such as beans, rice and peanuts.

Most of the Matsigenka natives living in the Urubamba region have had their territory recognized after land use planning and land entitlement. The native community of Timpia, whose boundaries delimit the extension of the study area, is inhabited by a population maintaining a nucleated settlement pattern, although it is still possible to find individual households or clusters of these throughout the area. According to a study made by the José Pío Aza Cultural Centre (2003), 40% of the population is still living in a scattered manner. In Timpia, it is possible that the nucleated arrangement could be understood as a consequence of the presence of the Dominican Catholic mission for almost 50 years, the primary school, and sanitation facilities.

Organizationally, the main hamlet of Timpia is made up of five neighbourhoods, named as follows: “Aviación”, “Paisandú”, “Nueva Urbanización”, “Pandishiroa”, and “San Juan de Irabare”. These neighbourhoods were likely to have been mainly established to follow an order in the settlement of new young families and the distribution of their households within the community lands. But they are mostly used when organizing soccer contests, which is one of the main social activities in the community. In terms of internal management, the Community’s General Assembly is the maximum decision making entity, in which most of the natives participate, being presided by the community chief and all the members of his council. The latter is responsible for the community’s representation for external affairs and for the management of all the common goods, among other responsibilities. In Timpia, both men and women are almost equally represented at a Council level; unlike other communities of the lower Urubamba. Several other organizations, like the APAFA (Association of school parents) and the “mother’s club” play an important role in the community; this in particular is responsible for performing several activities during communal work or “faenas” and for handicraft making.

At a regional level, Timpia and other 13 native communities belong to an organization called COMARU (Matsigenka Council of the River Urubamba), which is a federation of native communities that plays an important role in topics related to land management and training. This federation is also core when facing conflicts in land use between native and colonial lands. Several external organizations of different nature are involved in developing projects in the study area, many of them concerning the management of natural resources. The Regional Institute for the management of water and the environment (IMA), has impelled agricultural programs (e.g. aquaculture). Non-Governmental Organizations such as the *Centre for the Development of Indigenous Amazonians*, *Escuela para el Desarrollo* and *Shinai Serjali* have also been working in the community; especially the former one, which has had a strong presence in the region since early 1980s and responsible for the entitlement of many community lands.

Demographically, the population of Timpia is relatively young. The age of almost 77% of the inhabitants fluctuates between 0 and 30 years old. The Community’s age distribution is shown in the table 3.

Table 3: Age distribution in Timpia native community and in the Lower Urubamba Region

	<i>Age (years)</i>			
	0-14	15-29	30-49	50 or more
Timpia NC	44.75%	27.87%	17.68%	9.71%
Lower Urubamba	49.05%	26.47%	19.15%	5.33%

Source: CEDIA 2007 – Informe de Proyecto: “Mejoramiento de las técnicas agrícolas y forestales en el bajo Urubamba 2006”.

In terms of education, the community owns two primary schools: the first one located in the main hamlet, and providing basic multi-class education until the first year of high school (approximately 12 year- old students); while the second one is a single-class primary school located in Alto Timpia, where children from 6 to 16 years old share the same classroom and teacher; and therefore, they all receive the same level of education. In case a teenager intends to complete the high school education he/she must leave the community to attend a nearby school. The courses at school are taught in both, Matsigenka and Spanish languages. By the time of this study (July 2007), it was publicly known the desire and will of expanding the school built area in order to provide with higher education to the community members.

Referring to communication, the community has three radios and one satellite public telephone. At the time of the field study, negotiations to provide the main hamlet internet connection were being arranged; which would require training for a proper use. In terms of energy, the main hamlet is provided with electricity by a generator; there are light posts along the airstrip and some light bulbs inside and nearby the houses, which are provided with energy from 18:00 to 21:00 hours every day.

In terms of land use, several different land uses co-exist within the community and in its vicinities. On the north-eastern part of the community, allochtonous people who have migrated to this region, mainly with an Andean origin, inhabit their settlements with the purpose of developing commercial farming, grazing and forestry activities. Additionally, on the western border of the community, 44 hectares have been designated for the downstream component of the Camisea natural gas project. The project’s camps are located every three kilometres along the gas pipelines, and their main purpose is to build gabions for stabilization and erosion control (Appendix 4, figure 1-E). Moreover, the community owns an Eco Lodge, located by the Sabeti River, where tourism activities occur mainly during the dry season. For this purpose, the community has reserved 2600 hectares. Finally, Timpia forms part of the Megantoni

National Sanctuary buffer zone, and as such, the National Institute for Natural Resources (INRENA) has recently built a guard house in 0.5 hectares of a land designated by the community. Another fact that distinguishes Timpia from many other native communities is the fact of having an airstrip, of approximately 900 metres of length by 30 metres of width. This airstrip is easily spotted from remotely sensed imagery, as it is one of the few human influenced largest areas.



Figure 7: (A) Timpia main hamlet (community centre); (B) Alto Timpia hamlet. The spatial location of these hamlets within the community is shown in figure 2. (Photographs: Verónica Gálmez 2007)

4. METHODS

4.1. Environmental characterization of the study area

4.1.1. Physical characteristics

The physical characterization of the study area was based on: (i) geological and soils information obtained from thematic maps; (ii) physiographic information based on digital elevation models and aerial photographs; and (iii) land cover and land use information derived from satellite images and aerial photos. The physiographic information obtained from the digital elevation models included: elevation, slope, and aspect. Land cover information was obtained after satellite image interpretation and classification; and it was aimed at identifying open lands within the community. Moreover, field observations complemented the characterization. These datasets were manipulated using GIS capabilities to derive information for a holistic environmental characterization.

In this study, different spatial datasets were used; and they were acquired from primary and secondary sources. The primary data was mainly extracted from the field, while the secondary data was obtained from spatial data lending facilities and regional and national databases. The compiled spatial data used for this study is shown in table 4.

Table 4: Spatial data used in the present study

<i>Raster Format</i>				
Spatial data	Sensor	Spatial resolution / Scale	Provider	Acquisition date
Aerial Photographs Roll/Strip: 26/47-A (26-29)	Panchromatic black and white film	1/80 000	Instituto Geográfico Nacional (IGN)	19/07/1993
Aerial Photographs	Panchromatic black and white film	1/60 000	Servicio Aerofotográfico Nacional (SAN)	1963
Landsat	ETM+	30 metres (B1-B5; B7)	GLCF	12/08/2001
SPOT	HRG2	10 metres (B1,B2,B3,B4)	OASIS Programme	20/07/2003
DEM		90 metres	USGS/NASA SRTM	
DEM		30 metres	Created from contour lines (this study)	

<i>Vector Format</i>			
Spatial data	Original Scale	Provider	Observations
Upper and lower Urubamba cadastre	1/100 000	CEDIA	Shapefile depicting the native communities of the Urubamba region.
Hydrography	1/100 000	Extracted from the National Map – IGN	Shapefile depicting all the rivers and tributaries of the region (quadrangle 25q).
Topography	1/100 000	Extracted from the National Map - IGN	Shapefile depicting elevation contour lines measured every 50 metres (quadrangle 25q).

Geology	1/100 000	INGEMMET	Shapefile depicting the main geologic formations of quadrangle 25q.
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Concerning the geologic data, they were derived from the quadrangle 25q of the national geologic map (INGEMMET 2003). The map was acquired in a shapefile format so that it did not need to be digitized in order to be clipped with the study area boundaries (political limits). The clipping operation enabled the area calculation of each of the nine lithostratigraphic units present in the study area. The area calculations were performed using the *geometry calculator* tool available in the *ArcGIS 9.2* software. Concerning the soils data, it was obtained from the major soil units map (IMA 2005) with a .jpg file extension and therefore each of the soil units had to be digitized. The coverage of each of the four major units present in the study area was also calculated using the same software's tool.

Topographically, the study area was characterized upon elevation, slope, and aspect. Elevation data was extracted from a Digital Elevation Model (DEM). A 90m-DEM was downloaded in a *Geotiff* format (WGS 84 datum) from the Consortium for Spatial Information of the Consultive Group on International Agricultural Research geoportol. This DEM was originally created by the NASA's Shuttle Radar Topography Mission (SRTM). Once downloaded, the DEM was subset to meet the study area's extension. After the subsetting operation, data with elevation values occurring outside the Timpia boundaries were then avoided, stressing the differences in elevation within the study area.

In addition, a Digital Elevation Model derived from contour lines of the topographical map (scale 1:100 000) was created using the *Spatial Analyst* extension of *ArcGIS*. It was used during the first stage of the research and later on compared with the SRTM DEM for fitness assessment (Appendix 3-I). In order to calculate the amount of area covered by each altitudinal gradient, the SRTM DEM was classified into 8 different classes, with amplitude of 100 metres each. These calculations were made using the *Raster Calculator* tool of *ArcGIS*. Moreover, river profiles were created upon the SRTM DEM and the hydrographical network map, with the aim of evaluating the topographical variation across different sections of the main rivers.

Slope data was calculated from the SRTM DEM as the maximum rate of change between each cell value and its surrounding cells. The *ArcGIS Spatial Analyst's Surface Analysis* tool was used to calculate the slope in percentage per 90m-cell. For

verification, the resulting grid with slope values were compared against data obtained with clinometer measurements from the field (Appendix 3-I). Aspect data, as the direction land surface faces, was also calculated upon the SRTM DEM using the *Surface Analysis* tool. The aspect is expressed as an azimuth clockwise from the north (0°), back to north (360°). Flat areas were assigned an aspect of -1; and they were considered as having no downslope direction. As both, slope and aspect values, were calculated as continuous data; they were reclassified using the *ArcGIS Spatial Analyst's reclassify* tool so that a certain slope and aspect range of values could be easily represented.

4.1.2. Land cover analysis

With the aim of identifying the main land cover types within the study area and their spatial distribution, a supervised classification was performed after image manipulation. To interpret the landscape features using remote sensing, four aerial photographs, a Landsat ETM+ image, a SPOT HRG2 image, as well as field observations were required. The acquisition, pre-processing, processing and analytical work performed with the remote sensed datasets are explained below under each subtitle. The supervised classification procedure is particularly explained in detail hereafter.

I. Aerial photos

Four panchromatic B/W aerial photographs were acquired from the National Geographic Institute (IGN) and two from the National Aerophotography Service. The analogue aerial photos were scanned using the UTU Laboratory of Computer Cartography desktop scanner. Once scanned, the photos were opened using the *ERDAS Imagine 9.0* software and saved as image files.

The *Leica Photogrammetry Suite 9.0* software was used to perform photograph orthorectification. This was done in order to eliminate the geometric distortion of the aerial photos, and obtain planimetrically true images that could represent ground objects in their real-world X and Y positions. For this purpose, a frame camera image block file was created, and the camera model was defined using the information (average flying height, focal length, sensor name, fiducial marks, and central point) provided by the IGN when purchasing the aerial photos. Once all the photos were provided with interior

orientation, the ground control points (GCPs) were verified and the tie point's position was measured. Five to seven CGPs were accurately selected throughout the photos, mainly at the intersections of rivers and streams. The X and Y reference coordinates were obtained from the hydrological network shapefile, while the Z reference from the SRTM DEM. The following phase, the aerial triangulation, was performed for the calculation of the exterior orientation. The result of the triangulation was assessed while observing the value of the standard error of the last iteration, as well as the residuals of the GCPs and check points. Finally, the ortho resampling made use of the same DEM file to supply elevation information to create the orthorectified photos. The resample method selected for this process was the Nearest Neighbour. The successfully orthorectified images were visualized and the swipe utility of the *Erdas* software was used to see how well the aerial photos overlap. Moreover, a set of 2 photos showing different views of the same ground space captured from different perspectives were overlapped to create a stereopair. The *Stereo Analyst* Tool of *Erdas* software was used for this purpose.

II. Satellite images

i. Landsat ETM⁺ image

Each of the bands of a Landsat ETM⁺ image (Scene 5/68) was downloaded from the Global Land Cover Facility system of the University of Maryland. The software *Erdas Imagine* was used to stack all the image's bands together in order to compose a single image, which was then subset to meet the study area extension. Six channels of the image that share the same spatial resolution of 30m were used: ETM1, ETM2, and ETM3 from the visible portion of the electromagnetic spectra; ETM4 from the near infrared; and ETM5 and ETM6 from the short wave infrared spectra. The image was acquired in August 12th, 2001, coinciding with the time of the year (low waters season) when the field study was carried out. The latter became one of the main reasons for the image selection, in addition to its low cloud coverage and lack of haze presence. For referencing the image, 15 GCPs were taken throughout the study area with a GPS (most of which could be situated on the Landsat image) as well as communal gardens (which existed at the moment of image acquisition and still delimited at the time of the field work) were mainly used for georeferencing. Also, additional GCPs were taken from the hydrological network shapefile (1:100 000).

The processing of the image focused on the image enhancement in order to understand its land cover information content. The most utilized image manipulations were: (i) the radiometric enhancement, which involved the adjustment of the brightness values of the pixels; and (ii) the spectral enhancement, where the original pixel values in the multi-band satellite image were adjusted implying the usage of different types of mathematical operations. When making use of radiometric enhancement techniques, several contrast adjustment methods were applied and assessed in a band by band basis. These manipulations were done using the breakpoint editor tool of *Erdas Imagine* software.

When applying the spectral enhancement techniques, new images were produced as a result of the analyses performed with the aim of emphasizing certain phenomena in the image. Aside from a band by band analysis, the following ratios and indices were used:

- a) Ratio: $NIR/R = ETM4/ETM3$; where the pixel value in the Near Infrared band (0.750-0.900 μ m) acts as the divisor and value in the red band (0.630-0.690 μ m) as the dividend. It was used to reduce the effects of the relief in the reflectance values, as well as to identify differences in vegetation, especially in shaded areas.
- b) Normalized Difference Vegetation Index: $NDVI = (NIR-R) / (NIR+R)$; where the subtraction of the values in band3 from band4 is divided by the sum of the values in both bands. In this sense, if the pixel values in the red band are higher than those in the NIR band, the index value becomes negative, and as it is normalized, values may range between -1 and 1. This index was mostly used to assess vegetation vigour.
- c) Bare Soil Index: $BI = ((ETM5+ETM3) - (ETM4+ETM1)) / ((ETM5+ETM3) + (ETM4+ETM1)) \times 100 + 100$; where resulting values range between 0 and 200. In this index, five bands: ETM1 (blue), ETM3 (red), ETM4 (NIR), and ETM5 (SWIR) are used to compose an image where bare soils can be distinguished from areas covered with vegetation or water bodies. This index was created using the spatial modeler language of *Erdas* model maker tool (figure 8).
- d) Ratio: $ETM5/ETM2$: This ratio was used to distinguish water from non-water areas (e.g. Toivonen *et al* 2007) and therefore, giving the possibility for the creation of a water mask.

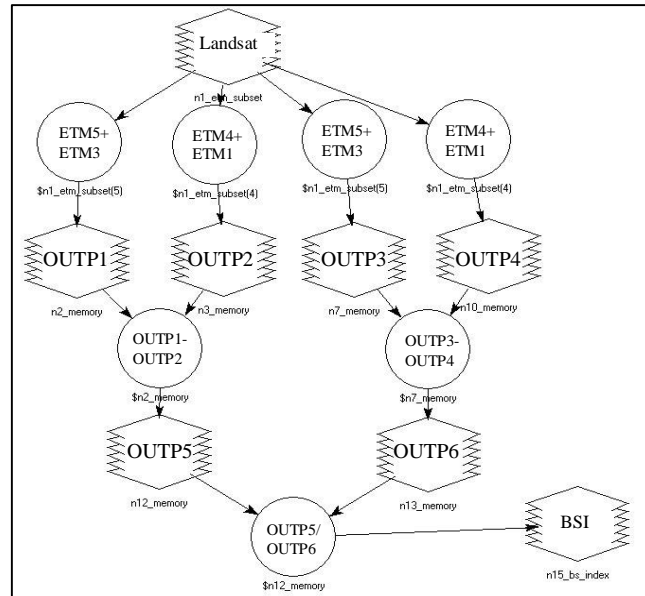


Figure 8: Erdas arithmetic model used for designing the Bare Soil Index. The Landsat ETM bands used were: ETM1 (blue), ETM3 (red), ETM4 (NIR), and ETM5 (SWIR).

ii. SPOT HRG2 image

A SPOT HRG2 image (Scene 56573740307201525282J) was obtained through the Optimizing Access to SPOT Infrastructure for Science Programme. It was acquired on July 2003, coinciding with the time of the year (low waters season) when the field study was carried out. When accessed, it already had a 2A pre-processing level, meaning that a radiometric correction of distortions was performed, and geometrical corrections were made in a standard cartographic projection (UTM WGS84). This image was registered onto the Landsat image, while many of the previous GCPs were also utilized. It was then subset to match the extension of the study area. The four channels of the image that share the same spatial resolution of 10m were used: B1 and B2 from the visible portion of the electromagnetic spectra, B3 from the near infrared, and B4 from the short wave infrared spectra. As for the Landsat image, since haze was not visible on the image, an elimination/reduction treatment was not deemed necessary; but several radiometric and spectral enhancements were performed:

- a) Normalized Difference Vegetation Index: $NDVI = (NIR-R)/(NIR+R)$
- b) Principal Component Analysis: It was carried out in order to condense most of the information (maximum variation) of the 4 bands into the principal

components, with the aim to reduce the redundancy of the data. The analysis output was assessed through the eigenvalues and eigenmatrix, which can be found in Appendix 1.

Due to the spatial resolution of the SPOT image, its lack of haze and clouds, and its proper interpretation under several image manipulations, a supervised classification was performed. The main purpose of the classification was to identify the distributional patterns of the open lands in relation to the forested lands and community centre, and quantify their extension for subsequent analysis. Before the image classification, initial limitations were tried to be overcome. The challenges for classification were related to: (i) the topographic effects (mainly shades) due to terrain rugosity; (ii) the spectral differences in forests' composition; and (iii) the mosaicism of cultivated areas. In terms of cloudiness, as the extension and location of the area covered by clouds were not significant, their presence did not influence the procedure. Following, the main steps of the classification are presented. As the effect of topography and its shadow in the spectral signatures of land cover classes could ideally be corrected through a topographic normalization using a DEM (e.g. Silverio *et al* 2005), two normalization artefacts were tested. The outcomes of this are described in Appendix 3-II

Ground truth data was collected in the field during the dry season months in 2006 and 2007. The geographical coordinates of all the visited gardens and other land cover types such as pasturelands, bamboo-dominated forests, and mountainous primary forests were recorded on a Global Positioning System (Garmin 12XL GPS) with estimated accuracy of ± 8 m. Coordinates were taken at least four times in each garden in order to calculate an average for each location. Information on the former land cover and land use was recorded as part of the interview applied to each of the gardens owners (described hereunder). In this sense, information on the land cover at image acquisition time could be known. The latter, however, only in few cases the owners were able to recall about the former land covers, and therefore, the amount of training areas for performing the supervised classification were rather limited. Some fallow lands and active gardens owned by the community were used apart from household gardens, since the area of those land cover types was greater than the ones individually owned.

Masks were created to exclude water bodies and depositional material exposed during the low waters season. For creating the water mask, an unsupervised classification for

few classes was performed to clearly differentiate the areas covered by water. This was selected as the best manner of distinguishing water from the land. Although bands 1 and 4 of the SPOT image somehow resemble the ETM2 and ETM5 respectively, the resulting image after applying the ratio B4/B1 was not successful for masking purposes. The created water mask was then compared with a mask created for the Landsat image using the ratio ETM5/ETM2 in order to visualize any significant difference (Appendix 3-III). It was then possible to estimate (using the ArcGIS *Raster Calculator* tool) the area covered by water during the dry season. As the eastern boundary of the community (figure 2) limits on its left bank with the Urubamba River, this section of the river was not supposed to be considered for the calculation, but as it is mostly used by the natives for transportation purposes, it was included. Therefore, the riverscape extension of the community was increased. A second mask depicting depositional material was created through an unsupervised classification using the Normalized Difference Vegetation Index (NDVI) image. Both masks were combined and excluded from all other areas covered with vegetation.

The assessment of the training areas was carried out through histograms, feature space plots, contingency analysis (through an error matrix, using the parametric maximum likelihood rule). The reports of the contingency analysis are presented in Appendix 2. Six classes were considered for the land cover supervised classification: 1) bamboo dominated forests; 2) non-bamboo dominated forests (where primary forests dominate in mountainous and hilly areas); 3) riverine vegetation; 4) mixed bamboo forests; 5) open lands, mainly pasturelands; and 6) open lands, mainly fields. After the classification, the *Erdas Imagine* GIS tools *Clump*, *Sieve*, and *Eliminate* were used to avoid one-single pixel in the fifth and sixth classes, as the minimum single cleared area encountered in the field was ~20m². Also, for the second class, it was assumed that the average natural gap size ranges between 0,56m² and 88,3m² (e.g. Ferreira de Lima 2005), therefore, all the gaps with a size of less than 60m² (6 pixels) were eliminated.

