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A Farmer-assisted Soil Survey and Land Evaluation in the Peruvian Andes

A case study for the San Marcos-Cajamarca and Quilcas-Huancayo ILEIA project pilot areas

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Participating institutions

Centro de Ideas	Non-governmental organization in San Marcos (Cajamarca)
ILEIA	Information Centre for Low-External-Input and Sustainable Agriculture, Leusden, the Netherlands
ISRIC	International Soil Reference and Information Centre, Wageningen, the Netherlands
UNALM	National Agricultural University La Molina (Universidad Nacional Agraria La Molina), Lima
Yanapai	Non Governmental Organization, Huancayo

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The authors would like to thank the farmers of the pilot areas for allowing us to make soil observations in their fields and for their interest to share their knowledge about soils during the field visits and the farmers meetings. We are grateful to staff members of grupo Yanapai (Huancayo) and Centro de Ideas (San Marcos-Cajamarca) for the essential organization work and communication with the village communities.
We hope that our contribution will assist the farmers of the pilot areas in their search for an economically stronger and ecologically sound farm management.

ABSTRACT

The Centre for Research and Information exchange in Ecologically Sound Agriculture (ILEIA) and the International Soil reference and Information Centre (ISRIC) have enunciated a project on farmer-based soil classification (etnopedology) in Peru, in close collaboration with the Soils Department of the National Agricultural University La Molina (UNALM), Lima. Two pilot areas were selected in the high mountain valleys in the Andes near San Marcos (5500 ha) near Cajamarca in North Peru, and Quilcas (4500 ha) in the Mantaro Valley. Farmers accompanied a classical soil survey executed by staff of UNALM. Farmers and scientists discussed in the field soil characterization, classification, soil related soil constraints to agricultural production and solutions how to overcome these. This report summarizes the results of both pilot zones and includes maps of physiography, soils, land capability and erosion risk.

The two ILEIA project pilot areas of San Marcos and Quilcas include a great range of soil types, which is recognized by both farmers and scientists. A correlation between the farmers soil names and the scientific soil classification system could not be made, because no consistent soil naming system was used by the farmers. Farmers have detailed soil knowledge, but focused on soil management practices.

Farmers and scientists agree on the most important soil-related production constraints, which are:

a Shortage of moisture during the growing season, especially in the low, but also present in the intermediate zone.
b Decreasing soil fertility, because of i) the low natural fertility of most soil types, ii) which is worsened by a diminishing length of the fallow period to restore soil fertility, iii) the insufficient availability of corral manure, and iv) the high costs of commercial fertilizers.
c Soil degradation dominated by water erosion.

To overcome the three major soil-related production constraints, farmers should aim simultaneously at improved organic matter management; optimal plant nutrient cycles; soil and water conservation; and an ecological and economic use of soil amendments and fertilizers. This combined package of soil management techniques, indicated as an "Integrated Soil Management" approach is needed to develop an ecological sound agriculture. Some practical recommendations include the following:

A more efficient use of the present irrigation systems in the low and intermediate altitudinal zone of San Marcos should be investigated. The feasibility of the irrigation canal under construction in the Quilcas pilot area should be evaluated.

The possibilities of increasing the soil organic matter content should be studied for the soils in the lower and intermediate zones. An improved use of local available organic fertilizer types should be evaluated with the farmers.

The high zone, at present increasingly used for arable land, should be reserved for natural pasture land and the growing of potatoes should be reduced in order to prevent the degradation of the land by water erosion and soil mining.

In large parts of the pilot areas anti-erosion measures are an obligation for the, insufficiently protected agricultural fields. A (re)introduction of proven techniques should be maximally supported by governmental and non-governmental programmes.

1 INTRODUCTION

The Information Centre for Low External Input and Sustainable Agriculture (ILEIA) and the International Soil Reference and Information Centre (ISRIC) have signed a Cooperation Agreement (no. 18) to carry out a number of investigations in pilot areas located in:

- Ghana: a semi-arid savanna zone in the north of the country near Langbensi and Wiaga;
- Peru: high mountain valleys in the Andes near San Marcos (Northern Peru) and Quilcas (Central Peru)
- Philippines: sub-humid low lying floodplains in the broad alluvial plain of central Luzon.

The main issues to be addressed in this collaborative project are:

(1) Correlation of traditional farmer's knowledge of soil and land suitability with (inter)nationally accepted systems of soil and land suitability classification, in order to identify main constraints and to propose possible solutions.

(2) Assess the geographical representativeness of the pilot areas for the agro-ecological zone and district in which they occur.

(3) Presentation of project results to farmers and the non-governmental organisations (NGOs) involved in participatory meetings.

(4) Establish linkages for international collaboration on developing a sustainable basis for agro-technology transfer, in a participatory framework.

This Summary Report covers the work carried out in Peru. It is based on the base documents prepared by the subcontracted agency, the Soils Department of the Universidad Nacional Agraria - La Molina (UNALM) in Lima (Valencia and Kauffman, 1996a and 1996b), ISRIC's field trip reports (Kauffman, 1996) and other publications relevant for the study area (ONERN, 1975 and 1976; Mayor, 1979; Holdridge 1967; FAO, 1988; Morales, 1987; Ministerio de Agricultura, 1995; Gammarra and Flores, 1989; Fernandez-Baca, 1996; McArthur, 1996). Most of this information is published in Spanish. Various technical terms had to be translated from Spanish and Quechua into English. When relevant, original terms are given in addition to the English translation. In addition, some other reports and MSc. theses were consulted (Axmann, 1996; Kool, 1996; Pidae, 1995; Schepel, 1996) .

Chapter 2 gives the procedures followed, focusing mainly on the interactions of farmers and scientists. Chapter 3 describes the edaphic factors of the project sites, soils and their management from the scientists and farmers point of view. Chapter 4 presents conclusions and recommendations for further work.

2 METHODOLOGY

2.1 Site selection

The selection of the pilot areas has been made by ILEIA staff in cooperation with the NGOs *Centro de IDEAS* in San Marcos, near Cajamarca, and *Yanapai* in Quilcas, near Huancayo (Figure 1). The boundary delineation of the pilot areas on topographic maps has been a joint effort of farmers, NGO staff members, and the soil scientists of UNALM and ISRIC.
The pilot area of San Marcos includes a part of the Western margin of the watershed of the river Shitamalca, and covers about 5500 ha. Centro de IDEAS uses the name *microcuenca* Shitamalca *margem derecho* (micro-watershed Shitamalca, right margin). In this report, the area will be referred to as the San Marcos pilot area.

The pilot area of Quilcas has an area of about 4500 ha. It is also known as *microcuenca* (micro-watershed) Suitocancha. This is not an accurate indication because the pilot area includes two distinct watersheds. The Eastern part belongs to the watershed of the river Suitocancha and its tributaries Viscas and Tiza, and includes the villages of Rangra and Nahuinpuquio. The Western part of the study area belongs to the much smaller watershed of the Anja river, and includes the villages of Quilcas, Llacta and Golpar. Both areas are separated by a mountainous watershed, called Tambo. The Eastern and Western areas, forming our study area, will be referred to as the Quilcas pilot area.

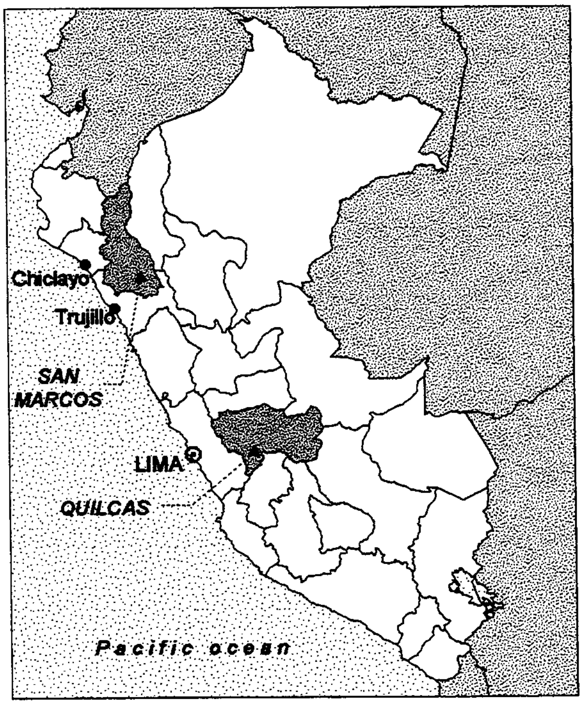


Figure 1 Location of the San Marcos and Quilcas pilot areas

2.2 Office work, field work and farmers meetings

Publications dealing with the pilot areas were purchased at the Instituto Nacional de Recursos Naturales (INRENA), and the Centro Internacional de la Papa (CIP), both in Lima. Topographic maps and aerial photographs were purchased by UNALM in Lima and Huancayo. An interpretation of the aerial photographs was made based on landform, slope gradient, vegetation and land use patterns. A first field visit was made to the pilot areas to delineate the study areas on the topographic maps, to establish contacts and agree on the workplan with the farmers communities and the NGOs involved. The field surveys required substantial time because of the acreage of the pilot area, being 3 to 10 times larger than the pilot areas in the other two ILEIA pilot countries, and because of the rugged terrain, with large parts of the area only traversable by foot.

The pilot areas consist of a high altitude (elevation between 2700 and 4600 m.a.s.l.) mountainous land dominated by very steep slopes , with large climatic differences within each pilot area. Therefore, the survey paid ample attention to landform, climate and land use, which is reflected in the recognition of three altitudinal agro-climatic zones in both pilot areas (see 3.1.1).
In the Quilcas pilot area, soils were studied at 21 sites, and in the San Marcos area at 20 sites. At each site, pits were dug and the soils were described, sampled, analyzed, classified and evaluated according to international and national standard procedures (Valencia and Kauffman, 1996a and 1996b).

The farmers and scientist soil information were correlated by realizing joint field observations. Generally a series of standard questions were asked by the scientist to the farmer. These questions focused on soil characterization, soil naming, land use and soil management operations. In practice these farmer-interviews had a rather free character, especially when production constraints were discussed. Land evaluation questions focused on three key issues: i) what are the dominant soil-related constraints to agricultural production, (ii) how to manage soil-related constraints to productivity, and iii) what are the ecological threats of present land use? Farmers frequently mentioned also non-soil related production constraints (see 3.4).
Independently of the ILEIA project, during the ILEIA project period, several students of the Wageningen Agricultural University realized research work on various subjects. The soil related subjects discussed in the resulting M.Sc. theses were compared with the findings of our study.

The Peruvian pilot areas are strongly contrasting in comparison to the pilot areas in the Philippines and Ghana, the latter consisting of rather flat areas situated at a low altitude and different agro-eco zone (less than 150 m.a.s.l.). Intermediate results of the soils study in the three ILEIA pilot countries (Ghana, Peru and Philippines) were presented by Kauffman (1996b). Intermediate and final results of the soil study were presented by the soil scientists and discussed with the farmers at two plenary meetings in Quilcas and during field excursions in both pilot areas. Furthermore, the results of the field work and the farmers meetings were presented at the V National Soil Congress, Lima (Kauffman *et al.*, 1996c), and are incorporated in this report.