After the image classification and verification, the forested land cover classes were compared among themselves according to the topographical aspect class in which they mostly occurred. This was done in a cell-by-cell basis. For this purpose, each of the land cover class image files (with spatial resolution of 10m) was converted into a raster grid file; and in turn, into a vector format. Each of the vectorized forest-based land cover classes was intersected with an empty vector grid (fishnet) of 90mx90m-cell size

created for covering the entire study area. This grid of cells was considered as the best alternative for this purpose, as the cells represent a solid spatial entity and at the same time they allow comparison. After the intersection process, each of the cells held a certain area covered by each considered land cover class. And if this coverage resulted to be more than half of the cell's area, then the cell was considered to belong to such land cover class. All the cells of the grid were then identified with a code, representing its membership to a certain land cover class. The continuous raster dataset with topographical aspect values previously calculated upon the SRTM DEM was converted into an integer cell-type raster format, so that it could then be converted into a vector grid of 90m-cell size (as the original DEM's pixel size). Both grids, the one holding land cover class values and the one holding aspect values were intersected in a cell-by-cell basis, and the amount of cells in each aspect class could then be calculated according to each land cover type. The output tables were exported from *ArcGIS* to Excel to derive the graphs.

Finally, the quantification of each of the land cover classes was calculated. The *Raster Calculator* tool of *ArcGIS* was mostly used for this purpose. In addition, to assess the distribution and amount of the land cover classes in relation to their distance from the community centre, their coverage in a class-by-class basis was calculated according to this distance criterion. For this purpose, a multi-ringed buffer of 200m radius was created, having its origin in the community's main hamlet centre; with known location measured with GPS in the field. In this sense, it was possible to calculate the extension of e.g. open lands in relation to a distance of every 200m from the community centre, in any direction. This was done with the purpose of assessing the degree in which the distance-to-centre variable influences the decision of selecting sites to clear. The output tables showing how a certain land cover class area varies when the distance from the centre increases were exported from *ArcGIS* to Excel to derive the graphs.

4.1.3. Land cover / land use change assessment

Land cover change through time was examined and three examples within the study area are presented. In order to identify the major land cover change occurring within the community and its vicinity, comparisons were made between current and past land cover types, as well as between native and colonial land use patterns. Also, land use changes due to the Camisea gas pipeline's right of way construction are addressed.

Detailed land cover / land use change detection was not aimed; but this exercise was included as part of the understanding process for shifts in traditional patterns and priorities in land use. For this purpose, satellite images (Landsat ETM+ and SPOT) as well as two panchromatic B/W aerial photos are used for the land cover change identification. The areal calculations were made using the *ArcGIS* software tools.

4.2. Assessment of the environmental site suitability for garden establishment according to natives criteria

4.2.1. Interviews with natives

Through semi-structured interviews, a total of 44 households responses were registered using a guiding matrix prepared beforehand, which served as the interview framework. The minimum and maximum ages of the interviewed natives were 21 and 80 respectively. Two approaches were considered for the interviews: (i) to analyze the native criteria for garden site selection, while recording different former and current land cover types and land use practices; and (ii) to record garden dynamics and preferred crops according to a specific site and conditions. During the interviews, a Matsigenka-Spanish translator participated as a mediator. The fact that the same translator participated in all the interviews during the field work standardized the interpretation of the possible responses variability.

It was then aimed to identify, according to natives' responses, the environmental factors which influence the criteria for the selection of garden sites for slash and burning. Edaphic and physiographic descriptors were assessed during garden visits. Regarding the second approach, it was aimed to distinguish specific site preferences for the most common crops, and possible correspondence between them and crop growth requirements.



Figure 9: Interview conducted in Alto Timpia

4.2.2. Soil sampling and analysis

Soil sampling was done in active gardens (considered as suitable sites for farming) and in non-farmed lands (considered as non-suitable for farming). In the first case and for each active garden visited, three to four sites were selected for soil sampling. According to the shape and size of each of the gardens, sub-samples were taken while advancing sinuously, trying to cover the central parts as well as the boundaries a certain garden. In each site a soil sub-sample was collected, as within garden variability was aimed to be reduced; generating in this way, a composed sample for each garden. For the soil sampling, a methodology suggested by the soil department of the UNALM when sampling agricultural fields was used (Bazán 2007 Pers. Comm). The sample depth was determined to be at 20-25cm (plough layer), as this is most influenced by agricultural practices. Fresh fallen leaves and superficial roots (1-3 cm) were removed from each sampling site, as well as big roots and/or stones. Each of the gardens sub-samples of ~250g were then mixed, poured and maintained in a 1kg-ziplock plastic bag for one month and a half, until they reached the laboratory for their physical and chemical characterization.

Additionally, colour was one of the most important attributes to characterize and compare the soils with. In the field, the colour of a soil sample was visually compared

with various colour chips of the Munsell chart; which are described and shown in the chart by combining the variables hue, value and chroma and presented as an alphanumeric code (e.g. 10YR3/3). Colour variations, as well as roots and stones presence and dimensions were annotated. Texture was also assessed (finger tested) using the field guidance of McRae (1988), in order to be later on compared with the laboratory's textural class denomination. Other important factors to be qualitatively considered were: soil structure, current and former land use and land cover, crop diversity, water presence, and workability. A total of 56 sub-samples were obtained throughout the study area.

Six additional sites were selected throughout the study area, representing nearby forested locations considered by natives as non-suitable for farming purposes. A modified methodology proposed by Behrens (1989) for the study of soils in a Shipibo community was applied. Upon arriving at a site, a starting place was selected as being the soil sampling centre of reference. Starting from this reference point, the site was divided using the four quadrants of the compass. A radius of 25m was used to locate a sub-sampling location and sub-samples were taken on 90° graduations of the compass. A total of 5 sub-samples were obtained from each site (1 from the centre of reference and 4 from the periphery). The five sub-samples were then mixed together to compose a single soil sample for each location.

After the field work, the soil samples were characterized by an analyst of the Soil Laboratory of the UNALM, in Lima. The following physical and chemical properties were analyzed: pH, salinity (electrical conductivity), organic matter, available phosphorus and potassium, sand, silt and clay content, cation exchange capacity, and exchangeable cations (Ca^{+2} , Mg^{+2} , K^+ , Na^+ , $\text{Al}^{+3} + \text{H}^+$). From the last two parameters, the following were calculated: sum of cations, sum of bases, and base saturation. Each of the mentioned properties was analyzed according to the Laboratory's protocols; being the methods used for the soil analyses as follows:

Table 5: Soil properties and methods used for their analysis in the laboratory

<i>Soil property</i>	<i>Measurement unit</i>	<i>Method used in the analysis</i>
Soil texture (sand, silt and clay)	Percentage (%)	Hydrometer method
Salinity	Millimho (dS/m)	Electrical conductivity of the aqueous extract in the relation soil:water 1:1 or in the saturation paste extract.
pH		Potentiometer measurement: by soil:water solution ratio of 1; or by 1 normal soil:KCl solution ratio of 2.5
Organic matter	Percentage (%)	Walkley&Black Method, organic carbon oxidation with potassium dichromate
Available potassium	ppm (1mg/Kg)	Extracted by 1 normal ammonium acetate solution at pH 7.0.
Available phosphorus	ppm (1mg/Kg)	Modified Olsen method: extracted by 0.5 molar sodium bicarbonate solution at pH 8.5.
Cation Exchange Capacity (CEC)	me/100g	Saturated with 1 normal ammonium acetate at pH 7.0.
Exchangeable bases: Ca ²⁺ , Mg ²⁺ , K ⁺ , Na ⁺	me/100g	1 normal Ammonium acetate replacement at pH7.0; quantification by flame photometry and/or atomic absorption.
Exchangeable acidity Al ³⁺ + H ⁺	me/100g	Yuan method. 1 normal KCl extraction
Sum of cations (Ca ²⁺ + Mg ²⁺ + K ⁺ + Na ⁺ + Al ³⁺ + H ⁺)	me/100g	
Sum of bases (Ca ²⁺ + Mg ²⁺ + K ⁺ + Na ⁺)	me/100g	
Base saturation (sum of bases*100/CEC)	Percentage (%)	

4.2.3. Plant sampling and physiographic measurements

Many of the garden crops, which could not be identified in the field were collected, pressed and preserved until reaching the dryer for their posterior identification in the Agronomy faculty of the UNALM. Most of the standing trees in cleared gardens and most dominant riverine vegetation were identified in the field, and some of the local names were also annotated. If identification was not reached, plant samples and photographs were also collected. The Gentry (1996) field guide was used for verification of in-field identifications.

Slope and Elevation were the major physiographic factors to be assessed in the field. In every garden and sampling site, slope values were measured using a SUUNTO Clinometer. Elevation was measured in metres above sea level using the GARMIN 12XL GPS.

4.2.4. Definition of the environmental site suitability variables for garden establishment

Potential sites for performing cropping activities were assessed under two different approaches:

- Suitable sites for cultivation in a community scale. This concerns influential decision variables such as slope, elevation and vegetation cover; information that was available for the entire study area. The selection of these variables is explained in detail hereunder.
- Suitable locations for gardening in a site scale. This includes decisions made upon soil characteristics; and such information is limited to the sites where soil sampling was made in the field.

I. Community scale approach

An assessment of the sites being selected as suitable for forest clearing was performed for the community as a whole. For this purpose, a 90m x 90m empty cell grid (fishnet) was created in a vector format using the *ArcInfo* licence of the *ArcGIS* software. The grid was set to cover the entire community. Each of the cells was considered as the basic unit for the analyses. This cell size was selected to match the DEM's pixel size used to obtain elevation and slope information.

Several environmental variables were considered influential for site suitability assessment. These variables were mainly identified from the interviews and garden visits, as well as from posterior data analysis. As natives consider certain land characteristics more suitable for agriculture than others, grades based on the natives' ranking of importance of each land characteristic regarding agricultural suitability were applied. Then, according to the specific variable under treatment (slope, elevation, vegetation, distance), a grade was assigned depending on the value range in which an observation (cell) occurred. This was done for the maintenance of the prioritized areas for clearing in relation to those areas less preferred. Then, the sum of grades per variable was done in a cell by cell basis, and therefore, cells with higher overall grading value were considered as having higher suitability for performing agriculture.

Following, the variables for the suitability assessment are described, as well as the criteria for their selection and their grading. They are presented here for facilitating the methodology understanding, but the variables considered under treatment are extensively described in section 5. The variables were derived from two different sources: (i) native responses and physiographic measurements in field; and (ii) after land cover data analysis, specifically after the quantification of open lands in relation to the community centre and main tributaries. These are described as follows:

- i. Definition of the variables addressed by natives and derived from field observations
 - a) Elevation: The altitudinal values were obtained from the DEM. Grades were given according to the altitudinal range in which each 90m-cell value occurred. This was done due to the fact that most of the active gardens tend to occur in a narrow altitudinal range. Cell values occurring between 400 and 460 m.a.s.l. were given a grade of 2. Cells with values of 460 to 580 m.a.s.l. were given a grade of 1; while cell values occurring below 400 and above 580 m.a.s.l. were not affected.
 - b) Slope: The slope values in percentage were derived from the DEM. Grades were assigned according to the slope range in which each cell value occurred. This was done due to the fact that most of the active gardens were preferred to be established within a certain slope range. Cell values of 0 to 7,5% were assigned a grade of 2. Cell values occurring between 7,5 and 15% had a grade of 1; while cells with slope values of more that 15% were not affected.
 - c) Vegetation: Sites where a certain natural vegetation type was found had different degrees for gardening suitability. These vegetation types were derived from the land cover classes obtained after supervised classification. The

Boolean capabilities of *ArcGIS* were used in this section for the performance of different extractions and overlaying operations between the 90m-cell grid and the land cover classes. Spatial analysis tools for raster and vector datasets were also utilized. Presence/absence of any of these types of vegetation in a cell by cell basis was registered. In this sense and upon native preference, cells with more than half of its area covered by the riverine vegetation land cover type were assigned a grade of 2; while cells with more than half of its area covered by bamboo-dominated forests land cover type were given a grade of 1. The rest of cells occurring in other vegetation land cover types were not affected.

ii. Definition of the variables derived from land cover analysis

- a) Distance to main hamlet community centre: The distance from the community centre to the centroid of each of the cells was calculated through a proximity analysis using the *point distance* function of *ArcInfo* licence (*ArcGIS*). Cells with distance values (in metres from the community centre) occurring within a radius of 3km were assigned a weight factor of 2; and cells occurring within a radius of 5km were given a weight factor of 1.
- b) Distance to the Urubamba River: The same proximity analysis explained above was used to calculate the cells' distance values from the Urubamba river. Cells with maximum distance values of 500m from the UR banks (right and left side or left side only according to the community's boundary) were given a weight factor of 2; while those cells having distance values of less than 1km but more than 500m from the UR banks were assigned a weight factor of 1.

- c) Distance to primary tributaries: For the distance calculation, the selected primary tributaries considered were: Timpia, Shihuaniro, Sabeti, Shimateni and Tsopiroato (figure 2). Each of the cells was given a distance value according to their minimum distance to each of these rivers; and the same proximity analysis previously explained was also used in this case. Cells having distance values of less than 500m from the rivers' right and left banks were given a weight of 1.

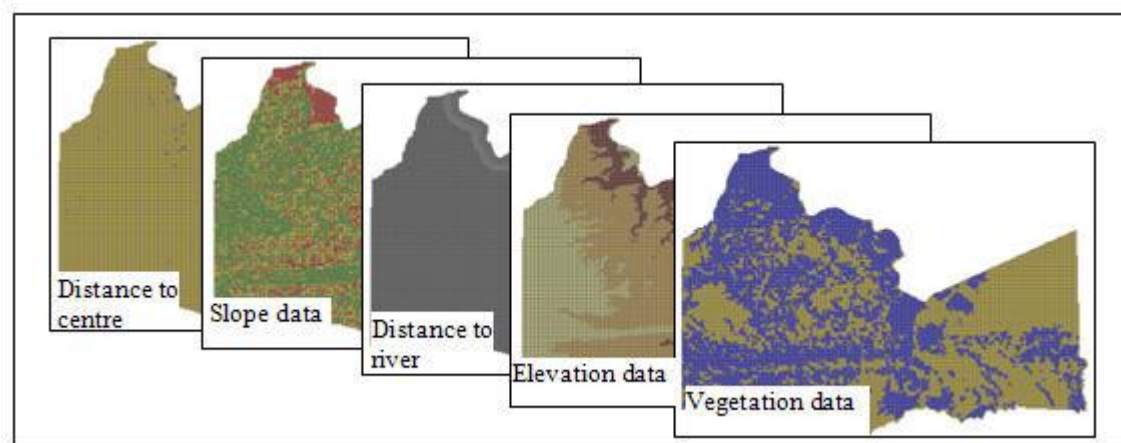


Image 10: Pictorial representation of the methodology for assessing the potential sites to be cleared, in a community scale

For the overall suitability assessment, a total of 11 variables (each depicted in a separate grid of cells) were considered (in image 9, only 5 are shown). Each of the grids containing grading values were then summed in a cell-by-cell basis, so that cells with higher overall values were set to represent the most suitable sites for establishing a garden.

II. Site scale approach

The information obtained from the interviews, garden visits and soils analyses were used for identifying the characteristics of the sites considered for their suitability or non-suitability for clearing and farming purposes. Due to the great variability in soil properties throughout the study area, instead of extrapolating their values throughout the community, a site scale correspondence was aimed.

Correspondence between native classifications of soil types according to the different soil characteristics were made with soil characteristics obtained from laboratory

analysis. Also, as the suitability for a site to be selected varies with the crop types, correspondence between crop agro-ecological requirements and soil type as perceived by natives is addressed. Moreover, suitability differences between the topography-influenced garden types are shown.

4.3. Evaluation of the result after correspondence of the native-based suitability criteria with ecological-economic zoning classes

The ecological-economic zoning (EEZ) classes (IMA 2005), obtained in a .jpg format were digitized to allow their usage in a GIS environment. Once the shapefile depicting the ecological-economic zones was created, it was intersected with an empty 90x90m-cell grid. This was done in order to provide each of the cells with the value of the zone which covered more than half of the cell's area. As for the study area a total of 11 zones were considered by the zoning developers, then each of the cells held one of these zone codes.

In a cell-by-cell basis, the ecological-economic zones were matched with the community scale site suitability classes, whose methodology was described above. The degree of similarity or disparity, expressed as a percentage, between the native agricultural knowledge-based suitable agricultural classes (native-based) and the ecological-economic zones with high, mean, and low agrologic quality was calculated according an areal overlapping (cell overlapping). Several overlaying tools available in *ArcGIS* were used to perform this comparison between both classification criteria.

5. RESULTS

5.1. Environmental characterization of the study area using spatial data resources

5.1.1. Physical characteristics

Concerning elevation, almost 80% of the study area is situated within an altitudinal range of 400 to 600 m.a.s.l. Whilst terrains with elevations ranging between 600 and 800 m.a.s.l. are present, they only represent 18% of the study area. Moreover, only in a small fraction of the community the elevation ranges between 800 and 1151 m.a.s.l. Figure 11 and table 6 show the spatial distribution of the altitudinal ranges and their areal quantification, respectively.

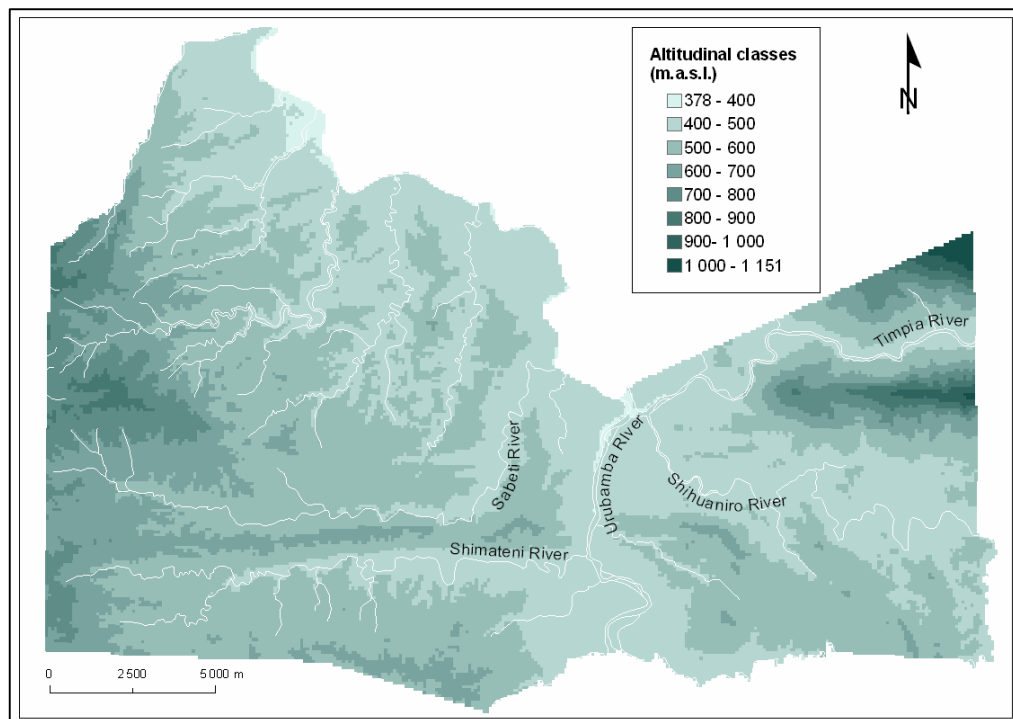


Figure 11: Elevation values (m.a.s.l.) classified into 8 different sets with amplitude of 100 m each. Darker areas depict higher elevations. The rivers and tributaries appear as white lines.

Table 6:
Coverage (ha and %) of each altitudinal class

Altitudinal Classes (m.a.s.l.)	Area (ha)	Area (%)
378-400	298,1	0,28
400-500	13949,9	38,75
500-600	14533,8	40,37
600-700	4515,8	12,54
700-800	2041,2	5,67
800-900	438,2	1,21
900-1000	140,13	0,38
1000-1151	87,48	0,25
Total		100

Concerning slope, 15% of the community's terrain presents slope values ranging from 0 to 5%; considered as flat to slightly inclined. They mostly occur in elevation ranges between 400 and 500 m.a.s.l. (figure 11). The most common slope values occurring in 43% of the community area vary from 5 to 15%. Whilst 27% of the lands have slope values ranging from 15 to 20%; only 13% of the lands have slopes between 25 and 45%. Less than 2% of the community territory has slopes above 45%. Figure 12 and table 7 show the spatial distribution of the slope ranges and their areal quantification, respectively.