3 RESULTS

3.1 The project sites

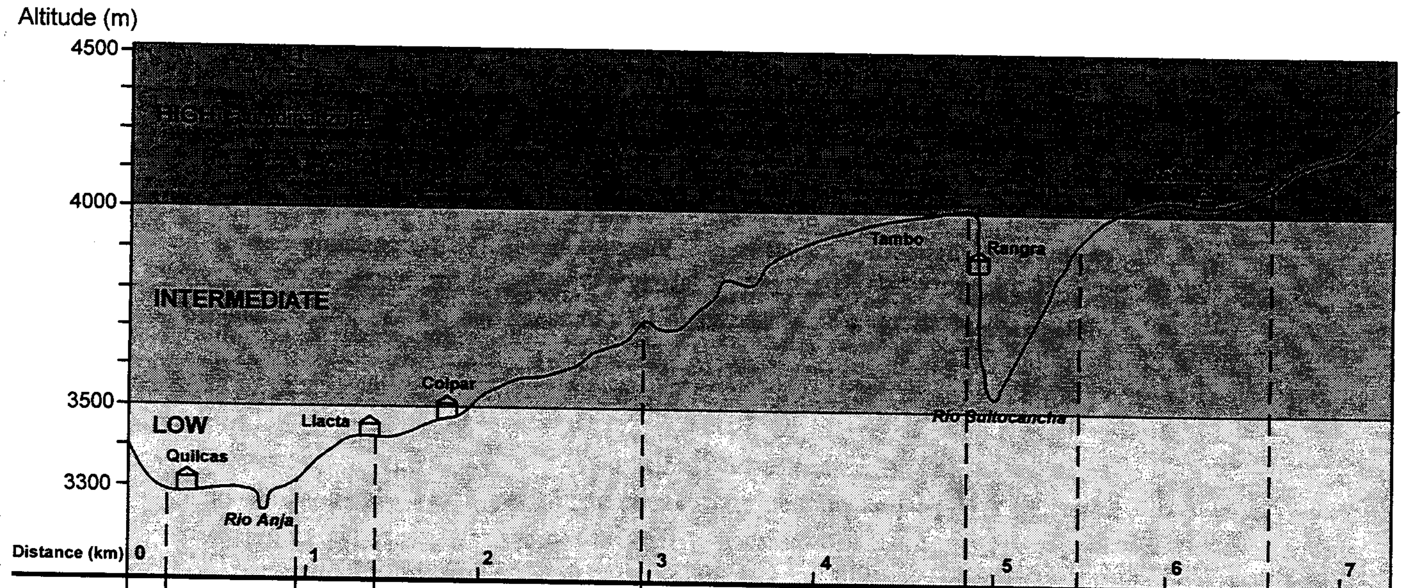
3.1.1 Physiography and geology

As detailed descriptions of the landforms and geology are given by Valencia and Kauffman, (1996a and 1996b), only a summary is given here.

San Marcos pilot area
The San Marcos pilot area is situated between 2700 and 4000 m a.s.l. and consist for two-third of hilly and mountainous land with a slope gradient between 25 to 75 %. Some flat to undulating land with a slope gradient between 0 - 8 % is found in the lower altitudinal zone. The area is drained by the Shitamalca and its tributaries, all deeply incised and forming V-shaped valleys with very steep slopes. The dominant parent materials of the soils of the San Marcos pilot area are limestone (*caliza*), claystone (*lutitas*) and sandstone (*areniscas*).
See map 1 - physiography of the San Marcos pilot area (adapted from Valencia and Kauffman, 1996a).

Quilcas pilot area
The Quilcas pilot area is situated between 3300 and 4600 m a.s.l. The Eastern part of this pilot area consists dominantly of steep mountain land with deeply incising V-shaped valleys of the rivers Suitocancha, Viscas and Tiza. A minor part of this land, at an altitude of near 4000 meter, has a nearly flat to undulating topography (see Photograph 5). The Western part of the pilot area has a small but significant portion of flat river terraces and undulating footslopes around the villages of Quilcas, Llacta and Golpar (see Photograph 3). However, also this part is dominated by steep hills and mountains. Metamorphic and sedimentary rock, schists and sandstones, form the dominant parent materials of the soils of the Huancayo pilot area. The area East of the Suitocancha river consists mainly of limestone.
See Map 2 - physiography of the Quilcas pilot area (adapted from Valencia and Kauffman, 1996b), and Figure 2, a topographic cross-section of the Quilcas pilot area.

Altitudinal zones
Holdridge (1967) recognizes four altitudinal life zones relevant for both pilot areas (*bosque seco-montano bajo tropical, bosque húmedo-montano tropical, bosque muy húmedo-montano tropical and Páramo muy húmedo subalpino tropical*). In addition to these, there are other altitudinal zone classification systems (ONERN, 1975 and 1976), based on climate, vegetation or land use, or a combination of these factors. The following pragmatic altitudinal zonification, adapted from Mayor (1979) will be used in this report: 2500-3000 m (very low), 3000-3500 m. (low) and 3500-4000 m (intermediate), 4000-4500 m (high) and > 4500 m (very high). This zonification is based on climate, vegetation and present land use. It should be noted, that in practice, these altitude limits are approximate indicators of the gradual boundaries between these zones. In addition the farmers altitudinal terms for *baja* (low), *media* (middle) and *alta* (high) zones are mostly relatively used, and difficult correlation with an absolute altitude.



Slope (%)		0 - 4	15 - 25	4 - 15 / 25 - 50	25 - 75	50 - 75	8 - 15	15 - 75
Soil name	An*	Quilcas	Anda-marca	Colpar/Calaloma	Shuhuanca	Rangra	Rachacpata	Nahuinpuquio
Soil depth		deep	deep	deep/shallow	shallow	shallow	deep	shallow
Soil colour		-	red brown	brown/ -	dark brown	yellowish brown	dark brown	strong brown
Soil texture		clay loam	clay loam	clay loam/gravelly loam	sandy loam	gravelly loam	loam	loam

* Andamarca

Figure 2 Topographic cross-section of Quilcas pilot area

3.1.2 Climate

The climate of the Andean mountains is strongly correlated with altitude. Key parameters of the altitudinal zones, relevant to the project areas, are given in Table 1.

Table 1. Climatic characteristics of altitudinal zones

Classes	Altitude (m)	Temp. (°C)	Rainfall $(mm)yr^{-1})$	Limitation
humid/semi-frigid	4000 - 4500	5	1000	high frost risk
humid/cold	3500 - 4000	9	1100	frost risk
sub-humid/semi-cold	3000 - 3500	14	850	some droughtiness
sub-humid/temperate	2500 - 3000	17	700	droughtiness risk

Source: ONERN (1975)

There are no long-term meteorological stations in the pilot areas. Average monthly data of the meteorological stations of Cajamarca and Hunacayo were taken from the FAO climatic database (1985). These stations are considered to be representative for the lower altitudinal zones of both pilot areas.

The lower altitudinal zone of San Marcos pilot area
Figure 3 gives the average precipitation and evapotranspiration data for Cajamarca, being considererd representative for the lower zone of the San Marcos pilot area. The rainy season starts in October and ends in April/May with highest rainfall in the months of January to April. The distribution of rainfal during the rainy season is not optimal, especially during the months of October to December supplementary irrigation is required to overcome frequent dry spells. Irrigation is required to grow a second crop in the dry season. At present, there are irrigation canals in the lower zone of 2500 to 3000 m, but according to the farmers, not enough water is available to irrigate all the arable land.

The lower altitudinal zone of the Quilcas pilot area
Figure 4 gives the average precipitation and evapotranspiration data of Huancayo, being considered representative for the lower zone of the Quilcas pilot area.
The annual distribution of precipitation and evapotranspiration is comparable to that at Cajamarca, except that monthly rainfall of Huancayo in January to March is slightly higher, while April has a lower rainfall. Supplementary irrigation is required also in Quilcas, especially between September and November. However, the Anja river, which drains the intensively used agricultural area around Quilcas, Llacta and Golpar, has not enough water for irrigation. At the time of this soil study, the farmer communities of Quilcas were constructing a 8 km long irrigation canal which collects water in the high zone in the upper catchment of

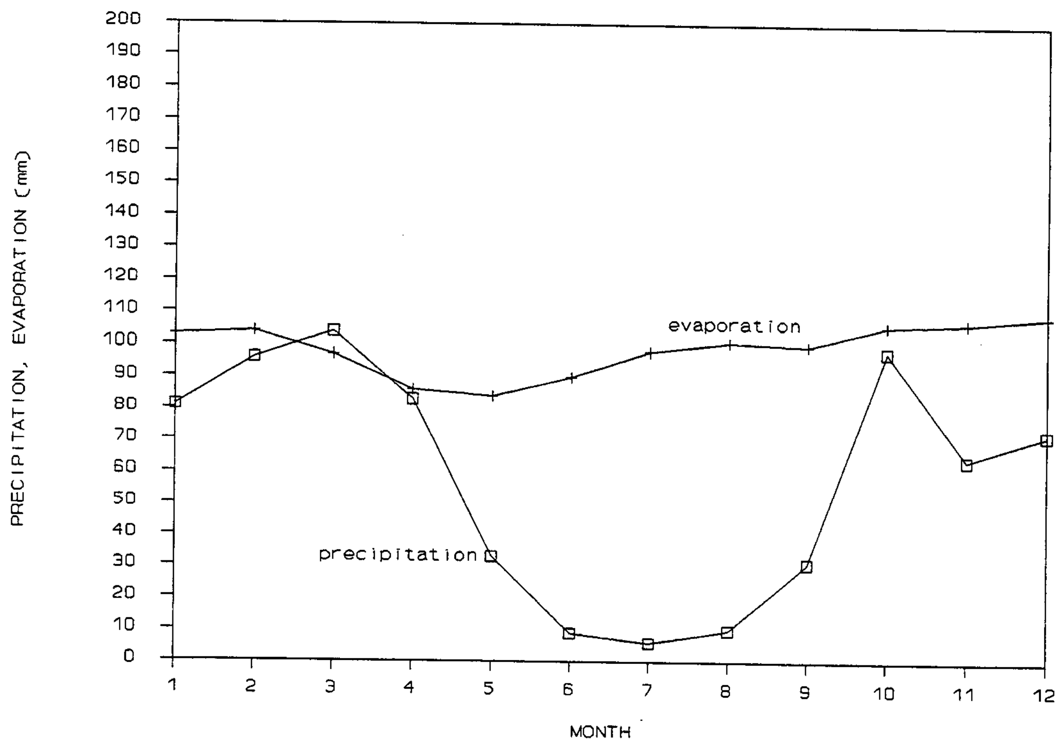


Figure 3 Precipitation and evapotranspirationof Cajamarca

the Suitocancha river, and which should travers the Tambo watershed boundary. Still to be constructed is a canal, which should bring the water down to the areas around Colpar, Llacta and Quilcas.

The intermediate and higher altitudinal zones of both pilot areas

There are no climatic data of meteo-stations representative of the intermediate and high altitudinal. However, the general climatic trend is as follows (see Table 1): the precipitation increases slightly with altitude; while temperature, and thus the evapotranspiration, decreases with altitude. The combined effect of increased precipitation and decreased evapotranspiration results in: i) a longer growing season, ii) a higher excess of moisture during the rainy season, and iii) a less pronounced deficit of moisture during the dry season. Hence, moisture availability in the high altitudinal zone is more favourable for plant growth than in the low zone. Nevertheless, the high zone (above 4000 m) is less suitable for most agricultural crops, because of the high occurrence of frost. Only potatoes, and principally the local varieties, can be grown at this altitude, although still with a risk of frost damage. Despite this risk, the area is increasingly used for growing potatoes (in view of high favourable economic returns).

3.1.3 Vegetation and land use

San Marcos pilot area

The land of the San Marcos-Cajamarca pilot area is intensively used. Except for extremely steep rocky land, every piece of land having some cultivable soil, including land with very steep slopes, is used dominantly for the cultivation of crops, pasture land and, to a lesser extent, for trees. Main crops are maize (up to about 3500 m), potatoes (all zones) and broad beans. Other crops are: barley, wheat, lentils, peas, linseed, Chocho (*Lupinus spp.*), Lactahu and Quinua (*Chenopodium quinoa*). Garlic is becoming more important, fetching a better price at the market than the dominant crops. In San Marcos in the low zone with irrigation, potatoes are already planted in June, whereas in Quilcas planting starts in October, presumably, because of lack of irrigation water and to avoid the frost risk in the months of May to August.