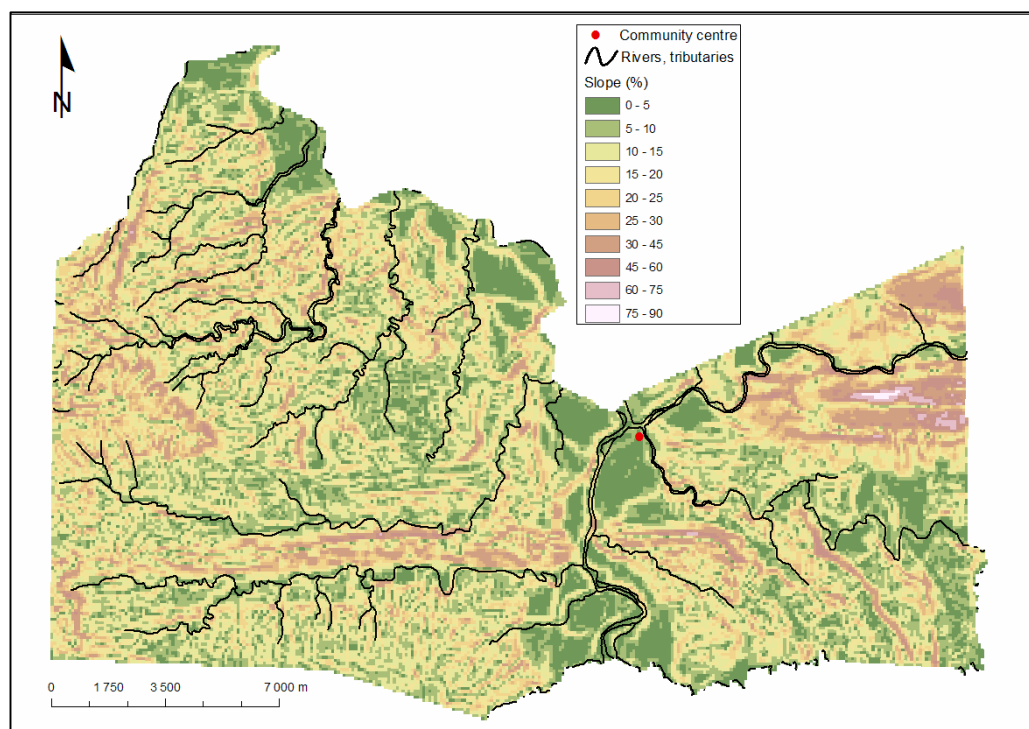


Figure 12: Slope classified into 10 different sets; calculated upon DEM

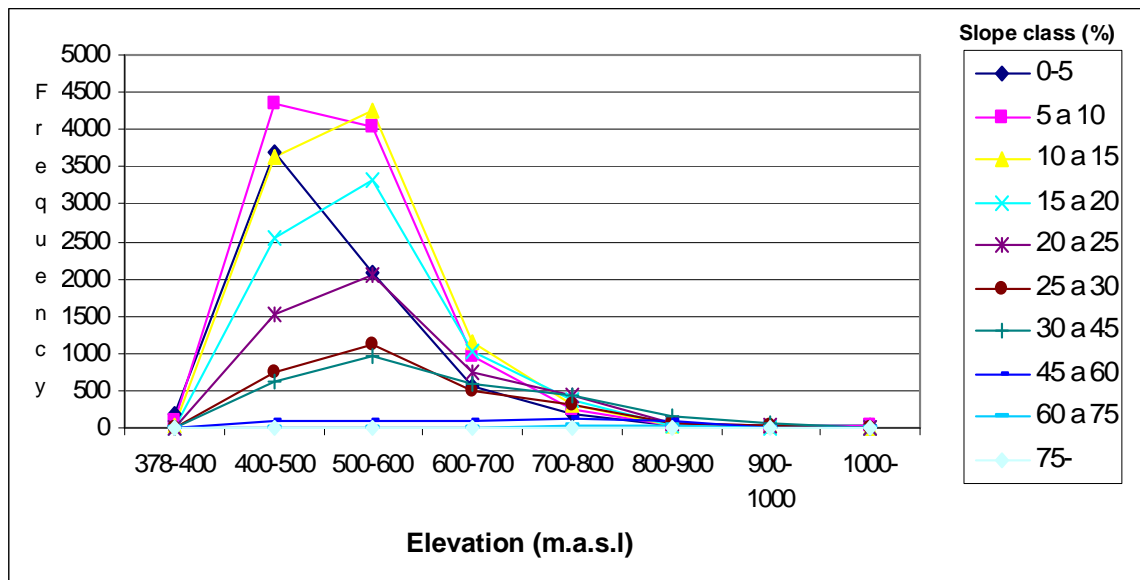


Figure 13: Slope class occurrences within an elevation range. The abscise axis denotes the frequency of cells in a slope class according to an elevation range. Note that the overall number of pixel occurrences in higher altitudinal ranges diminishes abruptly after ~650masl.

Table 7 and 8:
Area (ha and %) covered by each slope and aspect class

Slope Classes (%)	Area (ha)	Area (%)	Aspect Classes (degrees)	Aspect Classes (cardinality)	Area (ha)	Area (%)
0 – 5	5491,8	15,26	-1	Flat	159,97	0,44
5 – 10	7914,51	21,99	0-22,5	North	2820,42	7,84
10 – 15	7675,56	21,32	22,5-67,5	Northeast	4814,64	13,38
15 – 20	5938,11	16,50	67,5-112,5	East	4406,4	12,24
20 – 25	3919,59	10,89	112,5-157,5	Southeast	4540,86	12,62
25 – 30	2252,61	6,26	157,5-202,5	South	5355,72	14,88
30 – 45	2308,5	6,41	202,5-247,5	Southwest	3610,98	10,03
45 – 60	397,71	1,10	247,5-292,5	West	3046,41	8,46
60 – 75	81,81	0,23	292,5-337,5	Northwest	4238,73	11,76
75 –	15,39	0,04	337,5-360	North	3001,86	8,35
Total		100	Total			100

In relation to the aspect, almost 15% of the community slopes face to the south, while 13,3% of them have a north-east direction. They mostly occur within an elevation range of 500 to 600 m.a.s.l. (figure 15). Almost the same proportion (12%) of slopes occurs facing the east and south-east directions. Moreover, only 8,3% of the slopes face towards the north. Figure 14 and table 8 show the spatial distribution of the aspect ranges and their area quantification, respectively.

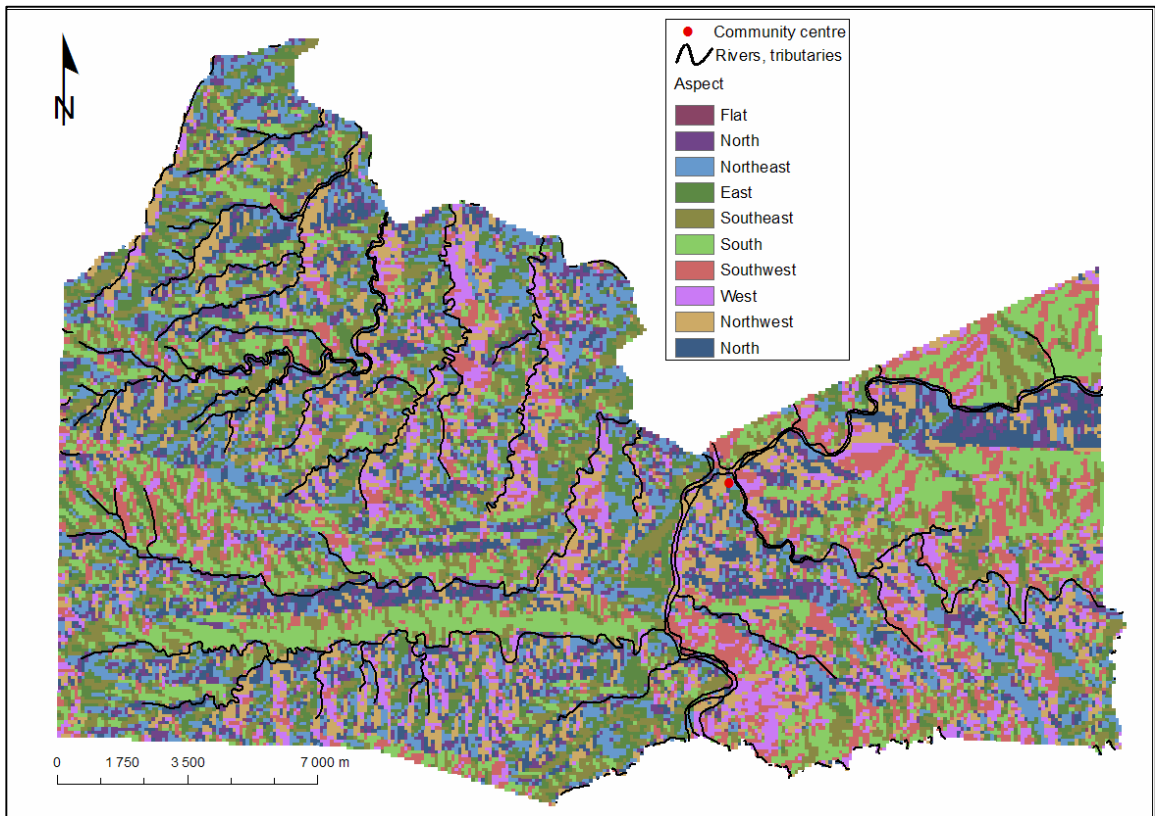


Figure 14: Aspect (cardinality) classified into 10 different sets; calculated upon DEM.

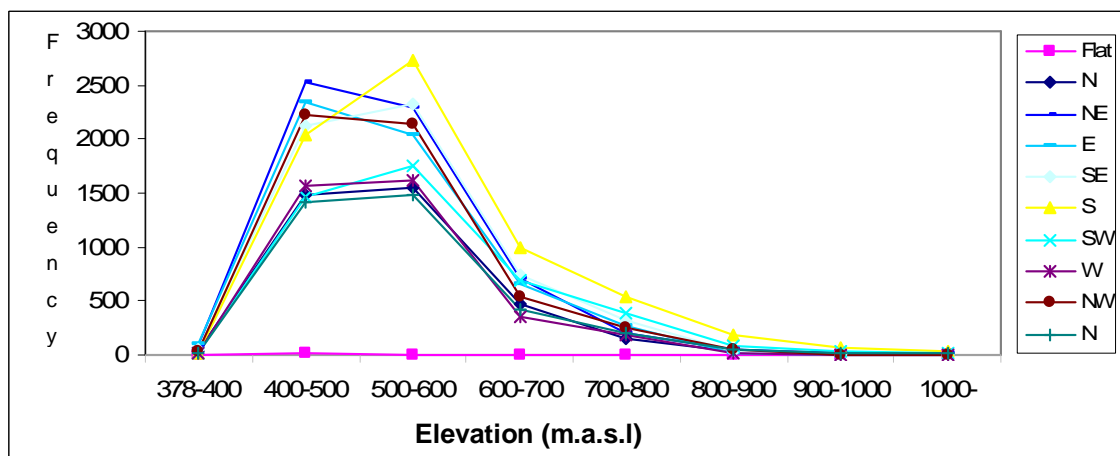


Figure 15: Aspect value occurrences within an elevation range. The abscise axis denotes the frequency of cells in an aspect class according to an elevation range. Note that the overall number of pixel occurrences in higher altitudinal ranges diminishes abruptly after ~650masl.

The relief in the study area is varied, and several geomorphological structures are distinguished. Terraces and dissected hills of different order are the main units in which the zone can be geomorphologically divided; in addition to the rivers floodplains with their particular landforms.

The Urubamba River flows at an elevation of ~400 – 420 m.a.s.l. along most of its sections within the study area; but only in its confluence with the Timpia River, its

elevation diminishes from 10 to 15 m; coinciding with the location of the community's main hamlet. The Urubamba floodplain is widest (~5Km) in the southern boundary of the community as well as by the Timpia river's mouth section. The most extended floodplain area occurs in the confluence of three of the most important rivers: Urubamba, Timpia and Shihuaniro.

The east side of the community (considering the Urubamba River as a natural dividing agent) accounts for 32% of the total extension of the community. On this side, and along the Shihuaniro river floodplain, its elevation never exceeds 500 m.a.s.l., while the slope increases gradually. Contrarily, the Timpia river appears to be in a more canyon-like situation in its upper section, as it is surrounded by a hill of considerable height (northward) and by a mountain of steep slopes (max ~35°) and altitudes reaching 1000 masl south-eastward. A series of profiles along the Timpia river (figure 16) show that, although the flat terrains are not common in most of their transversal sections, a relatively flat area coincides with the location of the Alto Timpia hamlet.

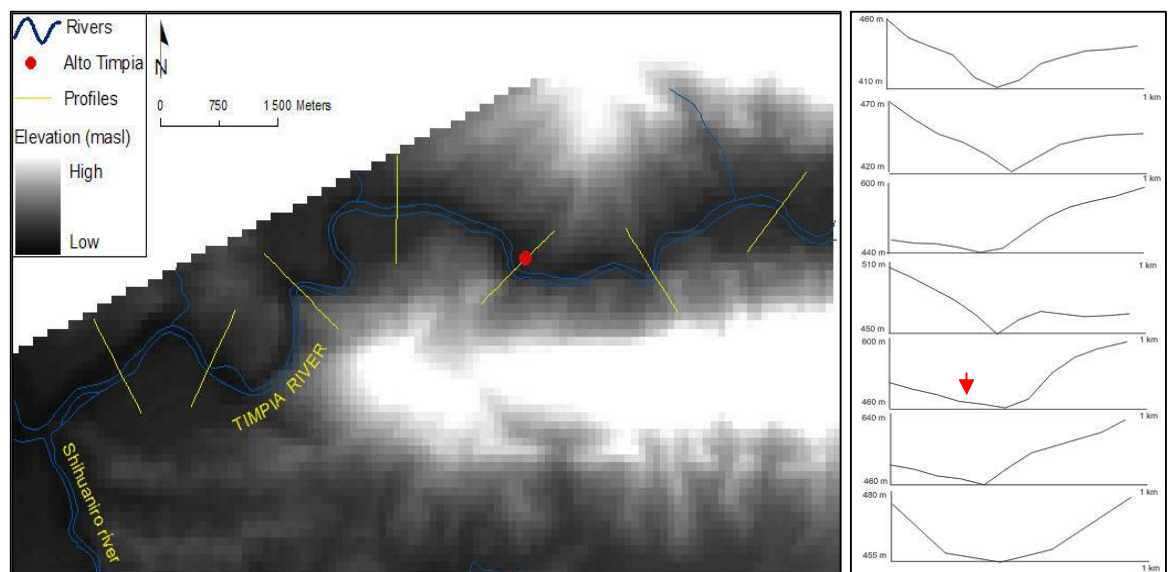


Figure 16: Digital elevation model and seven transversal cuts of the Timpia River. The first transect in yellow (left) corresponds to the first (upper) profile. The red dot (map) and arrow (profile) shows the location of the Alto Timpia hamlet.

The west side of the community, which accounts for 68% of its total area, is composed of dissected hills of different terrain elevations. On this side, important rivers are: Sabeti, Shimateni and Tsopiroato. At a distance of ~2km away the Sabeti river mouth, the elevation increases 100m, and this section of the river, where it bends, is particularly interesting as a cliff is exposed, becoming a preferred site for several species of mammals and birds (as claylicks). Southward and towards the Shimateni River, multiple

dissected hills with a maximum elevation of 600 m.a.s.l. cover an area of ~700 ha. The highest landforms in this side, also made up of dissected hills and covering ~2200 ha, are situated on the easternmost part of the community, where elevations reach 850masl. On this same side and at the level of the main hamlet, terraces of different heights are identified; and while the lowest terraces average an altitude of 430m.a.s.l; the highest ones average 480m.a.s.l. Refer to figure 2 for visualizing the location of the rivers and tributaries. Along the river banks, two of the most important components of the dry season landscape are: (i) fluvial bars (“playas”), which are colonized by riverine plants (“savoromashi”) and where *Gynerium sagittatum* (“savoroshi”) dominates; and (ii) islands; where sands and exposed river beds dominate throughout the low waters season.

A summary of the landform features related with the lithostratigraphic units present in the study area is shown in table 9.

Table 9: Main topographical characteristics in each lithostratigraphic unit

<i>Lithostratigraphic units</i>	<i>Related landforms</i>
Rio Tambo	It outcrops in sheer terrains, where the elevation averages 900masl and where slope values range between 30° and 40°.
Grupo Oriente	It outcrops south of the Timpia River. Steep slopes of ~25 ° predominate in this portion, the maximum elevations average 850masl, while the minimum reach 520masl. Only 18% of this formation coverage is situated north of the Timpia River, where sheer mountains reach an altitude of more than 1000masl.
Chonta formation	It outcrops south and north of the medium-upper section of the TR. It appears to outcrop in five different localities, all north-east of the community, encountered in altitudes ranging from 500 to 900masl and in terrains with varied slope.
Vivian formation	It outcrops north and south of the Timpia River. first appearing at an eastward distance of 2.8km from the community’s main hamlet. The nucleated settlement of Alto Timpia appears to be located in this formation.
Yahuarango formation	It outcrops in the middle and upper section of the Timpia River. Its outcropping coverage is largest on terraces and dissected hills with a maximum elevation of 650masl. It extends in the vicinity of the major tributaries of the Urubamba river. Near the community’s main hamlet. The most extended pastureland, as well as the first sector of the Sabeti River, become examples of locations where this formation appears to outcrop.
Chambira formation	It outcrops in dissected hills with an elevation of no more than 620masl. It also outcrops along the Sabeti and Shimateni rivers flow.
Ipururo formation	It outcrops along the complex dissected hills of the community’s southern boundary, and where maximum elevations reach 750masl in the extreme west side.
Picha formation	It is only present in the extreme upper west boundary of the area, where the elevation reaches ~850masl.
Alluvial deposits	They are most extended by the southern boundary of the community, being one of the most extended flat plains inside the community. One of the largest hydromorphic landscape features (~50ha) of the community is located in this formation, as well as the main hamlet.

5.1.2. Land cover characteristics

The forested land cover classes (table 10) include bamboo-dominated forests (where *Guadua* sp predominates); mixed bamboo forests (where the density of bamboo stands diminishes); and primary mountainous forests where the preponderant landforms are dissected hills and mountains characterized with steep slopes. In the low-waters season, water bodies occupy 1,7% of the territory, mostly represented by the Urubamba river as most of its tributaries, except the Timpia and Shihuaniro rivers, expose their river beds during this season. Sand bars and boulders occupy 2.21% of the community lands. Bamboo-dominated forests occupy some 30% of the territory; while open lands only represent 0,59% of the study area. Table 10 summarizes the main land cover classes identified for the community, while figure 17 shows how they are spatially distributed. Figure 18 shows the Normalized Difference Vegetation Index (NDVI) image for visual comparison.

Table 10: Major land cover types and their extension within the Community

<i>Land cover major class</i>	<i>Total coverage (ha and %)</i>	
Non-Bamboo dominated forests	15151,96	40.40
Bamboo-dominated forests	11164,53	29.77
Mixed-bamboo forests	8801,91	23.47
Depositional material	832,15	2.21
Riverine vegetation	691,52	1.86
Water bodies	632,88	1.7
Open lands	223,19	0.59
Total	37498,14*	100%

*The Urubamba River's northern section is included in the area quantification

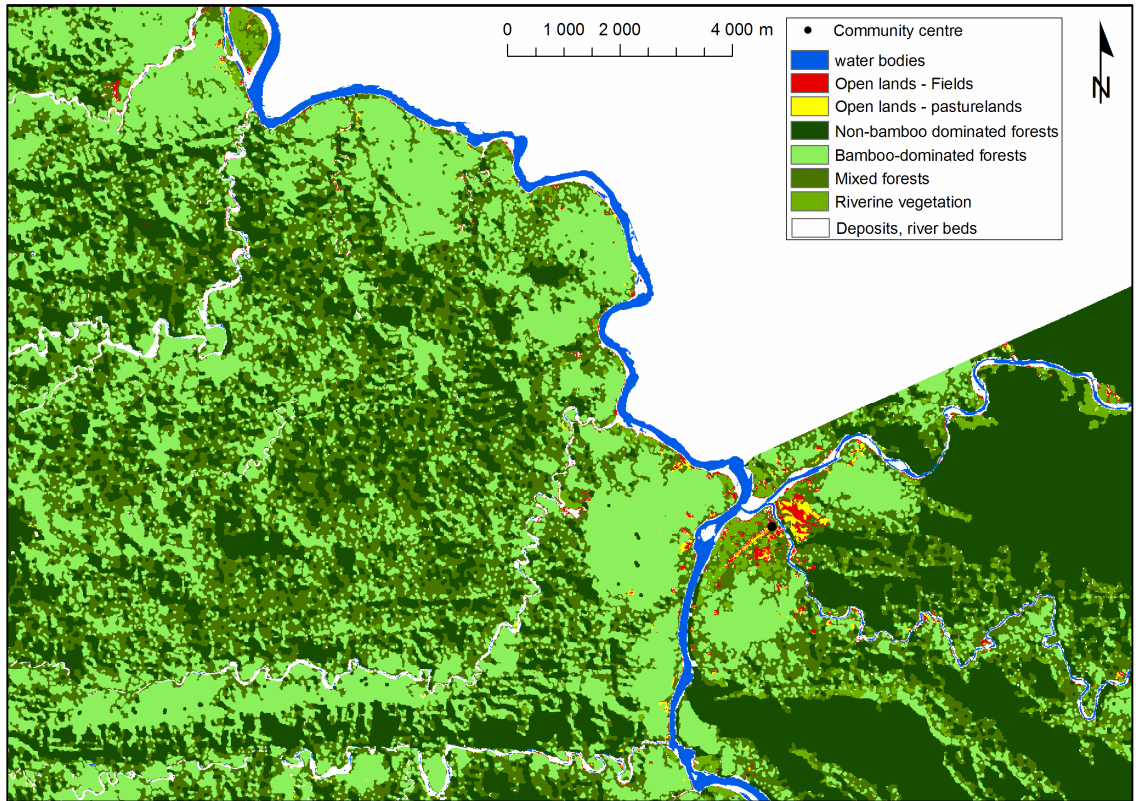


Figure 17: Land cover types based on supervised classification of the SPOT image



Figure 18: NDVI of the SPOT image, for comparison with classified image. Lighter areas depict more vigorous vegetation.