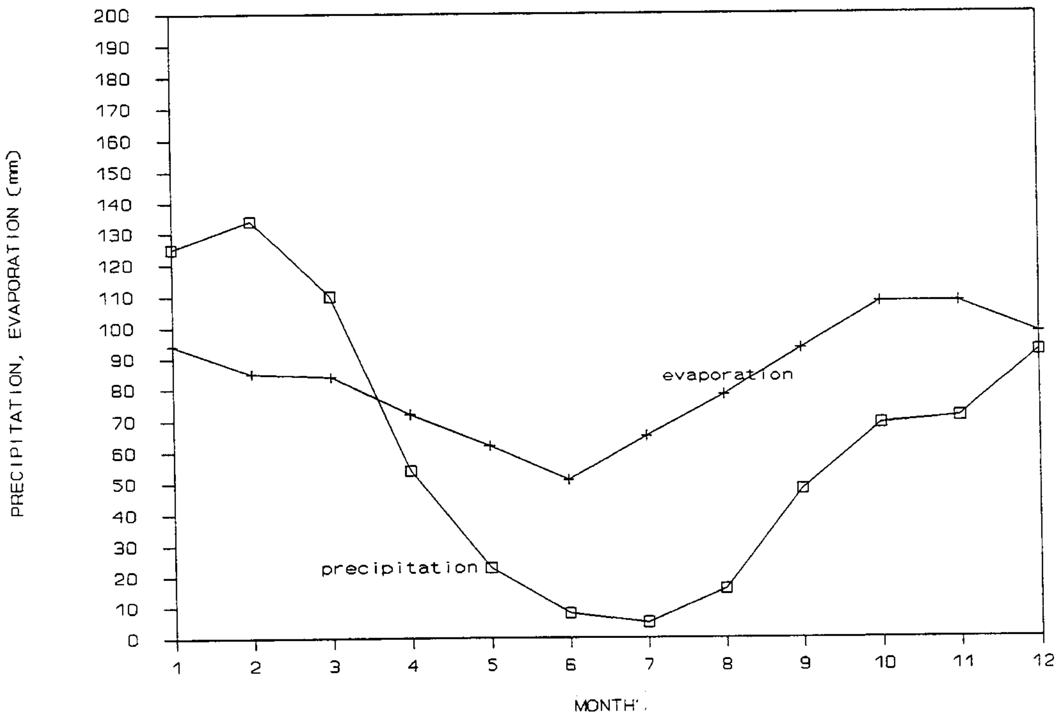


Figure 4 Precipitation and evapotranspirationof Huancayo

Quilcas pilot area

The most intensively used arable land is found on relatively flat terraces and undulating footslopes of low altitude land around the villages of Colpar Llacta and Quilcas. Dominant crops are maize, potatoes and broad beans, followed by oats, rye, wheat, beans and several vegetables such as carrots, cabbage, onion, beets, spinach. The steep hilly land near these villages includes severely eroded, bare hills, which can not longer be used for agriculture.

villages includes severely eroded, bare hills, which can not longer be used for agriculture.

The intermediate zone is also used for agriculture mainly for potatoes and cereals, but semi-natural pasture land dominates. Natural pasture land is the dominant land use in the high zone. However, during the past years, an increasing portion of the less steep land around e.g. the village of Nahuinpuquio is used for the growing of a number of local varieties of potatoes, having more resistance to frost than cultivars. Potatoes in the intermediate and the high zone include the indigenous Andean tubers Mashua (*Trapaelum tuberosum*), Olluco (*Ullucus tuberosus*) and Oca (*Oxalis tuberosa*).

Life zones and vegetation
As indicated before, Holdridge (1967) recognizes four altitudinal life zones relevant for both pilot areas: *bosque seco-montano bajo tropical, bosque húmedo-montano tropical, bosque muy húmedo-montano tropical and Páramo muy húmedo subalpino tropical*. It is noted that the term *'bosque'* (forest) creates confusion, because no (natural) forest is present in the San Marcos and Huancayo pilot areas. Grassland with some low shrubs is the dominant 'natural' vegetative cover.
In the Quilcas area a minor part of strongly eroded land is covered with trees, mainly *Eucalyptus spp.*, which were planted about 20 years ago. At present, in both areas, governmental and non-governmental programmes are stimulating the planting of native tree and shrub species such as Aliso (*Alnus*), Sauco (*Sambucus*) and Quinhual (*Polylepis*). These species are planted at parcel boundaries, so called *barreras vivas* and also used for the reinforcement of anti-erosion contour earth walls.

3.2. Science based soil survey of the pilot areas

The most important interacting factors in the development of natural soils are parent rock, land form, climate, hydrology and vegetation; in cultivated soils, man is also a key-factor. In both pilot areas all these factors vary considerably and have resulted in distinct soil types in the three altitudinal zones. The strong correlation of the altitude with vegetation and land use is obvious also for the layman. Such an altitude relationship is also valid for the soil geographic distribution. The high zone is characterized by dark coloured soils with high organic matter content, originally covered with a natural grassland. The very strong sloping intermediate and low zone has (light) brown or reddish coloured soils. The sloping land of the lower zone includes coloured soils and the nearly flat areas with seepage or groundwater near the soil surface has dark grey soils. However this general picture is an over simplification as soils vary depending on e.g. parent material, history of land use, grade of erosion and site specific drainage conditions. The soil survey identified nine soil types in the San Marcos pilot area and eight soil types in the Quilcas pilot area. Sections 3.2.1 and 3.2.2 will present brief descriptions of these soil types. More information, is given in the soil survey reports of these areas (Valencia and Kauffman, 1996a and 1996b). It is important to note that the depth of most types varies over a short distance as a result of the steep slopes and natural or man-induced erosion.

3.2.1 Soils of the San Marcos pilot area

For the correlation with international scientific soil classification, reference is made to Annex 1. The order of the soil types described below follows approximately the sequence from low, intermediate to high altitudinal zones. See Map 3 - Soils of the San Marcos pilot area (adapted from Valencia and Kauffman, 1996a).

The **Penipampa** soil type (4 % of the area) is a deep brown sandy loam, derived from allu-colluvial deposits. The soil is situated on nearly level to undulating, low altitude land, near Penipampa and Pomabamba. The soil has a very low organic matter content and is very acid. Because of the low slope gradient the Penipampa soil is intensively used for irrigated agriculture. However, because of its sandy nature and the low organic matter the Penipampa soil requires inputs of organic and inorganic fertilizers to maintain or increase soil fertility and its moisture holding capacity. When fertilized and irrigated, Penipampa soils are suitable to grow a range of crops.

The **Tauripampa** soil type (1 % of the area) is a moderately deep brown sandy loam, situated on a nearly level, low altitude land, east of Pomabamba. The soil has a very low organic matter content and has a low content of plant nutrients. Because of the low slope gradient the Tauripampa soil is intensively used for irrigated agriculture. However, because of its sandy nature, the low organic matter content and the low soil fertility the Tauripampa soil requires inputs of organic and inorganic fertilizers to maintain or increase soil fertility. When fertilized and irrigated, Tauripampa soils are suitable to grow a range of crops.

The **Ideas** soil type (6 % of the area) is a shallow yellow brown to reddish sandy loam derived from sandstone. It is found on (strongly) sloping low altitude land. The major limitation of the soil for agriculture is its shallowness and restricts its use for semi-natural grassland.

The **Huayanay** soil type (30 % of the area) is a shallow to moderately deep, light yellowish brown to grey calcaric clay derived from limestone. The soil is found on strong sloping land in the low and intermediate altitude zones (see Photograph 1). The soil has a very low organic matter content and a low content of plant nutrients (mainly restricted to nitrogen and phosphorus content). The soil is very sensitive to erosion. Despite these limitations, the Huayanay soil area are used for agriculture, although farmers acknowledge the low productivity of the soil. It is recommended to use this soil for natural pasture land. When used for agriculture, anti-erosion measures are an obligation and inputs of organic and inorganic fertilizers to increase soil fertility are required.

The **Poroporo** soil type (35 % of the area) is a deep dark yellowish brown clay loam derived from claystone (*'lutitas'*) (see Photograph 2). The soil is found on undulating to strongly sloping land in the three altitudinal zones. The soil reaction is slightly acid and the organic matter content is low, which is unusual low for the high zone. Natural fertility is medium to low. This soil is intensively cultivated, especially on land with a low slope gradient. The soil is moderately suitable for agriculture on undulating land, but requires inputs of organic and