When comparing the forested land cover types with the topographical aspect (figure 19), the bamboo-dominated forests tend to occur more frequently on slopes having a north-east direction. On the contrary, the primary forests which are not dominated by bamboo stands are more frequently encountered on slopes facing the south.

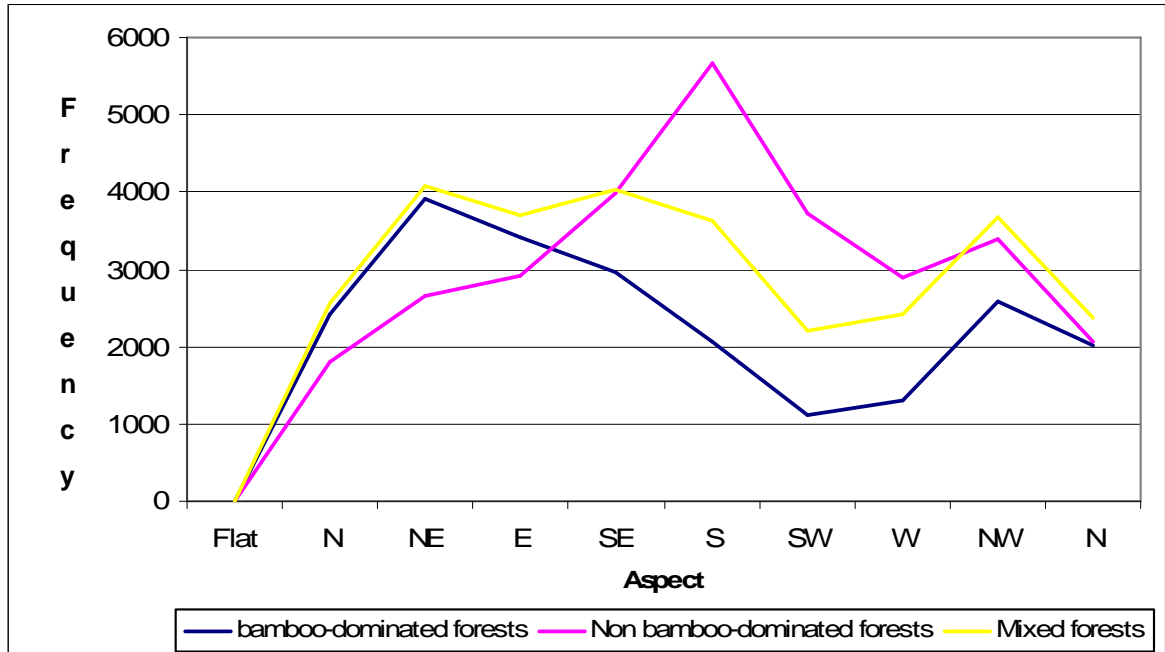


Figure 19: Topographical aspect against three land cover types. The abscise axis denotes the frequency of cells within each land cover type occurring in a certain aspect class.

5.1.3. Land cover classes in relation to distance from the community centre

Specifically for the case of open lands, it has been quantified that one third of the area calculated upon a 200m-radius circumference, with its origin in the community hamlet's centre, is covered by open lands (mainly fields). 3% of its total extension (136,02 ha) is included within this area. The major increase (14 ha) in open lands is found between the 400m and 600m-radius circumference area. To any direction, when the distance from the hamlet's centre increases up to 1000 m (1000m-radius circumference), almost 30% of the community's total land cover is composed of open lands. Moreover, 40% (55,08 ha) of the open lands-mainly fields land cover class extension is concentrated within a circular area of 2km radius from the community's centre. 44% of the pasturelands occur within the same 2km-radius circumference area from the centre. Nevertheless, considering both anthropogenic caused land cover classes, they only cover 7,5% of the lands occurring in any location within a radial distance of 2km from the main hamlet's centre. Moreover, almost one third of the open lands occurs at a distance of no more than 550 metres from the Urubamba river banks. The variation in area for the rest of the

land cover classes is shown in table 11 and figures 20 and 21. Table 11 shows the detailed areal values for each land cover class, as well as their variation in extension as the distance from the community centre increases. Figure 20 shows two graphs depicting specific areal values for each land cover class when the distance from the community, to any direction, is 200 m and 1200 m respectively. Figure 21 shows the area covered by each land cover class within a given distance from the community centre and in proportion to the total extension of each land cover class within the study area. The spatial distribution of the land cover classes in the vicinity of the community centre is shown in figure 22.

*Table 11:
Land cover classes and their coverage in relation to the distance from the community centre
Data shown in grey colour are presented as a manner of pie charts in figures 20 and 21.*

	<i>Land cover class</i>							
	Open lands-mainly fields	Open lands-mainly pastures	Non-Bamboo dominated forests	Bamboo-dominated forests	Mixed-bamboo forests	Riverine vegetation	Water bodies	Depositional material
Area (ha) in circumf of Rad 200m	4,05	1,03	0,05	0,09	3,86	1,06	0,66	1,44
% Circumf Area	33,09	8,42	0,41	0,74	31,54	8,66	5,39	11,76
% Total LC class area	2,98	1,18	0,00	0,00	0,04	0,15	0,10	0,17
Area (ha) in circumf of Rad 400m	9,11	6,22	1,85	0,09	13,44	10,23	3,60	4,87
% Circumf Area	18,44	12,59	3,74	0,18	27,20	20,70	7,29	9,86
% Total LC class area	6,70	14,44	0,02	0,00	0,15	1,48	1,15	1,18
Area (ha) in circumf of Rad 600m	23,99	15,43	3,22	0,25	26,37	19,18	7,21	17,15
% Circumf Area	21,27	13,68	2,85	0,22	23,38	17,00	6,39	15,20
% Total LC class area	17,64	17,70	0,02	0,00	0,30	2,77	1,14	2,06
Area (ha) in circumf of Rad 800m	34,18	23,11	6,27	2,35	52,44	40,69	18,67	22,69
% Circumf Area	17,06	11,53	3,13	1,17	26,17	20,30	9,32	11,32
% Total LC class area	25,13	26,51	0,04	0,02	0,60	5,88	2,95	2,73
Area (ha) in circumf of Rad 1000m	39,54	27,54	14,11	17,48	93,32	60,80	30,46	30,36
% Circumf Area	12,61	8,78	4,50	5,57	29,76	19,39	9,71	9,68
% Total LC class area	29,07	31,59	0,09	0,16	1,06	8,79	4,81	3,65
Area (ha) in circumf of Rad 1200m	43,98	29,48	28,62	63,02	129,37	72,76	41,90	42,03
% Circumf Area	9,75	6,53	6,34	13,97	28,67	16,13	9,29	9,32
% Total LC class area	32,33	33,82	0,19	0,56	1,47	10,52	6,62	5,05

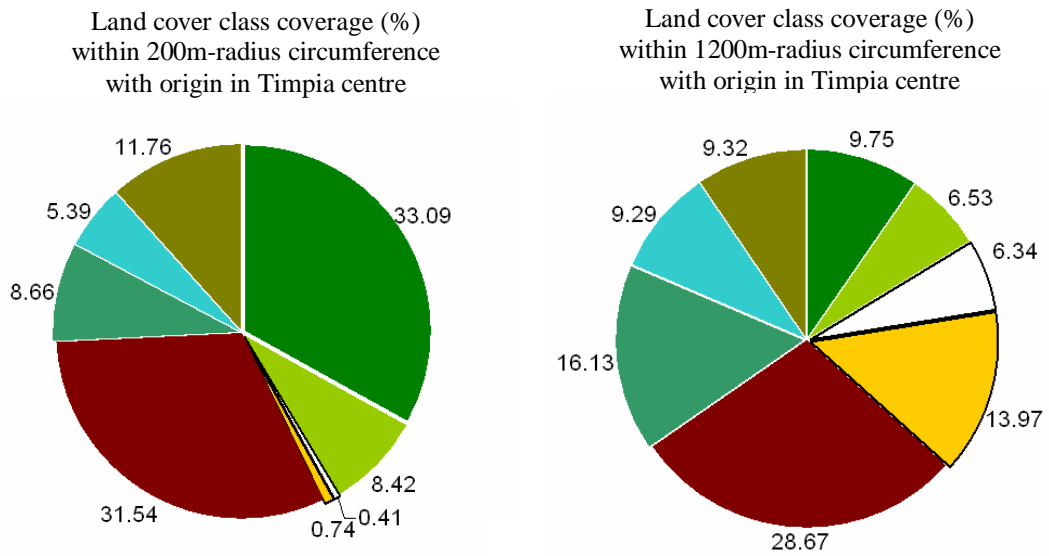


Figure 20: Land cover class coverage (%) within 200m-radius and 1200m-radius circumferences with their origin in the community centre.

Land cover class legend	
■	Open lands – mainly
■	Open lands – mainly
□	Non-bamboo dominated forests
■	Bamboo dominated forests
■	Mixed bamboo forests
■	Riverine vegetation
■	Water bodies
■	Depositional material

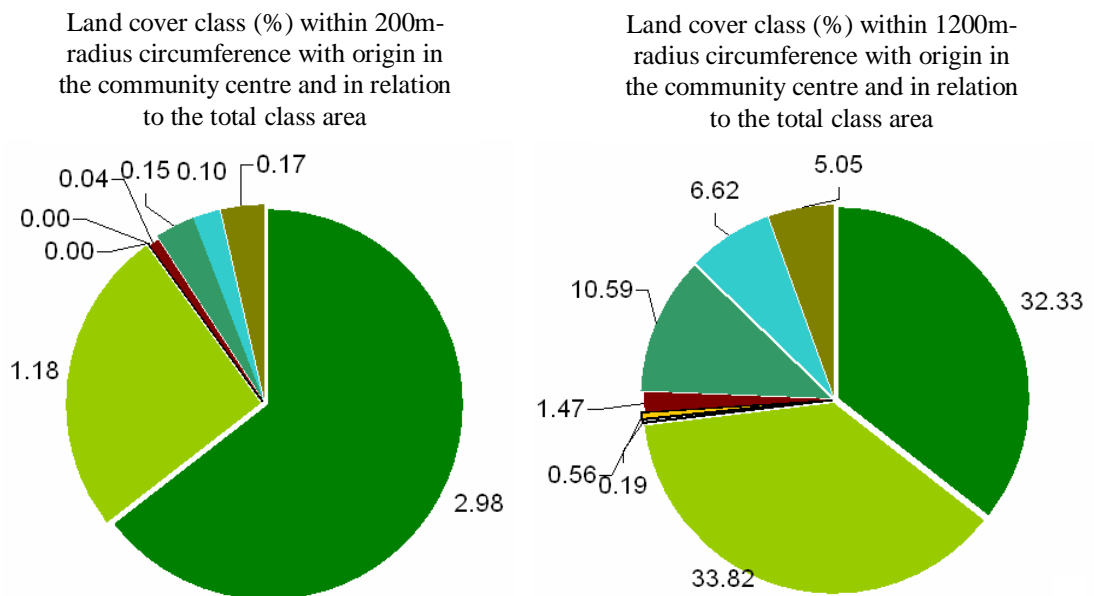


Figure 21: Land cover class coverage (%) within 200m-radius and 1200m-radius circumferences with their origin in the community centre and shown as a percentage of the total land cover class extension within a given distance from the centre.

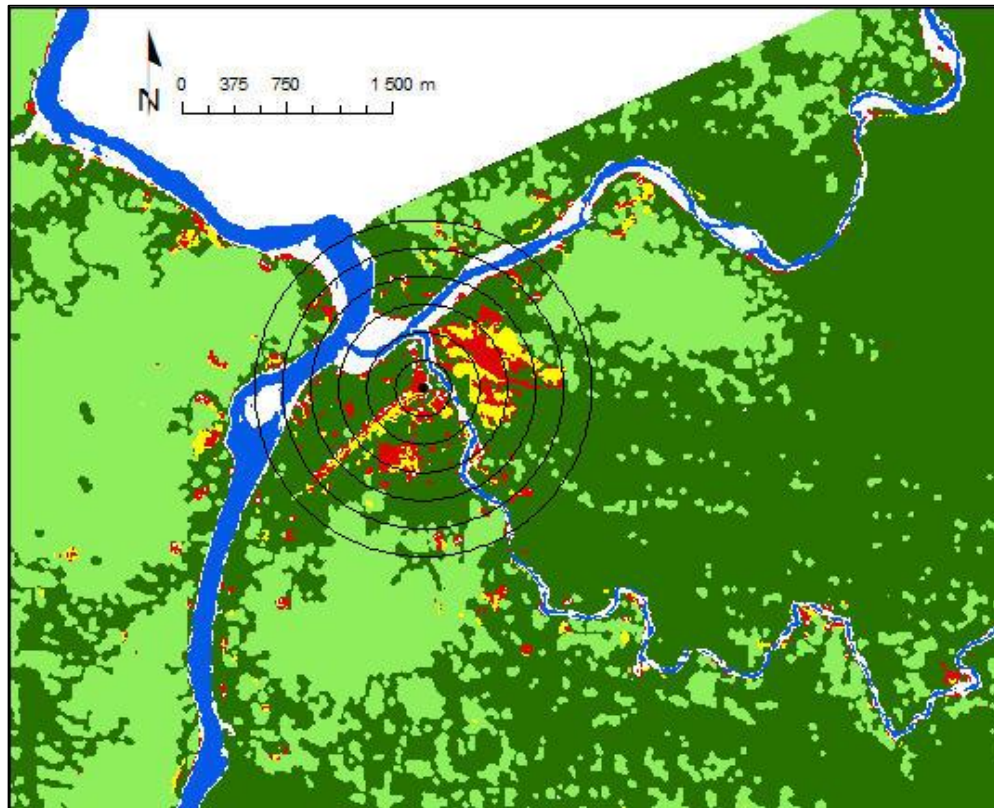


Figure 22: Portion of the classified image showing: open lands – mainly fields (red), open lands – mainly pasturelands (yellow), bamboo-dominated forests (light green), water bodies (blue), depositional material and river beds (white), and all other vegetation land cover types (dark green). Each of the concentric circumferences has a separation of 200m. The main hamlet's centre is depicted as a black dot.

5.1.4. Land cover / land use change

In a 30-year period, the community's lands and its vicinity territory have been subjected to land cover change. There is a disparity in land use patterns between native inhabitants and colonial settlements when the land is used for farming purposes (figure 23). Larger areas covered by forests outside the community boundary have been converted from bamboo dominated terraced forests into pasturelands (Figure 23: 1 and 2), and into agricultural lands (Figure 23: 5). Within the community, bamboo dominated forests are converted into pasturelands for cattle ranching (Appendix 4, figure F).

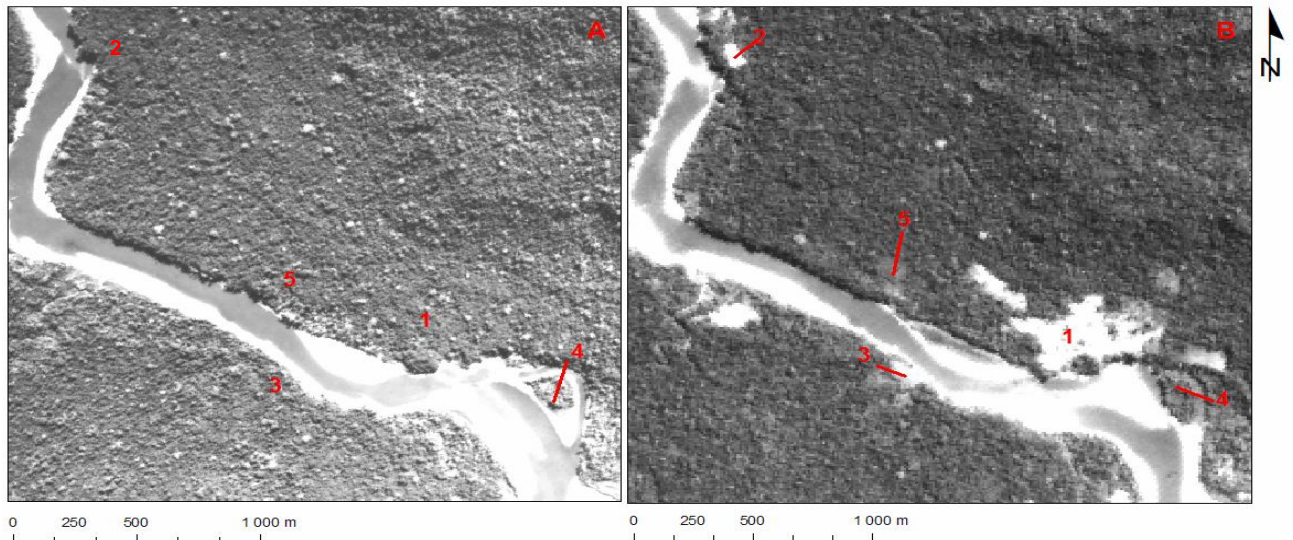


Figure 23: Aerial photo of a portion of the community. Photo A was acquired in 1963 and photo B in 1993; both during the dry season. The Urubamba River delimits the community's north-eastern boundary. Land cover change is addressed for comparison between native and colonial land use patterns

forests into pasturelands and agricultural fields. In this same area and between the years 2001 and 2003, ~35 ha were gained for farming/cattle ranching purposes. The forest cover within the community has been maintained almost intact during this 17-year period.

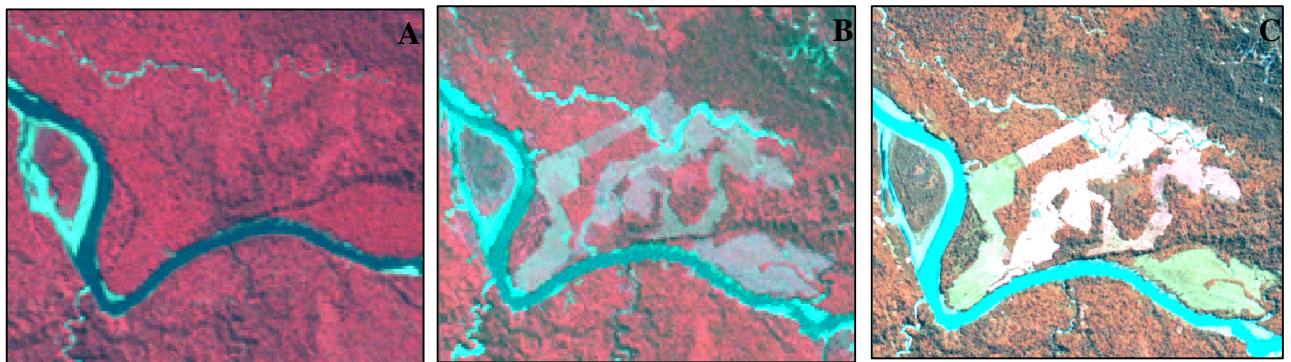


Figure 24: Three satellite images (A: Landsat TM, B: Landsat ETM+, C: SPOT) showing land cover changes through time. In all the images the Urubamba river (in blue/light blue) serves as a natural divisor between the Timpia community (south-west) and a colonial settlement (north-east). Image A was acquired in 1986; Image B in 2001, and image C in 2003.

Land cover change occurs within the community due to the forest clearing for the gas pipeline's right of way (ROW). For the clearing, widths vary from 25m to 80m; from its narrowest to its widest sections respectively. Currently, grasslands cover the ROW with a width of 25m. The ROW maintains a sinuous shape inside the Timpia territory, but when crossing the Urubamba River it continues with a more straight direction along the eastern bank of the Urubamba River. Inside the community, one of the most active

camps is the one located in the km 40 of the project's downstream component (red dot in figure 25-B). At this site, erosion control practices are mainly based on the management with gabions (Appendix 4, picture E). Every month, monitoring of the project activities is carried out by a delegation of Timpia natives.

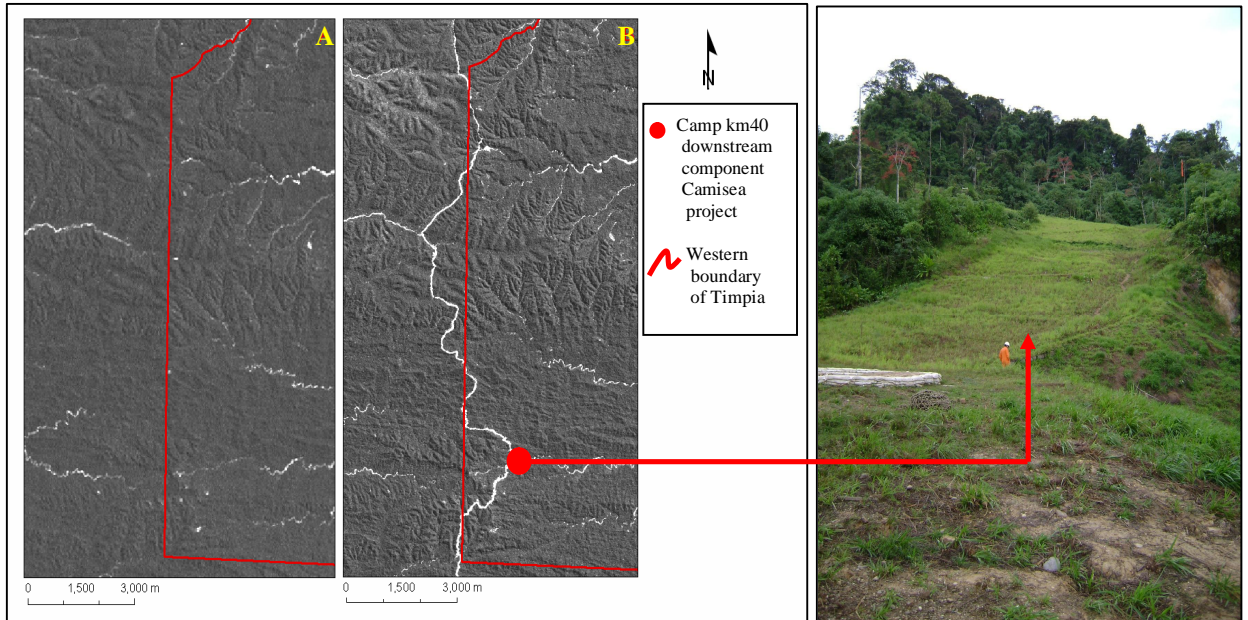


Figure 25: SPOT (A) and Landsat ETM+ (B) satellite images showing land cover change due to the transportation pipeline's right of way. Image B (ETM3) was acquired in 2003 while image B (B2) in 2001; both during the dry season. Right side picture: Right of way: Lands covered by grass at pipeline's km 40 (camp "El Paraiso"). (Photograph: Verónica Gálmez 2007)

5.2. Environmental suitability for cropping site selection

Before assessing the native criteria applied for selecting the most suitable sites for performing cropping activities, the agricultural cycle and garden types, as perceived during the field work, are described in depth.

5.2.1. Garden cycle and garden types

The garden cycle is composed of six major activities: Clearing, burning, planting/seeding, weeding, harvesting and fallowing.

I. Clearing

Natives clear a new garden almost every year (“oporoaganira” = slashed garden), commonly by the beginning of the dry season (“sariniku”); although some exceptions might occur. Areas are cleared for the establishment of new gardens, either from old fallows, from bamboo-dominated forests or lands dominated by riverine vegetation. Primary forests as the previous land cover for clearing was rarely encountered. From all the visited gardens, the former land use of 86% of the current gardens was old fallows, of which 70% were previously covered by bamboo-dominated forests (“kapiroshi”), while 16% by *Gynerium*-dominated lands (“savoroshi”). Only 14% of the former land cover comprised primary forests (“inkenishi”).

Table 12: Former land cover and land use previous to clearing activities. The frequency is derived from the amount of observations made in the visited gardens during the field work.

Former land cover	Former land use	Frequency (%)
Bamboo-dominated forests (“Kapiroshi”)	Fallow	70
<i>Gynerium</i> -dominated lands (“Savoroshi”)	Fallow	16
Primary forests (“Inkenishi”)	Forest	14

The reason why they start clearing right after the rain stops is due to the fact that the cleared field will then have more time to dry (without long period rains) before it is ready to be burnt. When other duties than gardening are more demanding at that time of the year, they might clear the garden later (in June-July), but then it could be that they complain about the non-complete behaviour of the burning process, and start speculating on the maize quality and its potential to grow strong enough. The clearing activities are done by stages: it first starts by cutting, depending on the garden physiographical location, the riverine vegetation, and bamboo stems. The second step consists of cutting branches and trees of small diameters (“iporosetake”). After these two phases, it might be the case that several trees of considerable diameter are kept unfelled for a longer time span than the gap between the first and second phases. Species of *Cecropia sp.* and *Jacaranda copaia* appear to dominate the standing trees in cleared gardens, which are then felled (“Itogakerora”) when needed, mainly to be used as fuel wood. This bearing in mind that some timber species burn faster than other ones; but in general, not a uniform pattern was found for the selection of fuel wood, although there is a preference for some slow-burning species. One of the main limitations for the decision of the garden size when clearing is that it must be small enough to avoid rapid expansion of weed, but big enough to provide food in sufficient amounts for family

needs, with a special concern about the manioc production for *masato*-making purposes. Most of the natives were not sure about their gardens' units of area when asked, as the typical answer for that question was based on vague linguistic responses, such as "big", "small" or "big enough". The average garden size encountered on the field was 0,56 ha, while the minimum and maximum garden areas were 0,2 and 1,5 ha respectively.

Table 13: Garden areal characteristics observed in the field

<i>On field garden measurements</i>		<i>Native's garden size categorization (no crisp classes)</i>	
Average garden area (ha)	0,56	Large	more than 0,8 ha
St.dev.	0,32	Medium large	0,5- 0,8> ha
Min garden area	0,2	Medium small	0,2 - 0,5> ha
Max garden area	1,5	Small	0,1 – 0,2> ha

Women can also select and clear their own gardens. It occurred for the first time this year that a group of women that received treated maize seeds and laying hens from a regional institution, were eager to clear their own garden. And in fact, and in comparison with other visited cleared gardens, it was one of the cleanest fields in the community, but as for most of them it was their first experience, the activity took longer. Also, in case of widowhood, women might clear their own gardens, but men relatives commonly help.

II. Burning

This activity takes place in the less rainy period of the dry season, while the intense sun helps to dry the debris of the slashed vegetation. The resulting ashes lie then below the larger unburned branches and stems. When seeding maize in a recently burnt garden ("opotaka") located on alluvial soils, what happens is that remains of "uva grass" plants occupy much of the garden's space, becoming a problem for a systematic hole arrangement. The immediate response to this situation is related to the lack of a good burning activity due to the insufficient time that the slashed material is left to dry, which in most cases is around two months. In many cases what happens is that natives complain about the rain behaviour the whole year, stating that some farming activities had to be carried out with delay.

III. Planting / Seeding

Depending on the location, the most common crops to be seeded at first could be either maize or manioc. They are both the crops which are planted in larger amounts, but it is definitely the maize crops which dominate in a newly established garden. On alluvial terraces, it is maize the first one to be seeded; and 3 to 4 maize seeds are placed in each hole of ~ 3cm of diameter. When manioc is planted, stalks of it are cut into pieces of about 15-20 cm long and then inserted into the soil. At the end of the seeding, the burned and unburned dispersed stems of “uva grass” are piled up in a corner of a garden in order not to disturb the maize growth and weeding activities.

As the aim is to reach diversity within the gardens, the most practiced polyculture is intercropping. The two-year old gardens are clear examples of this practice. A feeling of pride could be felt when natives show the diversity of cultigens they possess in their own gardens. When natives visited gardens that belonged to others, it was very common that they asked for some local varieties of manioc, cotton or bean which they themselves did not grow. In one single garden of ~1ha, (Valentín Basmo’s garden), several local manioc varieties were found, with differences in size, colour, leaf shape, plant orientation and ramification. Due to this dissimilarity, they were locally named in different ways. As an example, some of the varieties that could be found in this single garden were: “Toteiroganire”, “Kashiriganire”, “Koncharoganire”, “Chompariganire”, and “Konkariganire”. These names are the most known throughout the community, but they might change from zone to zone. In old gardens and nearby fallows, coffee and cocoa plants dominate. They were first introduced in the area several years ago as part of a development plan, but currently many of those plants do not produce anymore, and they are, in most cases, attacked by plagues. When asked about these cash crops, natives complained about their growth behaviour and production.

IV. Harvesting

Men and women both equally know how to harvest the crops, but sometimes women take the lead in this activity. Maize is the only crop which is harvested at once; and right after its harvest, manioc plants start their production, and in abundance. Even when the garden has been left without weeding for some time, manioc plants could still be available for harvesting. Root crops, such as cocoyam and yam, are left in the ground

until they mature and are needed. The gardens are visited for harvesting every time there is a lack of manioc at home or in case the community organizes a “faena” in which *masato* beer needs to be prepared. Only the amount needed is brought to the household, as an excess might get easily rotten. When harvesting, stacks of manioc are used for replanting, especially in those places where it has already been harvested and the soil is still soft.

One general problem when visiting the garden for harvesting was the fact that more and more natives complained about manioc being attacked by wild mammals (especially by tapirs). As this was a problem for many, for others it was a good opportunity to visit the garden at night and try to hunt the animal as game meat. In case there was time to walk through the forest (“inkenishi” or “inchatoshi”) when going farming or hunting, some plants are gathered as products for different purposes. For instance, concave pieces of “Pona” palm (*Iriartea* sp.) roots were sought to grate manioc, while “Tamshi” vine was sought for baskets making.

V. Weeding

Weeding activities start right away once the garden is planted / seeded. Soil properties and land physiography affect the speed of the weeding labour (especially slope steepness). Natives make an effort to weed their gardens at least once every 1.5 months, although small cleanings can be done in-between, as many respondents mentioned they clean a portion of the garden almost every week. Some natives identified differences in weed growth speed varying according to their gardens location within the community. The weeding labour depends on how rapidly a weed grows. Also, major thorough cleanings are done from 2 to 4 times per year. Although many natives established near the main hamlet had a very good command of Spanish and knowledge of current calendar reading, in the zone of Alto Timpia, most of the natives answered to questions related to weeding frequency referring to moon appearance and its cycle.

VI. Fallowing

After gardens have been entirely harvested, they are abandoned to fallow, but not indefinitely. It seems that nowadays, fallow periods are being reduced, as it was easy to hear from the medium-aged farmers that a fallow (“impomayashii”) belonged to this or

that person, meaning that the same piece of land served for farming purposes to two or more persons in less than 30 years.

A mosaic of gardens and fallowed areas of different ages conform the landscape near the community. Table 14 presents a summary of the averaged garden ages and their native denomination according to the age. Gardens considered as new ranged between recently planted/seeded to 6 months old; gardens of ~1 year old were mostly found; while old gardens started to be named as such when reaching ~1.5 – 2 years or more. The oldest gardens are dominated by root crops (e.g. cocoyam, yam, sweet potato) and plantains, in addition to the still unharvested manioc plants. A list of all the crops found in the field is shown in Appendix 6. An active garden of 4 years was rarely found, while a 10-year old garden was maintained solely for “barbasco” production.

Table 14: Native denomination of the gardens according their age

Garden stage	Native denomination	Age ranges (months) to be considered as if
New garden	Otyankari tsamairintsi	Less than 6
Garden	Tsamairintsi	6 -18
Old garden	Ogantagari tsamairintsi	18 or more

Figure 26 shows different stages of maize cultivation: In picture A, a 3-week maize growing under the unburned “uva grass” stems. Pictures B and C show, respectively, a new garden (1 month old) already cleaned and without cleaning. Picture D shows a 4-month old maize field before harvesting.



Figure 26: Maize cultivation in different phases (Photographs: Verónica Gálmez 2007)

Regarding the physiographical location of the gardens, three main types are distinguished. Soil properties therefore vary, and native soil denominations based on

certain soil characteristics are distinguished. Moreover, the preference for a determined cultivated crop also varies accordingly:

- *Riverside plots*: Characterized by flat slopes in sand bars. Crops such as beans and rice were found to occur in sandy environments along the Urubamba river during the low water season, especially in areas near the mouth of the Sabeti River. The bean plants depicted in image 27-A, belonged to a native farmer that needed to walk a distance of ~0,9 Km to reach them. Peanuts and beans are cultivated mainly until the month of November, as the river water level starts to rise afterwards.
- *Lower terrace gardens*: Characterized by flat and slightly inclined slopes. These sites are mostly colonized by *Gynerium sagittatum*, and they could also be eventually flooded. Soils are locally known as “potsitapatsari” and they are preferred for maize cultivation. Beans, sugar cane and plantains are mostly cropped.
- *Terra firme gardens*: In these gardens, slope varies the most, as well as garden ages. Soils are locally known as “kitepatsari” and “kiraapatsari”. These gardens are mostly used for manioc cultivation in relatively great amounts, along with other tuber crops. In fallows, unproductive cocoa and coffee plants are commonly found.

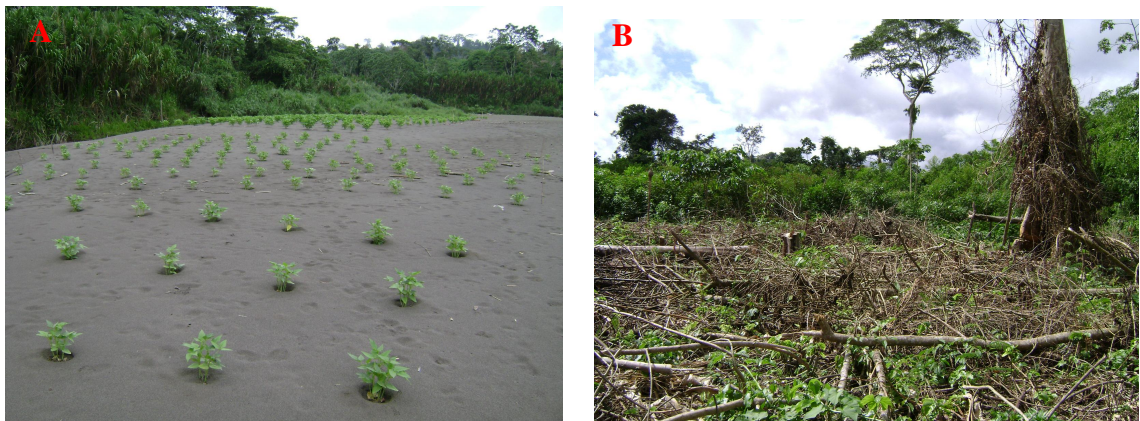


Figure 27: (A) Riverside plot; and (B) clearing for establishing a terra firme garden (Photographs: Verónica Gálmez, 2007)

5.2.2. General characteristics of the environmental criteria applied

According to the native responses, a sum of multiple environmental factors influences their decisions concerning the selection of the most suitable piece of land for clearing and garden establishment. These factors include soil properties (colour, texture, and inclusions) physiography (slope and elevation); seasonality, and natural vegetation. Other factors influencing their decisions concerning the selection of cropping sites are related to the presence of diseases affecting crops, as well as the possibility of temporal garden flooding; the latter being the cause of rotten tubers and therefore yield reduction. Due to recent external market influence (e.g. Henrich, 1997), additional factors such as distance to/from the main hamlet's centre, Urubamba River and tributaries, are also considered influential for the performance of farming activities; considered here for evaluation as a result of the amount of open lands occurring near these environments, and visible in the classified image (figure 17). A summary of the criteria used by natives for assessing the cropping site suitability is shown in table 15.

*Table 15:
Criteria applied by natives to distinguish potential sites for cropping, description of the criteria and quantified usage by natives; obtained from garden visits and interviews*

<i>Criterion</i>	<i>Description</i>	<i>Utilized by natives</i>
Texture	Basically content of sand and ease of tillage, determined by finger tests and compared with laboratory results.	90%
Colour	Colour of the plough later, determined by eye and posterior comparison with colour charts of the Munsell table.	78%
Slope	Steepness of the terrain, determined visually and posterior measurement with clinometer.	75%
Elevation	Site location in relation to the river's level, tightly related with the forest composition	72%
Vegetation	Plants used as indicators for the selection of suitability cropping sites	52%
Depth	Tillage depth	9%
Inclusions	Contents of gravel and stones determined by eye	2%

5.2.3. Community scale cropping site suitability assessment

Figure 28 shows the sites considered as the most suitable for the performance of farming activities within the community. Each of the environmental variables considered for their inclusion and their degree of influence in the assessment are described as follows:

I. Slope

Topographic slope plays an important role in the selection of a suitable garden site. Many of the natives distinguish only two classes of slope: Either the slope is *flat* (“opampatakera”) or *steep* (“okatigavatsatakera”); stating that it is always better to establish a garden in a flat area. On the other hand, aside from the mentioned slope classes, some natives distinguish an intermediate *moderately steep* slope class (“ogirimkavatsatakera”); stating that depending on the crop type, it is sometimes better to sow or plant in these lands. Some other reasons for the preference of this gentle slope class included the facility for garden weeding: Many natives stated that it is more tiring and time consuming to weed on flat areas as one has to be bent all the time, but when having a certain degree of terrain inclination, the garden can be easily cleaned when advancing backwards down the slope.

The local terms used above are common for almost all the natives throughout the community; except for the natives of Alto Timpia. They refer to *flat* areas as “ovonkuitake”, to *moderately steep* lands as “otsataniata”, and to *steep* slopes as “otishiabatsatira”. In general, the *steep* slope class was preferred for a specific crop (“barbasco”) as it grows best in areas where the bamboo forests do not dominate. The absence of this forest type started to be noticeable when reaching an elevation of approximately 550 m.a.s.l. (GPS measurement assessed with the DEM) or more. Also, it was commonly mentioned that the “barbasco” crop grows better in mountainous forests’ (“inchatoshi” and “inkenishi”) soils.

Natives’ definitions do not rigidly follow the scientists’ definition. When compared to the slope classification of one of the most national wide used systems (ONERN 1987), the resulting correspondence is presented in table 16.

Table 16: Native perception for slope, compared to scientists classification

<i>Scientific descriptive term</i>	<i>Slope (%)</i>	<i>Native perception</i>
Flat to slightly inclined	0-4	Flat
Moderately to strongly inclined	4-15	Opampatakera
Moderately steep	15-25	Moderately steep
Steep	25-50	Ogirimkavatsatakera
Very Steep	50-75	Steep
Extremely Steep	More than 75	Okatigavatsatakera

Therefore, slope can be categorized into three subsets (flat, moderately steep and steep), according to how natives perceive this land feature when dealing with agricultural purposes. *Flat* slopes were generally considered as such with a minimum slope of 0%, and an optimum at around 7%. Slopes considered as *moderately steep* were those averaging 25%, while a terrain was considered to be *steep* if slopes exceeded 50%.

In the field, the average slope encountered to be used for cropping activities was 6.3%. This average does not include the extreme slope value of one of the gardens located in a 70%-slope for growing “barbasco”. Also, some of the gardens were located in lands with a slope ranging from 18% to 26%, considered as moderately steep. But regarding the performance of the crop growth and yields in these lands, there was always an unsatisfactory response.

II. Elevation

Elevation is another factor to consider when selecting a site for clearing. Elevations of 403 masl and 580 masl were the minimum and maximum altitudes respectively where gardens were observed during the fieldwork. The latter observation was the highest garden known in the community. When asked about considering the possibility of clearing an area in a higher elevation, the most common response was that only the “barbasco” crop yielded satisfactorily. Neither manioc nor maize was considered to grow properly in those conditions. More than three quarters of the gardens were located in elevations between 403 and 460 m.a.s.l.; while gardens above 500 m.a.s.l. were reserved for barbasco cultivation. Therefore, most of the gardens were congregated in a narrow portion of the altitudinal gradient.

III. Vegetation

The preference for sites to be cleared also considered the presence of specific vegetation that determined the suitability or non-suitability of the sites for certain crops growth behaviour. In general, where *Gynerium sagittatum* grows, soils are considered to be the best; not only for maize cultivation, but also for beans, plantains and sugar cane. Some other sites considered as suitable for clearing include the presence of *Calliandra angustifolia* (“kobanti”), *Cecropia sp* and *Ochroma sp*.

Moreover, sites where bamboo-dominated forests occur in association with trees, are also well considered since fuelwood can be harvested after clearing. Two local names of trees were mentioned in several occasions as growing in places not suitable for clearing: namely: “ketiri” and “machingo”. The reasons were related to the null or low manioc production. However, when visiting the gardens, none of these plants above-mentioned could be found for their collection and identification. Some stated that near the Moboroari stream several trees of “machingo” stand.

IV. Overall community scale assessment

When the variables slope, elevation and vegetation above described are combined with the variables derived from the distance-to-community centre and rivers analyses, the results show that the most suitable sites for farming are restricted to a small fraction of the community. In this sense, the three classes considered to condense the most suitable sites for establishing a garden represent only 2.4% of the community area; while the three classes which aggregate the least suitable sites for cropping represent almost 50% of the native territory. Figure 28 visually shows the distribution of the suitability classes based on the native criteria. Moreover, table 17 shows the coverage (in hectares and percentage) calculated for each of the considered classes.