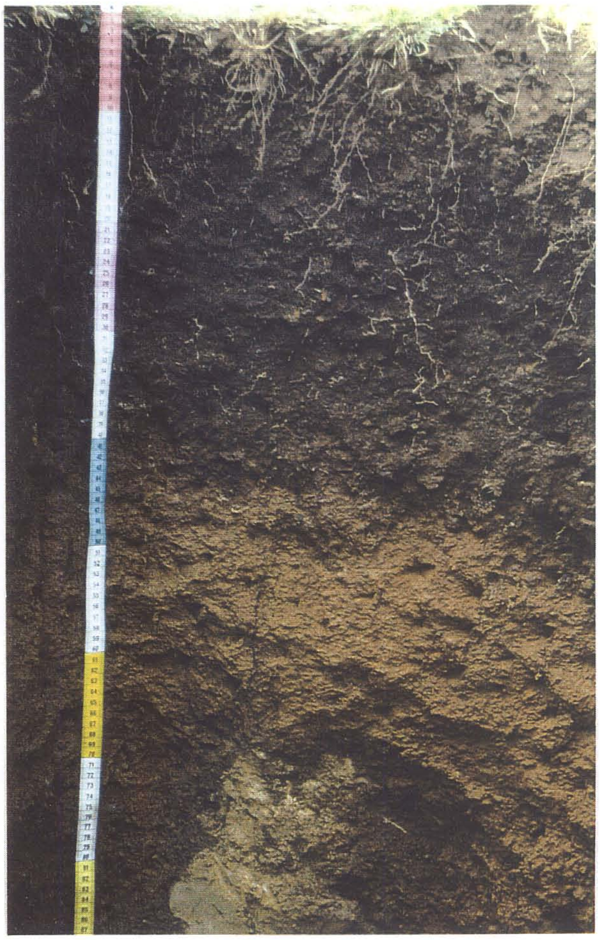
11 Human-induced soil erosion

12 Human-induced soil erosion

7 Colpar soil

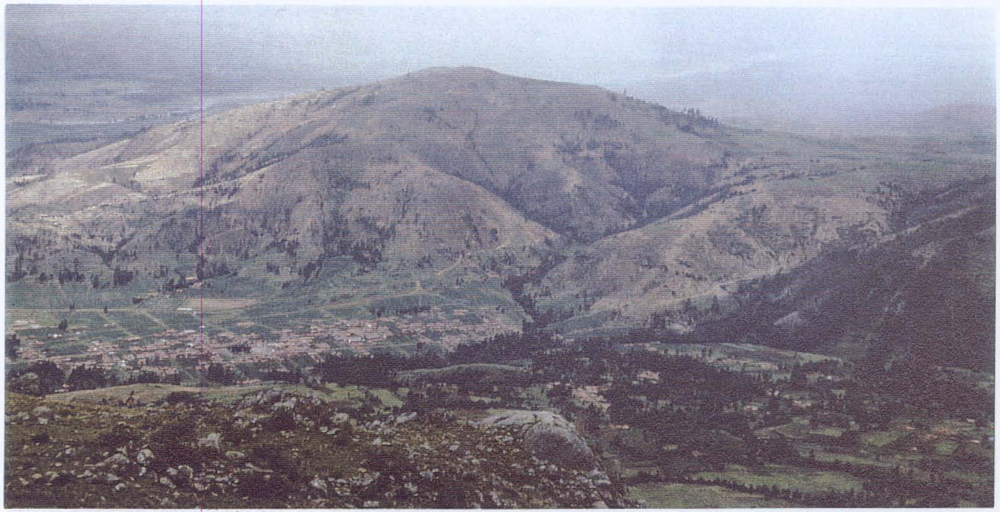
8 Andamarca soil

9 Shuhuanca soil

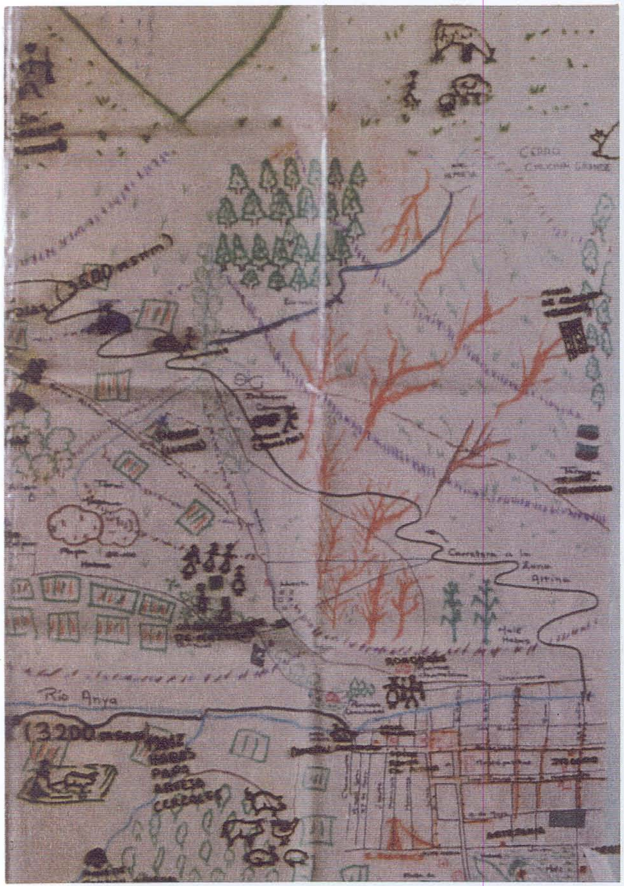


10 Rachacpata soil

Quilcas pilot area



3 Low zone, view on Quilcas village and bare eroded hills



4 Farmers sketch map

5 High zone near Nahuinpuquio

6 Intermediate zone near Rangra

1 Huayanay soil

2 Poroporo soil

inorganic fertilizers to maintain or increase soil fertility. On strong sloping land this soil should be used for pasture land and forestry. If used for arable land, anti-erosion measures are an obligation.

The **San Nicolas** soil type (13 % of the area) is a deep dark grey brown calcaric (silty) loam derived from limestone colluvium. It is found on strong sloping land in the intermediate to high zone. The soil reaction is neutral because of the high content of calcium carbonate content. The organic matter content is, for the high zone, rather low. The natural soil fertility is moderate, except for available nitrogen content, which is low. The soil is suitable for many crops. However, main limitations include the strong slope gradients which requires anti-erosion measures, and a low temperature regime which will limit the number of crops.

The **Ullilin** soil type (1 % of the area) is a shallow to moderately deep black clay loam, with a dark grey mottled subsoil, caused by water saturation during a large part of the year. The soil is found on a undulating lower footslope, with groundwater near the soil surface. The soil reaction is neutral and the organic matter content is high. When drained this soil is suitable for many crops. Presently it is used principally for high productive pasture land.

The **El Cruce** soil type (2 % of the area) is a deep dark brown loamy sand derived from sandstone. The soil is found on undulating footslopes in the high zone near Alimarca. The soil is very acid and a low organic matter content, which is unusually low for the high zone. Notwithstanding a low natural soil fertility, this soil is cultivated because of its low slope gradient.

The **Alimarca** soil type (1 % of the area) is a deep black clay with a distinct yellowish brown deeper subsoil. The soil is found on strongly sloping high altitude land near Alimarca. The soil is very acid and the organic matter content high. The natural soil fertility is medium. The soil is suitable for pasture, but not or marginally suitable for arable land, because of its high altitude and the strong slope gradient.

Land capability

An assessment of the soils according to the national land classification rules was made (Valencia and Kauffman, 1996a), giving the recommended main land use capacity (*capacidad de uso mayor*), following 4 classes: arable land, pasture land, forestry and protection land. The first three classes are subdivided according to their suitability in 3 subgroups: high, moderate and low suitable, which are determined by the presence of soil-related production constraints. The results are presented in Map 4. According to this land classification system, the San Marcos pilot area does not have highly suitable land, 5 % of the area is classified as low suitable for arable land, 9 % moderately suitable for pasture land, 54 % for forestry land and 31 % as permanently protected land. These results strongly contrast with the present land use, where arable farming and pasture land use are domimant and forestry and protected land are minimal. Production constraints determining the science based classification include climate (too dry or too cold), slope soil erosion risk (high slope gradients) and soil fertility (low availability of plant nutrients). Most land classes has two or three production constraints. A part of these constraints can be overcome by improved soil management techniques, e.g.

irrigation to overcome dry climate, anti-erosion measures for sloping land and soil fertilization to overcome the low soil fertility. Soil improvement will be further discussed in section 3.3.2 Soil Management.

3.2.2 Soils of the Quilcas pilot area

For the correlation with international scientific soil classification, reference is made to Annex 2. The order of the soil types described below follows approximately the sequence from low, intermediate to high altitudinal zones. See Map 5 - soils of the the Quilcas pilot area (adapted from Valencia and Kauffman, 1996b).

The **Quilcas** soil type (5 % of the area) is restricted to the nearly flat river terraces around the village of Quilcas. The soil layers with different texture are sedimentary deposits of the river Anja. A 50 to 100 cm thick loam to clay loam soil layer overlies a coarse gravel subsoil. The nearly flat topography make the Quilcas soils favourable for agriculture. Soil fertility is medium to low. The nearly permanent cultivation of this soil with many crops requires inputs of organic and inorganic fertilizers to maintain or increase soil fertility. Soil physical properties require special attention. The soil has a tendency to become very hard when dry. Organic materials (e.g. crop residues) should be maximally returned to the soil to alleviate this hard setting of soils. In addition, when soils have been cultivated for an extensive period with heavy implements, root development may be restricted by a dense compacted layer (a so-called 'plow' layer). Such a plow layer was observed and discussed with some farmers of the Quilcas community during the 1996 field survey. Disintegration of such a layer can be done in a mechanical way by sub-soiling, or biologically by growing deep rooting crops such as alfalfa. With adequate soil management, Quilcas soils are suitable to grow a large range of crops.