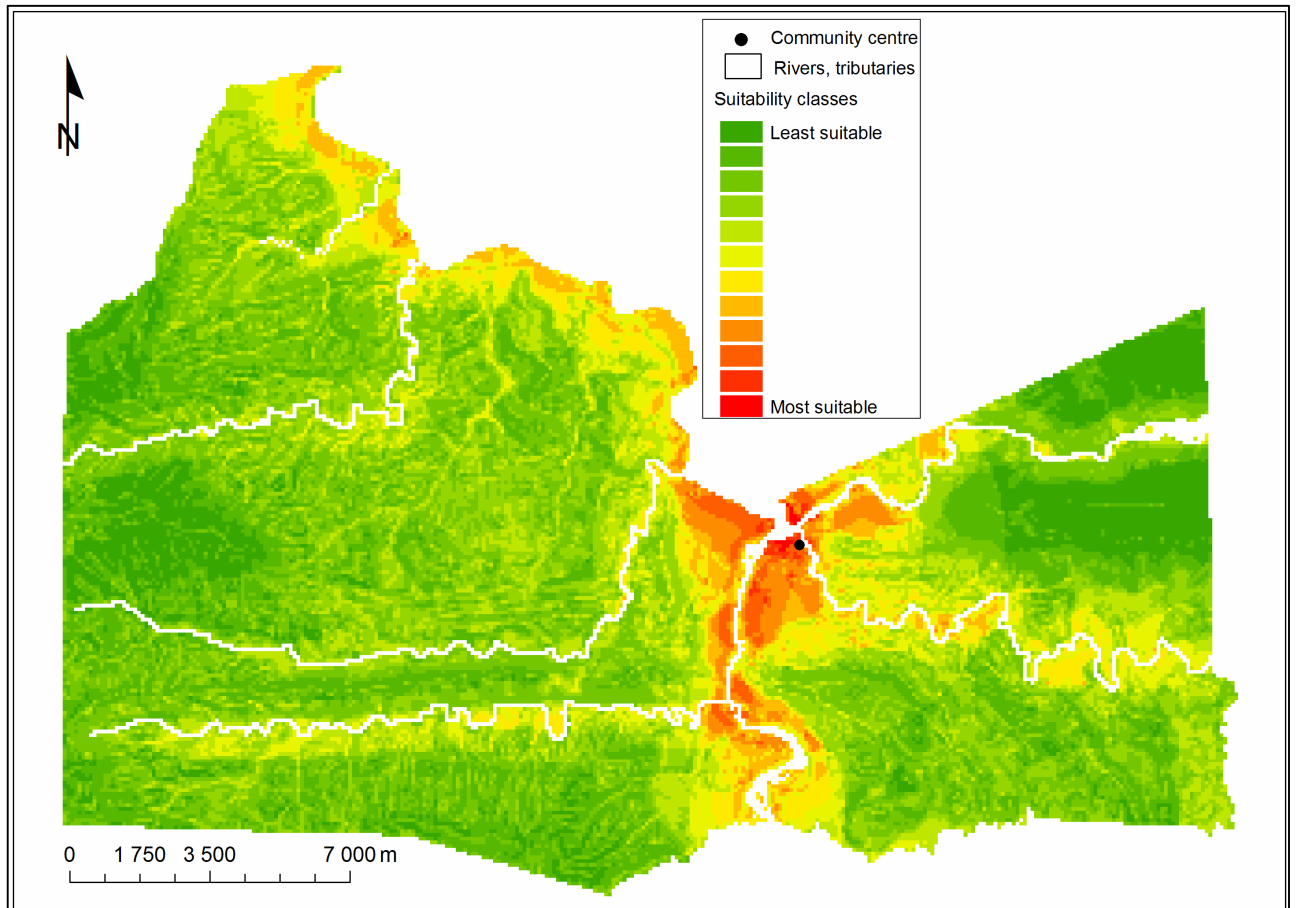


Figure 28: Macro-scale representation of the most suitable areas to be cleared for farming purposes.

Table 17: NAK-based suitability classes and their coverage within the community

NAK-based suitability class	Area (ha)	Area (%)
0 (least suitable)	2997,81	8,33
1	5895,18	16,38
2	8875,98	24,66
3	7164,45	19,90
4	4465,53	12,41
5	2643,84	7,34
6	1766,61	4,91
7	1159,92	3,22
8	660,15	1,83
9	296,46	0,82
10	54,27	1,51
11 (most suitable)	15,39	0,0428

5.2.4. Site scale suitability assessment

Soil characteristics strongly influence the selection of suitable sites for cropping activities. Two major considerations are found to be decisive in the criteria that natives apply when selecting the most suitable sites for garden establishment: (i) the ability of the soil to sustain a specific crop, and (ii) its degree of workability. These considerations are applied when identifying major differences in some soil properties, such as colour and texture, the latter one related to the soils workability. The easiest soils to work with would be the sandy ones, while the most difficult ones would be the clayey ones. Referring to the first consideration, black soils are preferred for maize growing, while red, yellow and brown soils are also selected for manioc growing. The latter is further detailed below.

I. Correspondence of the analyzed soil characteristics with the description of the Matsigenka soil types

i. Texture and Colour

Soil colour appeared to be the primary basis to decide upon the suitability of the land; and it is, in most cases, associated with the soil texture. This association can be explained with the fact that one single word containing both of the soil properties is used when naming a type of soil. Taking this into consideration, the natives establish a difference when the soil is sandy, naming it “panekiri”; and if it is not a sandy soil, they call it “patsari” (having the same meaning as “earth”). Moreover, these local names are not used alone to describe a soil type; they are always accompanied with a colour description of it. In this sense, any soil can be named e.g. “potsitapatsari” if it is a black non-sandy soil and “potsitapanekiri if it is a black sandy soil. In the field, when asking about the name of a soil type in any garden, it was most probable to get any of the responses shown in table 18.

Table 18: Types of soils defined by colour and texture

<i>Texture/Colour</i>	<i>Black</i>	<i>Yellow</i>	<i>Red</i>	<i>Brown</i>
Sand	Potsitapanekiri	Kitepanekiri	Not described	Not described
Not sand	Potsitapatsari	Kitepatsari	Kiraapatsari	Kamaropatsari

When comparing these soil types with the soil colours of the Munsell chart, the following equivalences can be established (table 19).

Table 19: Equivalences in soil colour between soil types (defined by colour and texture) and Munsell chart codes

<i>Native perception</i>	<i>Scientific descriptive terms</i>	
Soil type	Munsell Colour Chart Code	Colour name
Kiraapatsari	5YR4/6	yellowish red
	5YR4/4	reddish brown
Kitepanekiri	10YR5/6	yellowish brown
	10YR4/4	dark yellowish brown
Kitepatsari	10YR5/8	yellowish brown
	7.5YR5/4	brown
Kamaropatsari	10YR3/2	very dark greyish
Potsitapatsari	5YR3/1	very dark grey
Potsitapanekiri		

Moreover, when the main soil types described by the natives are corresponded with the soil characteristics resulting from the laboratory analyses, the following can be said (table 20):

Table 20: Correspondence between native soil types according to colour and texture and soil characteristics (laboratory results). The measurement units and abbreviations are explained in section 4.

Local name (Colour/ Texture)	Soil characteristics																
	pH	E.C	O.M.	P	K	Sand	Silt	Clay	CEC	Ca ⁺²	Mg ⁺²	K ⁺	Na ⁺	Al ⁺³ + H ⁺	Sum of cations	Sum of bases	Base satur.
Kitepatsari	3,5	0,1	1,9	1,3	49,3	45,5	37,8	16,7	13,4	1,2	0,4	0,2	0,1	6,7	8,5	1,9	15,2
Potsitapatsari	7,0	0,2	2,3	4,1	88,0	15,0	73,0	12,0	12,6	11,1	1,2	0,3	0,1	0,0	12,6	12,6	100
Kitepanekiri	4,3	0,1	1,1	2,7	109,0	60,0	30,0	10,0	8,6	2,8	0,7	0,3	0,1	3,3	7,2	3,9	46,8
Kamaropatsari	4,0	0,1	1,5	1,3	71,0	55,0	34,0	11,0	11,4	2,0	0,6	0,2	0,1	6,7	9,7	3,0	34,2
Kiraapatsari	3,7	0,1	2,0	1,3	45,7	50,0	34,0	16,0	16,3	1,2	0,4	0,2	0,1	9,4	11,3	1,9	11,6

ii. Workability and texture

Apart from the main soil types defined above, the soil must have additional characteristics that make them appropriate for farming. These characteristics are related with the workability of the soils. This is in many cases assessed by driving the machete on the top ground and grabbing a portion of the soil with the hand. What is evaluated is the soil hardness or softness. In general, soils are called “metsopatsari” if they are soft and “kisopatsari” (or sometimes “kusopatsari”) if they are hard. Moreover, when the main soil types described by the natives according to their workability and texture properties are corresponded with the textural characteristics of the soils analyzed, the following can be said (table 21):

Table 21: Correspondance between native classes for workability and soil texture

Soil Texture	Native classes for soil workability	
	Metsopatsari (Soft soils)	Kisopatsari (Hard soils)
Sand (%)	50,36	32,00
Silt (%)	36,00	50,75
Clay (%)	13,64	17,25

iii. Inclusions

Soil inclusions were not considered a strong variable influencing the native decision for the selection of sites for clearing. However, the general classification used, and their correspondence with the inclusions dimensions measured in-field are presented in table 22.

Table 22: Soil inclusions and its influence when selecting sites for slashing

Inclusion dimensions	Native perception	Utilized for selecting slashing sites
Stoneless soils (varying % of silt, clay and sand)	Kipatsi	91%
Gravel / small stones (Max diameter of 2 cm)	Shimentyakiteri / Mapuiporokise	9%
Big stones (More than 2 cm of diameter)	Omapuisetake	0%

II. Suitable characteristics of the soils for farming activities

i. Colour

Of the interviewed natives, 83% considered “potsitapatsari” as the best soil to be selected, as maize crops perform better. And, when asked about a change in the soil colour after the first or second year of cultivation, the general answer was that no difference in colour could be easily distinguished. Therefore, natives solely consider soil colour for site selection but not when deciding to abandon the field to commence the fallow phase.

ii. Workability

Soft soils (“metsopatsari”) are preferred when selecting a site for gardening in *terra firme* locations. This situation varies when selecting a site for *lower terrace* gardens, where soils are considered to be “kisopatsari” or hard soils. This indicates that, although the soils are difficult to work with, maize crops perform better, and therefore, these soil types are preferred.

iii. Inclusions

The general response concerning the presence of stones and gravels reveals that places where these inclusions are found, no gardens are established. In all the visited gardens, not a single site containing inclusions was found. In two of the sites considered as not suitable for slashing, inclusions with an averaged diameter of 2.5 cm and 10 cm respectively were found. In general, suitable sites are restricted to locations where pure “kipatsi” (soil without inclusions) can be found.

iv. General suitable soil characteristics

Table 23 summarizes the soil characteristics of the sites considered as suitable and non suitable for garden establishment. Active gardens' soil characteristics are presented as suitable sites as they were already established. These include gardens of 1 and 2 years old, while the former land cover of most of these gardens was bamboo-dominated forests. Suitable sites are mostly situated in lower terraces, while non-suitable sites are mainly situated on hills, and therefore, they include more variability in elevation and slope, as well as vegetation dominance.

Table 23: General soil characteristics of the soils considered as suitable and non suitable for garden establishment.

Soil characteristic	Active gardens	Suitable sites	Non-Suitable sites
pH	3,99	6,96	3,56
EC	0,09	0,22	0,10
OM	1,57	2,25	1,93
P	1,65	4,10	1,30
K	78,45	88,00	41,83
Sand	44,18	15,00	49,00
Silt	40,00	73,00	36,00
Clay	15,82	12,00	15,00
CEC	12,71	12,64	13,76
Ca+2	3,04	11,12	1,18
Mg+2	0,57	1,16	0,36
K+	0,24	0,28	0,15
Na+	0,13	0,09	0,19
Al+3 + H+	3,95	0,00	7,55
Sum of cations	7,93	12,64	9,43
Sum of bases	3,97	12,64	1,88
Base saturation	31,43	100,00	16,42

Apart from the number of factors considered for selecting a site for performing cropping activities, not all the cultivated crops have the same soil requirements for a satisfactory growth. Table 24 presents a summary of the natives' responses concerning the preferred soil types to grow the most common crops encountered in the community's gardens. Agroecological requirements of pH and texture retrieved from the literature are presented for correspondence with native selected soil types.

Table 24: Preferred soil types according to the most common crops

Crop (English/Matsigenka)		Soil type Colour/Texture	Slope	pH and texture requirements*
Manioc	Sekatsi	Kitepatsari	Opampatakera	pH: 5.5-7.5 Texture: loam, silty loam
Maize	Shinki	Potsitapatsari	Opampatakera	pH: 5.5-7.5 Texture: Loam, loamy sand, loamy clay
Barbasco	Kogi	Kitepatsari	Ogirimkavatsakera	
Sugar cane	Shanko	Kitepanekiri Potsitapatsari	Opampatakera	pH: 5.5-7.5 Texture: Loamy, loamy sand
Cotton	Anpei	Kitepatsari Potsitapatsari	Opampatakera	pH: 6.0-8.0 Texture: loam
Cocoyam	Onko	Kitepatsari Potsitapatsari	Opampatakera	
Yam	Magona	Kitepatsari Potsitapatsari	Opampatakera	
Papaya	Tinti	Potsitapatsari	Opampatakera	pH: 6.5-7.5
Banana	Parianti	Potsitapatsari	Opampatakera	pH: 4.5-8.0 Texture: Loamy, loamy clay
Rice	Aroshi	Potsitapatsari	Opampatakera	pH: 5-7 Texture: loamy
Sweet potato	Koriti	Kitepanekiri	Opampatakera Ogirimkavatsakera	pH: 4.5-7.5 Texture: Loamy sand
Peanut	Inki	Potsitapatsari	Opampatakera	pH: 6.5-8.0

* From literature review

5.3. Correspondence between native suitable sites for garden with provincial EEZ agricultural lands

According to the Provincial ecological-economic zoning classification, there are 11 zones within the community. Regarding the agrological potential of the zones (refer to the zoning codes in table 25), only zones 7 and 12 are designated with a high agrologic quality; while zones 1, 8, and 9 have a mean agrologic quality; zones 10 and 11 hold a low agrologic quality; and zones 19, 21 and 25 have no agrologic quality at all. Table 25 summarizes the identified zones and a brief description of such is included. Figure 29 visually displays the distribution of the ecological-economic zones.

Table 25: Ecological-economic zones considered for the study area

<i>Class</i>	<i>Code</i>	<i>Description</i>
A: Productive zone	12	Productive forestry zone, with high agrologic quality, associated to pasturelands in zones of high bio-ecological value.
A: Productive zone	1	Zone for clean culture in the lowlands, with mean agrologic quality
A: Productive zone	11	Productive forestry zone, with low agrologic quality, associated to protection lands
A: Productive zone	7	Productive forestry zone, with high agrologic quality, associated to pasturelands
A: Productive zone	8	Productive forestry zone, with mean agrologic quality, associated to protection lands
A: Productive zone	10	Productive forestry zone with low agrologic value, associated to protection in high bio-ecological value zones
A: Productive zone	9	Productive forestry zone with mean agrologic value, associated to protection in high bio-ecological value zones
A: Productive zone	18	Zone with interest for tourism activities
B: Zone with special treatment	19	Zone for recuperation due to deforestation
B: Zone with special treatment	21	Recovery zone – Camisea gas project pipelines
C: Ecological Protection zone	25	Zone for the protection of high bioecological value mountainous forests

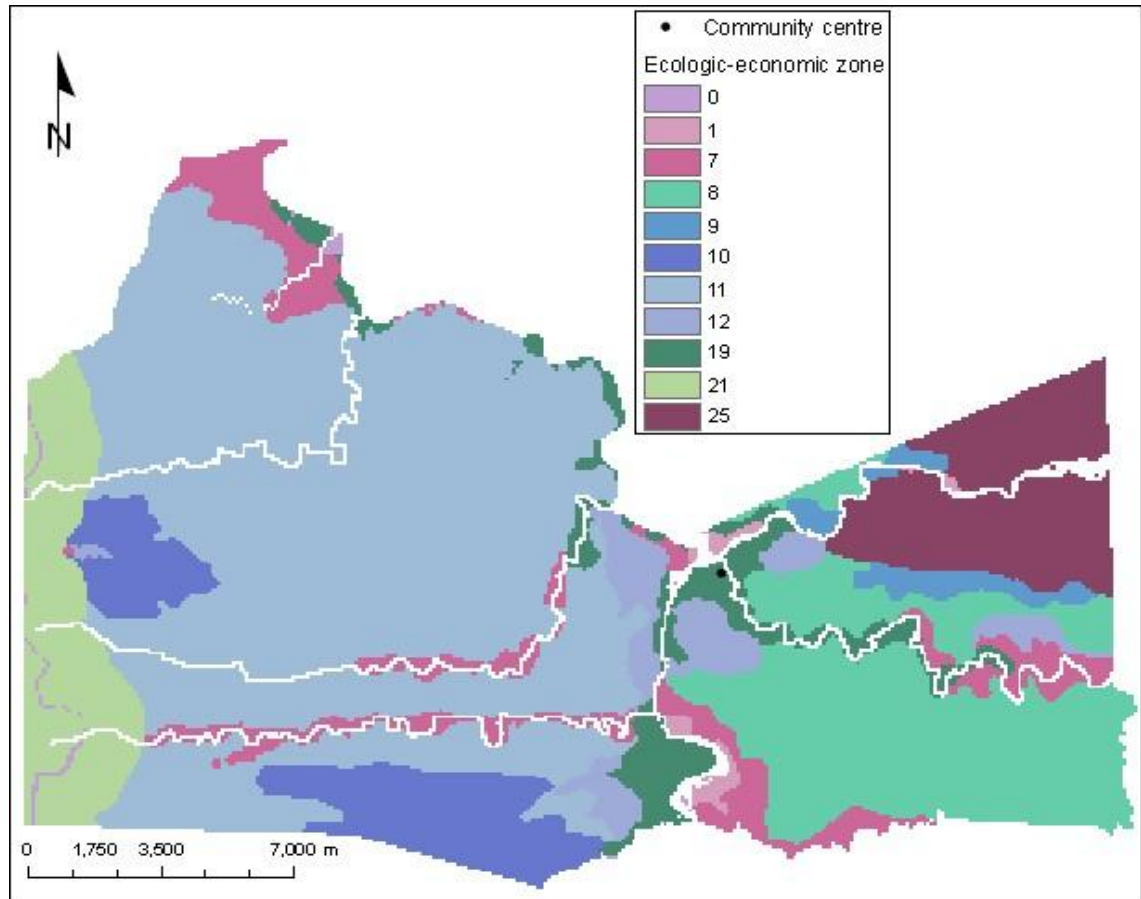


Figure 29: Ecological-economic zones (IMA 2005). Refer to table 25 for a code description

The areal correspondence of the community-scale assessment of the sites' suitability for agricultural purposes based on native criteria, and the zones derived from the Provincial ecological-economic zoning (EEZ) shows, among other results, that: (i) almost 13,5% of the native-based suitability class 10 (considered the second most suitable class) is included in the EEZ-based zone 12 (with high agrologic quality); (ii) The two zones considered, according to the EEZ, as having high agrologic quality, represent 10,7% of the study area. And more than half the area of the native-based suitability class 9 (the third most suitable) corresponds with these two EEZ zones (in table 26 named as A⁺); (iii) Zone 19, considered under the EEZ as a special zone for recuperation due to deforestation, corresponds with half the area of the lands considered as the most suitable (class 11) for performing agriculture according to the native-based suitability classification. (iv) The least suitable native-based class corresponds with 62,5% of the ecological-economic zones with no agricultural quality.

Table 26: Correspondence of Provincial ecological-economic zones and native-based suitability classes. The native-based suitability classes range from values 0 to 11, considering 0 as the least suitable class and 11 as the most suitable class.

EEZ zones	% of study area	Reclass*	Native-based farming suitability classes in EEZ class (%)											
			Most suitable						Least suitable					
			11	10	9	8	7	6	5	4	3	2	1	0
12	3,9	A+	0,00	13,46	33,33	47,61	20,65	11,58	8,44	5,02	1,57	0,45	0,29	0,65
7	6,8	A+	0,00	9,62	21,24	7,09	17,10	28,75	26,32	13,00	4,22	1,59	0,35	0,05
Total A+			0,00	23,08	54,57	54,71	37,74	40,33	34,76	18,02	5,78	2,04	0,64	0,71
1	0,6	A	50,00	15,38	6,78	3,96	4,11	3,56	1,28	0,28	0,02	0,00	0,00	0,00
8	15,5	A	0,00	0,00	0,00	0,27	6,61	10,52	15,40	20,14	21,26	17,32	14,75	2,47
9	1,6	A	0,00	0,00	0,00	0,00	0,24	1,38	2,59	1,17	0,90	1,80	2,83	0,95
Total A			50,00	15,38	6,78	4,23	10,97	15,46	19,26	21,58	22,19	19,12	17,58	3,42
10	7	A-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,12	2,17	6,79	16,31	23,74
11	45,6	A-	0,00	0,00	0,00	2,86	14,76	23,11	33,56	54,03	62,44	58,98	41,76	9,60
Total A-			0,00	0,00	0,00	2,86	14,76	23,11	33,56	54,14	64,61	65,78	58,07	33,34
19	4,3	NA	50,00	61,54	38,64	38,20	36,45	20,72	10,68	3,09	0,56	0,32	0,10	0,00
21	6,9	NA	0,00	0,00	0,00	0,00	0,00	0,00	0,43	1,31	3,74	7,81	14,24	16,30
25	7,8	NA	0,00	0,00	0,00	0,00	0,08	0,37	1,31	1,86	3,12	4,94	9,38	46,23
Total NA			50,00	61,54	38,64	38,20	36,53	21,09	12,42	6,25	7,42	13,06	23,71	62,53

*A = mean agrologic quality; A+ = high agrologic quality; A- = low agrologic quality; NA = Non-Agricultural quality

6. DISCUSSION

6.1. *Native criteria for site suitability assessment*

Natives make use of environmental site characteristics and soil properties to distinguish locations with different suitability degrees for clearing and garden establishment. Although it is possible that the particular criteria used to discriminate site suitability could be linked with specific time/site environmental elements (e.g. bamboo-dominated forests, seasonal flooding), in many tropical rainforest regions, farmers and peasants make use of similar major environmental indices to discriminate among “good” and “bad” sites for farming (e.g. Saito 2006; Habarurema *et al* 1997; Steiner 1998; Barrios *et al* 2003). The native criteria analyzed in this study do not constitute an exception.

When soil properties are assessed, farmers might distinguish soil types based on colour, texture, stoniness, weediness and quality of burning (e.g. Saito 2006); and when a site is assessed, the type of vegetation growing on the soil could serve as an indicator of a suitable or unsuitable site for cultivation (e.g. Barrios *et al* 2003). In many cases, the most important abiotic factors identified for influencing the selection criteria are related to soil properties. In general, however, the preference for farming in sites located in lower terraces, with flat to slightly inclined slopes and black soils is noticeable. Moreover, aside from the criteria mentioned, Shepard *et al* (2001) distinguished that wind, as an abiotic factor and form of perturbation, could be considered influential for the identification of the different habitat that native Matsigenka people make.

In Timpia, when soil characteristics are assessed during the first stage of site discrimination, soil fertility (productivity) is not considered as such. The latter statement is supported by the studies of Johnson (2003) and Ohl *et al* (2007), who concluded that soil hardness and texture are probably more influential criteria than fertility in choosing a garden location. In Timpia, speculations on how well a garden could perform are assessed at first stage based on soil texture, colour and workability; the former and the latter being probably related with soil moisture. As this last parameter could not be evaluated on field, further studies should strive to identify whether it is worth to include soil water content as a criterion for site suitability discrimination. Texture is considered as an important factor for site selection. Johnson (2003), when studying the Matsigenka natives of the Shimaa community, found that the first lands to be cleared were

predominantly sandy, and that their primary attraction was their easiness to clear and to work.

Natives do not establish a clear relationship between soil types and slope steepness. Nevertheless, differences in soil types were found to be more related with their physiographic location (e.g. lower terraces, sandy bars, foothills). As natives soil types' characteristics are tightly linked with the soil's position in the landscape and their associated features; it is then not surprising that the most suitable soils selected for clearing hold determined properties that characterize either the alluvial soils or the different soil types in *terra firme*. In a less traditional agricultural development stage, farmers might use different land management according to the identified soil type (e.g. Habarurema et al 1997), but this was not the case for the natives under study, as they give the land almost the same treatment when farming. However, they do acknowledge differences in crop behaviour according to the soil type, and therefore, they prioritize the establishment of a certain crop in sites where it is known it could perform better than in other locations.

When assessing the suitability of the sites according to the natural vegetation present in the study area, it was only in some cases that a plant species was considered as an indicator of an unsuitable site for farming. Only in one study concerning the Orinoco floodplain indigenous people (Barrios *et al* 2003), it was found that they identified several plant species which were considered by locals as growing in sites not suitable for farming. Regarding this, the identification of unsuitable sites for farming according to this criterion could be beneficial for the recognition of areas where agriculture would not be developed by natives. Therefore, when planning that a portion of land could be allocated for a given use other than farming (e.g. ecotourism), there would be the assurance that overlapping of land use activities is unlikely.

The distance to the main hamlet's centre and Urubamba River is an important factor when determining the land use for agricultural purposes. Most of the land utilized for farming activities occurs along the Urubamba River and a great portion near the main hamlet. The aggregation of open lands suggests that these variables should be considered as influential factors when predicting the selection of suitable arable lands. A similar situation occurs in a Piaroa indigenous community of Venezuela (Freire 2007) whose settlement patterns are similar to the ones of the Timpia natives. In such study, the selection of the natives' gardens in peripheral communities is partly determined by

the distance from the village centre, on the one hand, and the recognition of ancestral bonds with the land, on the other. Since the village is more sedentary and most of the produce is still carried by foot, the expansion of the cultivated area is limited by a person's walking capacity. This is supported by a study concerning the indigenous population in the Sarayaku community, Ecuador (Siren 2007). In such study, as most indigenous people nowadays live in permanent settlements, the travel cost to distant old-growth forest may also be so high that people prefer to clear fallows closer to settlements instead. Even in the more traditional Matsigenka communities, Wezel et al (2005) concluded that at present, the swidden cultivation system is very similar to the traditional one. The difference is that the Matsigenka now cultivate fields within a certain range to the village without moving through the forest; and that they also re-establish new fields on fallows within short periods of time.

6.2. *Land use for agricultural purposes*

While the results show that open lands cleared for the establishment of gardens and pasturelands occupy only a small percentage of the community; more studies are needed to determine the increment rate in area of open lands. This could serve as an index for identifying a potential shift in agricultural patterns, although the latter seems to be unlikely to occur, even though colonial settlements' intensive practices occur just on the other margin of the Urubamba River. Therefore, what could be interesting to identify, based on current data on open lands area, is if available high yield-arable lands satisfy the natives' needs, especially if population tends to increase. This, bearing in mind the suitable environmental characteristics of a site considered appropriate for clearing by natives; having such characteristics been discussed throughout the document. In this respect, after the identification of the potential arable lands' total extent in two Matsigenka communities (Ohl *et al* 2007), it was concluded that suitable lands for agriculture are not even close of being considered as a limiting factor for population growth. The sufficiency in suitable arable lands should then be related with the local environmental limiting factors.

Most of the *terra firme* lands cleared for establishing gardens are naturally covered by bamboo-dominated forests, which are well-known for their rapid regeneration and garden coverage if it is left for fallow. Non dominated-bamboo forests occur in higher

elevations; and harsh topographical conditions become a limiting factor for garden establishment. Therefore, it is unlikely that gardens would be established in these locations, even if arable lands in lower terraces become scarce.

Site characteristics, such as steep slopes and stone presence, considered unsuitable for farming practices, may act as natural protecting agents against potential farming in forested lands with such characteristics. In this context, the farming range becomes narrow considering the terrain rugosity of the study area. Therefore, as farmability is limited by these terrain attributes, the community's lands do not seem to be extremely prone to deforestation due to farming activities. The latter being conditioned by other factors: such as population growth, the maintenance of the traditional manner in which the land is used for farming, and by shifts in land use allocation policies.

Yet, there has not been any sign for land ownership competition, which suggests that land for clearing is not considered a scarce resource. The community's area is relatively large in comparison with other native communities of the Lower Urubamba Region, but it is also the sixth most populated Matsigenka community of all La Convención Province (out of 44 as in SICNA 2007). Still, there are dispersed groups of households inhabiting downstream and upstream lands, far from the main hamlet. Uncertainty exists when predicting whether an increase in nuclearization patterns due to an augmentation of basic services needs could result in farming land scarcity problems in this community. The population statistical records in Timpia suggest that there has been an increase in the population growth rate throughout recent years. But when relating the population growth and agricultural land use, Freire (2007) has discussed that in native lands, a growth in the population is accompanied by a proportional enlargement of both fallow and gardening areas, rather than by expanding gardening areas alone, which characterizes most colonist models of land use. The latter is supported by the results presented concerning land cover change; where the lands used for agriculture show a clear different pattern between the intensive colonial practices and the natives' cultivation techniques.

The land use change caused by factors other than traditional subsistence/incipient commercial practices is currently more threatening than farming and cattle ranching themselves. The construction of the gas project downstream component's ROW, while

converting forested lands into pasturelands, has increased the rate of change in the original primary forest cover, in comparison with traditional swidden agriculture.

Concerning fallowing, one of the reasons causing changes in the location of the gardens is the presence of wild mammals, which appear to have lately increased their visiting frequency to cultivated lands. As a response, natives locate more traps surrounding the gardens, or they might even visit their gardens by night more frequently for attempting to hunt them. The last option is to abandon the garden and to clear another one far enough from the previous location so that the lack of visitors would be assured. Garden abandonment in this context does not seem to be related with the depletion of soils nutrients, as in the absence of the visitors the natives would continue farming the same garden. In contrast, it seems to be related with the weariness of being in constant competition for manioc produce and with the increase in gardening time demand and workload. This latter reason of forced garden abandonment has not been found in the literature as affecting fallowing activities. Other common reasons described by Staver (1989) for garden abandonment included declining in yields, conversion to other use, lack of time and presence of intensive weeds. In Timpia, the reasons for garden abandonment were varied among natives, but the presence of weeds was the most common response; in addition to a poor manioc production.

Additionally, natives have increased their concerns as the mammalian visits become more frequently after poultry animals (chickens and hens) started to be raised. These animals were introduced as a part of a regional institutional programme. This suggests that care must be taken about the side effects of allochthonous practices introduction.

6.3. *Soils in Timpia: native soil types and classification systems*

Although natives mainly describe their soil types in terms of colour (e.g. *potsitapatsari*, *kitepatsari*, *kiraapatsari*), this term is an expression that embraces several other soil properties. Soil colour in highly weathered environments reflects differences in mineralogical, organic and textural composition. Moreover, the organic matter and Fe oxides are the most important pigmenting agents in soils under this condition (Fontes *et al* 2005). The most preferred soils for farming, locally known as *potsitapatsari* (meaning “black earth”), mostly corresponds with a Munsell hue of 10YR. By knowing this characteristic, the same authors have identified, that in average, soils in highly

weathered conditions in Brazilian Amazonia, with a hue of 10YR indicate e.g. high or low concentrations of a certain mineral. Although soil colour is an important aspect that natives consider when selecting suitable sites for clearing, it does not seem to be influential when leaving a site for fallowing. This coincides with the fact that even though soil fertility in highly weathered soils could change rapidly, colour parameters do not (Ketterings et al 2000). Therefore, a decrease in soil fertility due to slash and burn agriculture could not always be related with a change in soils colour.

Soil colour has also been related to nutrient availability, especially seen in organic matter, nitrogen and Cation Exchange Capacity (CEC) (Johnson 2003). In relation to organic matter content, the preferred soil types (*potsitapatsari*) presents the highest concentrations of organic matter when contrasted with the other soils. The organic matter content, together with clay content, determines the CEC of the soils (Kauffman *et al* 1998). In the case of these soils, although organic content is maximum, silty textures dominate, and the CEC is not found to be the highest when compared with the other local soil types (e.g. *kiraapatsari*). But, if the silt content is considered as an indicator of the soils lixiviation degree; and knowing that a low silt degree is associated with aged and strongly lixiviated soils (Kauffman *et al* 1998); then this description coincides with the *potsitapatsari* soils, which have maximum silt and organic matter content, but poor soil development.

One of the most striking contrasts between these preferred soils and least preferred soils is related with the pH values. In this sense, the *potsitapatsari* soils are the only ones holding neutral to slightly alkaline values; and therefore, they occur in a suitable pH range for the growth of most of the cultivated crops, as they satisfy this agrologic requirement (tables 23 and 24). This pH indicates the low or null acidity and the high base saturation for the same soil type. The results coincide with Kauffman *et al* (1998), who stated that a pH of 5.5 is a critic value, as above this threshold the exchangeable aluminium is not present in soils. Although the *potsitapatsari* soils seem to appear restricted to a small portion of the community's lands, they are the most desired for farming.

The soil types *kitepanekiri* and *kitepatsari*, they both refer to "yellow soils" but they differ in the sense that the former ones are considered as "sandy" and the latter ones as "not sandy". This native definitions coincide with the higher percentage of sand content

found for the *kitepanekiri* soils when compared to the *kitepatsari* soils. Moreover, considering that sandy soils in *terra firme* are less acidic (Kauffman *et al* 1998), this in turn coincides with the lower pH values held by the *kitepatsari* soils when compared to the pH values of the *kitepanekiri* soil type. Moreover, the characteristics of the workability terms *kisopatsari* and *metsopatsari* appear to be related with soil texture, but further studies are needed to confirm this correspondence.

In the Matsigenka community of Tayakome, near the Manu National Park, Ohl *et al* (2007) also concluded that the best soils for cropping hold the highest pH values (max pH 5.5), although much lower than the average values found in the present research. Moreover, in the Matsigenka community of Shimaa, Johnson (2003) found highest pH values in soils considered as “black” (*potsitari*), but he did not correspond with his results the topographical position of the most preferred sites for cropping. When relating the rate at which crop yields decline with cropping and the initial pH of the soils, Sanchez *et al* (1976) have early discussed that soils with a pH of 6 or more often take as long as 15 years for yields to fall 50% below those of the first cropping season, while the crop yields of lower pH soils tend to be reduced in more than 50% already by the second year of cultivation. Coincidentally, Johnson (2003), when studying the preferred soils to be farmed by Matsigenkas, concluded that in these, pH, phosphorus and potassium values do not seem to vary with garden age and remain within acceptable limits.

As a general indicator for plants nutrient availability, the sum of bases (Ca^{+2} , Mg^{+2} , K^{+} and Na^{+}) is far higher in *potsitapatsari* soils than in any other soil type described. This property appears to be positively correlated with the silt percentage (Kaufman *et al* 1998). The soil types *kiraapatsari* and *kitepatsari*, commonly found in *terra firme* locations, have, as expected, the lowest sum of bases. In addition, the base saturation appears to be highest in *potsitapatsari* soils, indicating the soils highest nutrient availability for the plants.

Based on the soil major classes (IMA 2005), the most suitable sites for farming according to the native criteria, and where a great portion of the active gardens are located, correspond with the soil class “Cheni Sepahua”. These are classified as Inceptisol (US Soil Taxonomy) and Cambisol (FAO). As of its origin, this soil class is situated on sub-recent and old alluvial sediments; and present claystone, sandstone and

luthite residual materials. In this major class, the pH, considered as neutral (6.6-7.3) to extremely acid (less than 4.5) corresponds with the neutral soil type locally known as *potsitapatsari*. The major soils classification does not present a textural percentage range of values; but in general, the soils of the “Cheni Sepahua” class are sandy loam. The *potsitapatsari* soils, occurring in this class, are considered as silty loam, being the silt percentage highest in this soil type (table 20). This major class mostly occurs on alluvial deposits, and in the lithostratigraphic units named “Chambira” and “Yahuarango”, which are in general constituted by luthites, siltstones and sandstones. In certain sites where the native soil type was known as *kitepanekiri* (yellow and sandy), high values of available phosphorus content were found. This soil type corresponds with the major soil class “Mainjo Miscelaneo”, which is classified as Entisol (US Soil Taxonomy) and as Regosol (FAO). Although these soils are influenced by sub-recent and old coluvio-alluvial deposits (IMA 2005), a part of them appear to be located on the geological formation “Vivian” which is an extreme unit with poor nutrients and calcium carbonate (Räsänen pers. comm. 2007). It is important to take into consideration that, in the supposed case in which agricultural frontier needs to be expanded; the soils influenced by this extreme formation would be one of the least appropriate for farming purposes.

One of the sites locally classified as non-suitable for clearing was located on the major soil class “Saniriato”. The soils present in this class are classified as Entisol (US Soil Taxonomy) and Regosol (FAO). In this site, the base saturation is among the lowest, indicating the poor nutrient availability for the plants. Its topography and distance from the main hamlet are also considered as not appropriate for farming. Soil pH is extremely acid, while soil texture, described as “medium to fine” by the major soil classes’ description, was considered to be “loamy” after laboratory analyses. A clarification concerning the textural value ranges of the major soil classes description is needed for a fruitful comparison between these and the local soil types.

In general, the native descriptions of the soil types follow the major characteristics of the major soil types, but more information on local soils is needed to establish a concrete correspondence between the regional soil classification and the natives’ description. Natives give more importance to soil physical than to chemical properties when assessing the most suitable site for clearing, but as these are tightly related, the

physical description provides a general overview of the potential chemical soil properties.

6.4. Remote sensing: land cover and land use implications

Aerial photography and remote sensed imagery were core sources for the identification of land cover classes and the human activities related with them. Their complementing role in assisting the reconnaissance of open lands was of sum aid in assessing the portion of the community's lands not accessible due to time and topographical constrains. After image manipulation, it was possible to make an image classification that enhanced the visualization ease of open lands. In this respect, it is important to mention that the open lands cover class included the new gardens, the recently cleared areas, and household locations. Detailed and continuous information gathered from the field is necessary if a discrimination of solely active gardens is aimed. If the latter is reached, the usage of recent satellite imagery is core considering that a garden cycle might range between 1 and 3 years, and that the garden openness diminishes with age as weeds commence to dominate. For the purposes of the present study, the level of identification of open lands was sufficient to obtain a general pattern of the garden spatial distribution. And in the absence of current areal information of open lands within the community (and in the surrounding ones), the results provide the basis from which further research could continue for e.g. analysing the expansion of the agricultural frontier and land cover change detection.

While the Landsat image was used at the first stage of the research to identify potential sites where open lands occur, using e.g. band indices such as the bare soil index; its spatial resolution limited its scope. It was either that the open lands area was not big enough in certain locations to be detected as such, or that the reflectance values of the different agricultural land features were averaged to depict spectral information in the 30m-pixel size. An alternative was to use a SPOT image. The larger spatial resolution of the SPOT image enhanced the open lands depiction. It is known that the selection of the most suitable remote sensed imagery to be used must be tightly linked with the landscape feature under study; and given the forest clearing sizes, the SPOT image seems to have performed satisfactorily.

Although in this study a clear distinction of fallow lands on satellite imagery was not targeted, this land use could be derived by identifying the reflectance patterns of the secondary growth forests. Nevertheless, the distinction of those seems to be anything but straightforward. As Smith (2001) concluded in one of his studies, primary and older secondary forests were spectrally indistinguishable on all the images, as once an agricultural plot is abandoned, it quickly proceeds through the successional process, with only 15 years of regrowth required for a secondary forest to become spectrally inseparable. In a similar case in an Ecuadorian indigenous community (Siren 2007), the most challenging aspect of the image classification was that the differences in spectral signatures between fallow and old-growth forests were in the same magnitude as differences caused by topographic shade effects.

In Timpia, a large proportion of the fallow lands occur in areas naturally dominated by bamboo in association with other arboreal species. In some areas, old non-productive cocoa, coffee and citric crops were encountered as undercanopy components of the dominant bamboo. Moreover, their identification as fallow lands could only be registered in field but not through the satellite imagery with the available ground information. When the SPOT NDVI was tested to find differences in sites were fallows were encountered, the bamboo dominance restricted their identification. This could be related to the fact that during initial stages of fallow period, the NDVI values increases very quickly, but tends to saturate after a certain biomass density (Yemefack *et al* 2006). Therefore, registering the age of a certain fallow is also important for the correspondence of this land use with their spectral patterns (e.g. Vieira *et al* 2003). Anyway, the NDVI was a useful tool as it is known to compensate for changing illumination conditions, surface slope and extraneous factors (e.g. Lillesand *et al* 2004).

The SPOT image and the DEM were of sum aid when determining the spatial distribution of a certain land cover type and its relation with the physiographic descriptors, especially with the slope aspect. Regarding the bamboo-dominated forests, it could be seen that above a certain altitudinal range, the dominance of these bamboo stands started to decline. It could be interesting to determine which abiotic factor (e.g. soil property) correlates the most with the dominated bamboo species, and therefore, by studying the distribution of such a variable, some facts could be said about the bamboo preference for determined environmental conditions. In this respect, it is currently believed that bamboo-dominated stands do not correlate with soil texture, but with

perched water tables (Griscom *et al* 2003). Under the scope of this study, it can be said that bamboo forests dominate in terrains with slope ranging between 0 and 10% and facing north-east. On the contrary, the non-bamboo dominated forests occur in areas where the slope mostly faces the south. The concept of site exposure is widely proposed as a major control of plant microhabitats and hillslope form. Differences in insolation vary according to site aspect thereby forming a range of microclimates in multifaceted landscapes. Moreover, the topographical aspect has been correlated with other measures such as species diversity, soil nutrient status, soil surface cover, post-fire erosion and weathering intensity (Wilkinson *et al* 2006).

6.5. *Remote sensed imagery: complementary potential uses*

One of the proposed alternative uses of the SPOT NDVI image is to clearly show the spatial distribution of the less traditional households. Many of the houses located in the vicinity of the main hamlet have replaced their thatched roofs with calamine ones, which exhibit a distinctive reflectance, as seen on the satellite image. Therefore a difference can be made between those households who have changed their thatching patterns, which could be somehow seen as a degree of detraditionalization within the community. It would be interesting to relate the time consumed to harvest “Kapashi” palm leaves (which are the most used for thatching) from the upper forests, with the spatial distribution of calamine-thatched houses. This could be done by georeferencing the locations where these palm stands are most prone to be found and by identifying, in the satellite image, the locations where households are settled without (bare soil reflectance patterns), and with (calamine reflectance patterns) calamine roofs. Therefore, information on: palm inventories (their location), least time distance for palm harvesting, and thatching changing patterns could be related.

An alternative use of remote sensing data, considering the current community’s development activities, would be to identify different tourist foci. In this sense, one of the biggest “cochas” located near the Sabeti River (and about 1.7 km apart from the Urubamba River) can be clearly identified using the SPOT image. Isolated patches of these ecosystem types host a great number of bird species, particularly the “Shansho” or “Hoatzin” (*Opisthocomus hoazin*), which was spotted during the field work in early hours.

6.6. *Correspondence of ecological-economic zoning and native cropping suitability*

There is no doubt that the macro ecological-economic zoning (EEZ) of La Convencion Province has attempted to generate core information on the potentialities and limitations of the territory under study. These data could be used as the basis for the formulation of development plans. Additionally, the EEZ initiative seems to have followed the methodological framework suggested by the national authority. According to this methodology, it is in the preliminary and validation phases that the participatory approach must receive most of the attention. Theoretically, in the preliminary phase, the EEZ technical multidisciplinary team must be composed of experts in traditional knowledge issues, among others. While in the validation phase, the EEZ technical results must take into account the stakeholders involved with the aim of reaching process internalization through workshops. However, in the provincial macro-zoning approximation document, the traditional knowledge as such, is not addressed. On the other hand, the most common activities practiced by the natives (e.g. hunting, fishing) in these areas do appear to be considered when describing each of the ecological-economic zones; but no previous description of these activities seems to be considered.

The results of the community scale assessment presented in this study, based on the criteria natives apply for discriminating suitable sites for clearing, is limited by the variables it includes; as not all the addressed variables (e.g. soil properties) could be spatially represented. But the topographical attributes considered might somehow resemble general patterns of the soils in some physiographical positions (e.g. soils from alluvium or in *terra firme* areas). The elevation, slope, vegetation and distance from the external market, were found to be sufficient initial indicators for discriminating suitable from non-suitable sites for cropping. Moreover, the results suggest that the suitable sites for performing agricultural activities are restricted to a small portion of the community.

After establishing correspondence between the different native-based suitability classes and the ecological-economic zones, a large portion of the zones defined as having high agrologic value coincide with the four most suitable native-based classes. According to the EEZ, in these zones, it is suggested that aside from its high agrologic quality assigned, these sites should not be used for the establishment of permanent cultures or clean agriculture. Moreover, these zones are spatially coinciding with much of the area

occupied by sites considered as suitable for clearing. Therefore, as native communities are already occupying these territories, it is unlikely that they interrupt their farming activities in these areas. Complementary productive activities such as agroforestry could be implemented as a potential restorative practice, but the concept of agro-diversity within gardens should always be considered in any project.

A second large portion of the areas considered as most suitable according to the native criteria coincide with the ecological-economic zone designated for recuperation due to deforestation. This zone, according to its description, is seen as facing deforestation problems in mountainous forests; and it groups provincial territory sectors in which the productive activities have surpassed the natural aptitude of the lands. Moreover, in these zones not a single productive activity is recommended, but only research and conservation. The topographical description made for this zone does not coincide with the topographical features identified for these areas under the present study. The main hamlet of the community, its communal pasturelands, airstrip and most of the community “neighbourhoods” are considered as occupying this zone. But as the population augments its nuclearization patterns, the agricultural activities might become more intensive in these sites, as these lands, due to their attributes and nearness to the external market, are expected to continue being cultivated. It would be interesting to see if, in a greater scale (e.g. meso or micro zoning), the zone considered for recuperation due to deforestation could be partitioned or analyzed in detail in order to establish a distinction between the different causing agents of deforestation within the Province. Moreover, the terms *high*, *low* and *mean* agrologic value, assigned to each zone could be better quantified in order to avoid the usage of vague linguistics for the characterization of these zones, and therefore, zoning description misinterpretations could be avoided.

6.7. *Local participation and its implications in land use planning*

If land use planning is not conceived with the locals’ involvement, it is most likely that the plans would not be adopted as thought. When external organizations suggest innovations concerning the management of the lands, the population's initial interests in the novelty practices could suggest continuity and a project’s success. The latter, however, is not likely to occur. Therefore, the incorporation of new technologies might strive to identify the natives’ needs instead of providing what is thought to be needed.

The commonly used verbs “to speed up”, “to increase”, and “to optimize” should be used in the context of the environmental limits and traditional practices, and should go hand in hand with “to develop locally”, when aiming for sustainability.

Understanding the native knowledge on the environment is core for getting to know their local reality. If land evaluations concerning the most suitable land uses were made jointly with native people, it could be more probable that new development initiatives would be better accepted. When elaborating land management projects, and external strategies (e.g. aquaculture, agroforestry) attempt to modify the native traditional land management, it is important to consider these modifications as a modernization of the farming system (e.g. for obtaining higher yields), and not as an amelioration of it; which may otherwise imply social behavioural shifts and a probable failure of the methodology as a sustainable practice. Although the continuity of a project depends on external funding, a constant monitoring of the activities after the project’s completion is core for its successful implementation.

It is not intended to criticize what regional entities have been doing so far in the land use planning arena, but to emphasize that the usage of a real bottom-up approach could be more beneficial for the locals development and for a more efficient resource allocation when dealing with land use planning issues.

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APPENDICES

Appendix 1: SPOT image Principal Component Analysis assessment

For the Principal Component Analysis (PCA), the four bands of the SPOT image were utilized. The first principal component (PC1) shows the widest variation in data. The analysis was assessed through the eigenvalues (table 27), and eigenmatrix (table 28). In table 27, it can be seen that PC1 and PC2 account for almost 98% of the variance in data. In table 28, the rows represent the 4 bands of the image, while the columns represent the 4 PCs, the latter corresponding to each of the axes summarizing the pixel values. In such matrix, information on how well a band can be represented by an axis is shown. In this case, 95% of the variance of the pixel values in band1 is contained in the PC1 axis, while the remaining variance is defined by the other axes.

Table 27: Eigenvalues

<i>PC</i>	<i>Eigenvalues</i>
1	932.5526591672134
2	90.30242663124623
3	18.26967818186776
4	1.174475202937791

Table 28: Eigenmatrix

	<i>PC1</i>	<i>PC2</i>	<i>PC3</i>	<i>PC4</i>
Band1	0.9527367667834	-0.1571742841705	0.2530064607297	-0.0598049198943
Band2	0.01490474383813	0.5779078502896	0.1118297598778	-0.8082663360491
Band3	0.08331848635553	0.7545645357920	0.2924622364686	0.5815120217125
Band4	0.2917679414563	0.2682370636098	-0.9153948196676	0.07051716223653

Appendix 2: Supervised classification: Training areas assessment

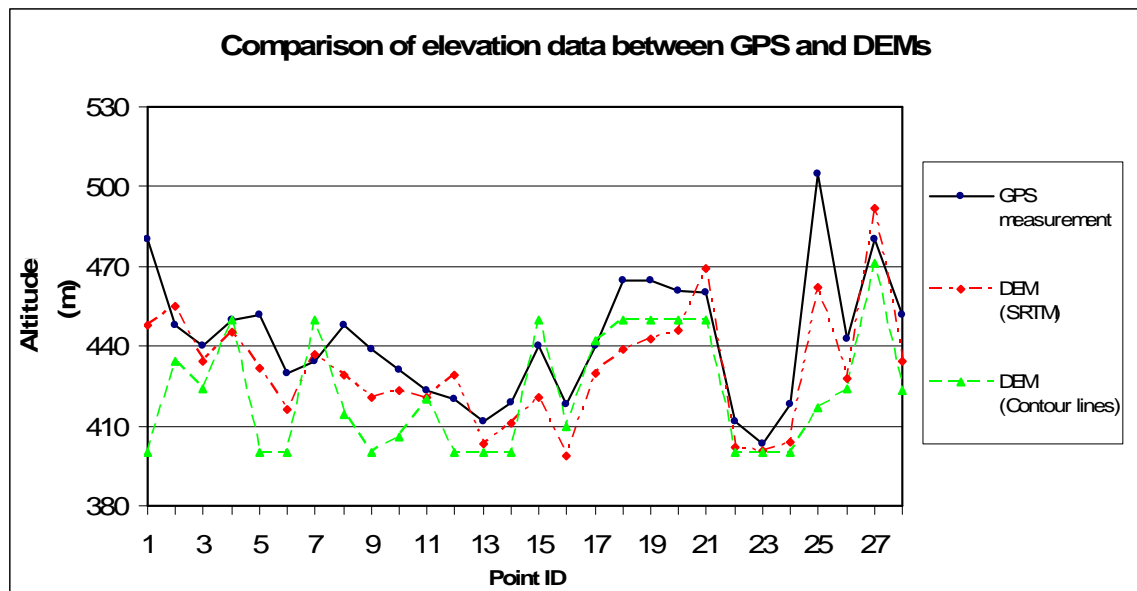
*Table 29: Training areas assessment:
Contingency analysis by error matrix*

	<i>Bamboo dominated forests</i>	<i>Non-bamboo dominated forests</i>	<i>Riverine vegetation</i>	<i>Open lands – mainly fields</i>	<i>Open lands – mainly pasturelands</i>	<i>Mixed-bamboo forests</i>
Bamboo dominated forests	99.84	0.00	0.00	0.00	0.00	0.91
Non-bamboo dominated forests	0.00	98.18	0.27	0.00	0.00	0.15
Riverine vegetation	0.00	1.37	89.20	0.00	0.00	9.59
Open lands – mainly fields	0.00	0.00	0.00	98.88	1.4	0.00
Open lands – mainly pasturelands	0.00	0.00	0.99	1.12	98.60	0.00
Mixed-bamboo forests	0.16	0.45	9.54	0.00	0.00	89.35

Appendix 3: Spatial data assessment: three concrete cases

I. Digital elevation models (DEMs)

When using the SRTM DEM, the elevation within the study area ranged between 378 and 1151 m.a.s.l. On the other hand, according to the DEM created from contour lines, the altitude inside the community ranged between 400 and 1142 m.a.s.l. When visually comparing both DEMs, the SRTM DEM allowed more continuity in the data; while the second one (created from contour lines) showed more homogeneous altitudinal patches and sharp shifts in elevation values. Appendix 3, figure 1 shows that data derived from the SRTM DEM fits better to the elevation data obtained from in-field measurements with GPS.

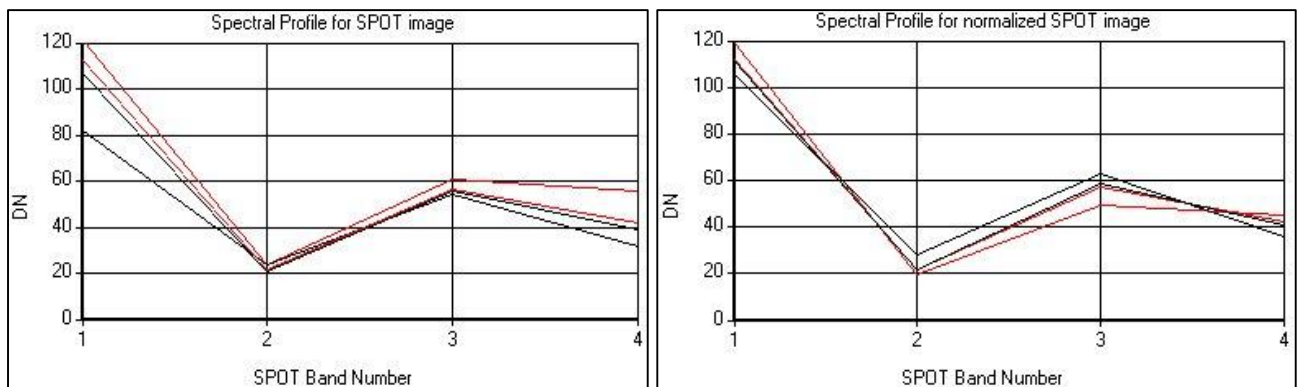


Appendix 3, figure 1: Fitness of DEMs values with the altitude values obtained from GPS field measurements. Note that each of the points depicted in the x-axis is an average of several in-field measurements.

II. Normalization process assessment

Two normalization exercises were tested: (i) a topographic normalization using transformations based on a Lambertian reflectance model; and (ii) an equal-area normalization procedure. They both are available for testing using the *Erdas Imagine* software. In the first case, it is assumed that the surface reflects incident solar energy uniformly in all directions, and that variations in reflectance are due to the amount of incident radiation. In the second case, the procedure made use of an equal-area

normalization algorithm that shifts each pixel spectrum to the same overall average brightness (Erdas 1997). Image values are adjusted by scaling the sum of the band values for each image position to a constant value. And this procedure equalizes the overall relative brightness of image pixels, removing topographic illumination variations (Smith *et al* 1999). In this study, the resolution of both accessible DEMs was too coarse to meet the requirements of the image needing topographic correction. The first topographic normalization option was tested using the scene’s solar elevation and azimuth angles of the SPOT image, as well as the DEM created from the contour lines. The results were of poor quality (Appendix 3; figure 2). When testing the second normalization option (equal-area normalization), the topography-related spectral variation was not reduced satisfactorily: the relief-related spectral variation was reduced in the visible band (B1), and SWIR (B4); but it was increased in the visible B2 and in the NIR bands. So, as variation was reduced in some bands, it was gained in others. The outcomes of the normalization processes are shown in Appendix 3, figures 2 and 3.



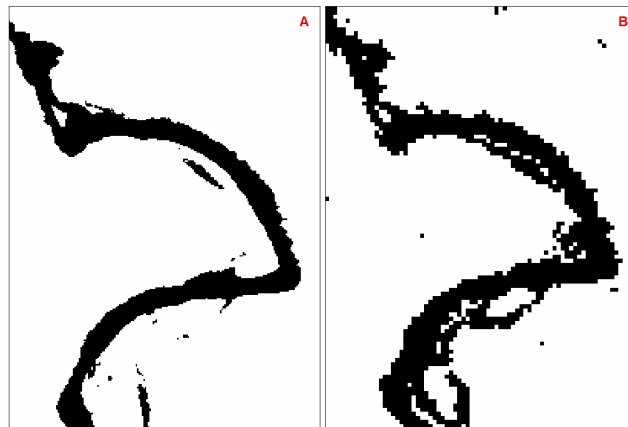
Appendix 3, figure 2: Spectral profiles of the SPOT image before and after equal-area normalization. Spectral signatures of two 20 mature forest pixel groups located in the non-shaded (red lines) and shaded (black lines) of a ridge before (left) and after (right) normalization.



Appendix 3, figure 3: Image normalization for relief shade. Picture A: original SPOT image (B2,B3,B4). Picture B: Topographic normalized image (using DEM created from contour lines). Picture C: Equal area normalized image.

III. Water masks

When manipulating the satellite images for the identification of the different land cover types in the study area, a water mask creation was considered necessary as it is known that it enables distinction between water bodies and terrestrial features (e.g. Toivonen *et al* 2007). Using the Landsat (band ratio ETM5/ETM2) and SPOT (unsupervised classification) images, two masks were created. The hydrographical network within the community appeared rather limited, as many of the tributaries of the Urubamba River exposed their river beds during the dry season. Islands dominated by vegetation could be distinguished from sandy and stony environments. After comparison of the water masks created, it could be seen that both masks showed a similar pattern. The latter, however, bearing in mind that the images used for the mask creation were acquired in two different years but in the same month of the low-waters season. The mask created from the Landsat image showed a sharper pattern, while the mask created from the SPOT image was visibly smoother. This is explained by the spatial resolution difference between both images.



Appendix 3, figure 4: Water masks: (A) created upon SPOT image unsupervised classification and (B) upon Landsat ETM⁺ image band ratio ETM5/ETM2.

Appendix 4: Complementary activities: Hunting, Fishing, Poultry and External jobs

Hunting		
Frequency (% of interviewed natives)	Weapon	Game animals (in order of frequency)
75% answered averaging 2.4 times/week	50% shotgun (cartridge limitation)	"Collared peccary", "white-lipped peccary", "curassow", "agouti", "tapir", "guan", "dusky titi monkey", "squirrel monkey", "howler monkey".
25% could not make estimations on hunting frequency as it varied according to meat stock.	50% bow and arrow	
	25% mentioned they also use their own gardens as traps for game.	

Fishing		
Averaged Frequency (times/week)	Weapon and frequency	Fish name (names in Spanish and presented in order of frequency)
5,1	70 % nylon and hook	"Boquichico", "bagre", "dorado", "sábalo", "doncella", "zúngaro", "mojarritas", "huacahua".
	18 % castnet ("atarraya"/"tarrafa")	
	8 % waiting net ("triki")	
	8 % bow and arrow	

Ownership of domestic animals		
Domestic animal	Frequency (% of interviewed natives)	Problems
Hens	80 %	90% of the interviewed natives mentioned that mammalian visits are considered a threat for gardens crops and for poultry..
Ducks	33 %	
Chickens	25 %	
Guinea pigs	4 %	
Livestock	4 %	
No domestic animals	8 %	

External jobs		
% of interviewed natives that have, at least once, worked for an external company	Most frequent labours	Contracting companies (in order of frequency)
40 %	Making gabions Opening paths Reforestation	"Walsh" "Techint" "Veritas" "PlusPetrol"

Source: This study and according the Natives' responses.



Appendix 4, figure 1: (A) Tapir encountered in the vicinity forests of the main hamlet; (B) Native carrying harvested manioc from his garden to his house; (C) “Boquichico” fish; caught with bow and arrow; (D) Fishing with “Barbasco” plant roots; (E) Gabions being constructed near the km40-camp – Camisea Gas project downstream component inside the community; (F) Livestock owned by a member of the community (Photographs: Verónica Gálmez 2007)

Appendix 5: List of crops found in the Community's gardens

<i>Matsigenka name</i>	<i>English name</i>	<i>Spanish name</i>	<i>Scientific name</i>
Sekatsi	Manioc	Yuca	<i>Manihot esculenta</i>
Huaiganire	Yellow manioc	Yuca amarilla	
Shinki	Maize	Maíz	<i>Zea mays</i>
Kogi	Barbasco	Barbasco	<i>Lonchocarpus</i> sp.
Shanko/sanko	Sugar cane	Caña de azúcar	<i>Saccharum officinarum</i>
Anpei	Cotton	Algodón	<i>Gossypium barbadense</i>
Onko	Cocoyam	Uncucha, Pituca	<i>Xanthosoma</i> sp.
Shonaki	Daledale	Daledale	<i>Calathea allouia</i>
Magona	Yam	Sachapapa	<i>Dioscorea</i> sp.
Tsirianti	Pineapple	Piña	<i>Ananus comosus</i>
Tinti	Papaya	Papaya	<i>Carica papaya</i>
Maroro	Bean	Frejol/Poroto	<i>Phaseolus vulgaris</i>
Parianti	Plantain/banana	Plátano	<i>Musa</i> spp
Kutapari*		Plátano blanco	
Kiraapari*		Plátano rojo	
Konkaribarianti*		Plátano carpintero	
Kamoguitopa*		Plátano enano	
Posiroparianti*		Plátano manzanito	
Sera		Plátano de seda	
Kitsokiri		Plátano de la isla	
Cocona	Cocona, Peach Tomato	Cocona	<i>Solanum sessiliflorum</i>
Konogui	Inca peanut	Sachainchi	<i>Plukenetia volubilis</i> L.
Sarigueminiki	Cacao	Cacao	<i>Theobroma cacao</i>
Kafiki	Coffee	Café	<i>Coffea arabica</i>
Potsoti	Achiote	Achiote	<i>Bixa orellana</i>
Intsipa		Pacae, guaba	<i>Inga edulis</i>
Koriti	Sweet potato	Camote	<i>Ipomoea batatas</i>
Tsitikana	Chili pepper	Ají	<i>Capsicum</i> sp.
Kemi	Squash	Zapallo	<i>Cucurbita</i> sp.
Shantira	Watermelon	Sandía	<i>Citrullus vulgaris</i>
Vivinkoki	Pigeon pea	Pitipoa	<i>Cajanus cajan</i>
Inki	Peanut	Maní	<i>Arachis hypogaea</i>
Aroshi	Rice	Arroz	<i>Oryza sativa</i>
Seri	Tobacco	Tabaco	<i>Nicotiana tabacum</i>
Pamoco	Calabash tree		<i>Crescentia cujete</i>
	Caimito	Caimito	<i>Pouteria caimito</i>
Kuri	Peach palm	Pijuayo	<i>Bactris gasipaes</i>
Ana	Huito, Genipa	Huito	<i>Genipa americana</i>
Kapashi		Kapashi	<i>Hyospathe tessmannii</i>
	Frijol de palo		<i>Caianus caian</i>

* These names may vary according to the hamlet and its location within the community.

Appendix 6: List of interviewed persons

<i>Name</i>	<i>Age</i>	<i>Provenance</i>
Napoleón Saringabeni	54	Timpía
Teodoro Gushi	55	Timpía
Adolfo Nochomi	32	Timpía
Ricardo Amario	26	Timpía
César Mendoza	39	Timpía
Wilibaldo Fernandez	24	Timpía
Javier Mendoza	45	Timpía
Teresa Guzman	~65	Timpía
Ananies Ignacio	34	Timpía
Marcial Gushi		Timpía
Daniel Manugari	38	Timpía
Belisario Mentian	~68	Timpía
Tenorio Martinez	~70	Timpía
Francisco Wisco	58	Timpía
Jaime Pio Saavedra	42	Timpía
Luis Matamala	59	Timpía
Isolina Semperi	32	Timpía
Salustio Angulo	40	Timpía
Antonio Vankegui	~35	Alto Timpía
Regino Timpia	~80	Alto Timpía
Alfredo Avuivanti	45	Alto Timpía
Luis Achigueri	30	Alto Timpía
Valentin Basmo	~45	Timpía
Nicodemo Vargas	21	Timpía
Elias Vargas	~70	Timpía
Braulio Semperi	25	Timpía
Dolores Primo*	40	Timpía
Selvi Bello		Timpía
Armando Cárdenas		Timpía
Ubalдина Corinti		Timpía
Tomás Andrés		Timpía
José Tenteyo		Timpía
Roger Domínguez		Timpía
Cristóbal Timpía		Timpía
Marleni Viteri		Timpía
Andrés Barboza		Timpía
Oliver Pio		Timpía
Anselmo Maonte		Timpía
Soledad Fernández		Timpía
Pedro Pablo Ojeda		Timpía
Gerardo Fernandez		Timpía
Florencio Erika		Timpía
Julia Yobeni		Timpía
José Semperi		Timpía

* Transalor and field guide