The **Colpar** soil type (6 % of the area) is a very deep uniformly brown coloured clay loam (see Photograph 7). This soil is found on footslopes near the village of Colpar. It has favourable physical properties, roots can freely develop till great depth. The soil fertility is low because of the high acidity of the soil and the low content of plant nutrients. The soils are intensively cultivated and requires inputs of organic and inorganic fertilizers to maintain or increase soil fertility. When fertilized, Colpar soils are suitable to grow a range of low altitudinal crops.

The **Andamarca** soil type (13% of the area), non-eroded phase, is a deep strong reddish brown loam or clay loam (see Photograph 8). This soil is found on strongly sloping low and partly intermediate altitude land around Quilcas. The soil is very acid, has a low organic matter content, and the content of plant nutrients is low. A substantial part of this soil type is very seriously eroded and frequently only the soft weathered rock remains (see Photograph 3). Farmers are not aware about the history of this man-induced soil erosion and consider the eroded land as completely lost for agriculture. The non-eroded land is marginally suitable for cropland and grassland. Forestry is recommended for both the eroded and the non-eroded soils.

The **Shuhuanca** soil type (16 % of the area) is a shallow dark brown sandy loam (see Photograph 9). This soil is found on strongly sloping land in the intermediate bordering to the high altitude zone. The soil is very acid, has a medium organic matter content and a very low content of plant nutrients. The Shuhuanca soils are not suitable for cropland, moderately suitable for grassland and in the intermediate zone moderately suitable for forestry.

The **Calaloma** soil type (25% of the area) is a shallow to moderately deep gravelly loam to sandy loam over a hard or soft weathered rock. The colour of the subsoil is either brown or dark grey depending whether the soil has a free or poor drainage. Grey subsoils are also found on very steep land. The Calaloma soil is found over large areas mainly in the strongly sloping high altitudinal natural grassland extending into the intermediate zone. The soil has in natural conditions a relatively high organic matter content. In areas being cultivated in the past the amount of organic material has decreased. Soils are very acid and the content of plant nutrients is very low. The Calaloma soils are moderately suitable for grassland and are not suitable for cropland and forestry.

The **Rangra** soil type (2 % of the area) is a shallow to moderately deep yellowish brown gravelly loam. The soil is found on strong sloping high altitude land near the village of Rangra. The soil has an, for the high zone, unusual low organic matter content, is very acid and has a very low content of plant nutrients. The soil is moderately suitable for pasture and not suitable for cropland and forestry.

The **Rachacpata** soil type (20 % of the area) is a deep dark brown loam with a thick nearly black topsoil (see Photograph 10). The clay content distinctly increases with depth. The soil is found on sloping to strongly sloping high altitude natural grassland, East of the Suitocancha river. The organic matter is high, is very acid and has a very low content of plant nutrients. The soil is suitable for natural grassland, marginally suitable for cropland, and not suitable for forestry.

The **Nahuinpuquio** soil type (13 % of the area) is a shallow strong brown loam. The soil is found on strongly sloping high altitude grassland, East of the Suitocancha river. The organic matter content is low, is very acid and has a very low content of plant nutrients. The soil is moderately suitable for natural grassland, and not suitable for cropland and forestry.

Land capability
Similarly to the San Marcos area, an assessment of the soils according to the national land classification rules was made (Valencia and Kauffman, 1996a). The results are presented in Map 6. According to this land classification system, the Quilcas pilot area does not have highly suitable land, 10 % of the area is classified as low or moderately suitable for arable land, 15 % low or moderately suitable for pasture land, 24 % for forestry land, and 52 % as permanently protected land. Similarly to the San Marcos pilot area, the present day land use in the Quilcas area contrasts strongly with the results of the science based land capability classification. Also in the Quilcas pilot area, pasture land and arable farming are the dominant land uses. Production constraints determining this classification include climate (too dry or too cold), slope soil erosion risk (high slope gradients) and soil fertility (low availability of

plant nutrients). Most land classes has two or three production constraints. A part of these constraints can be overcome by using improved soil management techniques, e.g. irrigation to overcome dry climate, anti-erosion measures for sloping land, and soil fertilization to overcome the low soil fertility. Soil improvement will be further discussed in section 3.3.2.

3.3 Farmers soil knowledge

3.3.1 Soil classification

Mcarthur (1996) reports that farmers in the Quilcas area classify soils in terms of three inter-related criteria: color, texture and location (elevation). Directly associated with these factors is land use, expressed by cropping patterns and management practices. Gamarra and Flores (1989) report that for the Western Mantaro valley area the following classification criteria used by the farmers: Color (5 classes), texture (4 classes), soil depth to rock (2 classes) and landform/slope gradient (5 classes).

During our fieldwork the use of some of these criteria were approximately confirmed in the joint farmers-scientist soil observations. However, the detailed classification system, as reported by Gamarra and Flores (1989), is not consistently used by the farmers in the Quilcas pilot area. Most farmers preferably use terms, which are directly related to productivity in subjective terms of good, moderate and low, followed arbitrarily by some terms related to soil properties, landform or land use (Valencia and Kauffman, 1996b). These terms are summarized in Annex 3.

In addition, action research workshops were held by other scientists contracted by ILEIA, in the two pilot areas to visualise farmers knowledge of natural resources. These workshops resulted in a large number of farmers prepared sketch maps of resource maps, transects, resource flows diagrams and seasonal calendars, of which originals are kept at Centro de Ideas in San Marcos and Yanapai in Hunacayo. An example of such a sketch is shown in Photograph 4. The results of these workshops were discussed by Mcarthur (1996) and Fernandez-Baca (1996). Unfortunately, the information on the sketch maps has not been transferred to a topographic basemap. As a result, the farmers soil information included in these sketches could not be correlated with the maps of our study.

Although a consistent and detailed soil characterization classification system is not operational in the Quilcas area, the discussion with the farmers in the plenary meetings resulted in much practical soil management information, which is discussed in section 3.3.2.

3.3.2 Soil management

Moisture availability and irrigation

Farmers mentioned shortage of moisture during the growing season for both the low and the intermediate zones. The total annual rainfall varies considerably from year to year. In addition, the onset of rains is uncertain, and the rainfall distribution during the growing season is irregular. These effects are aggravated in sandy and shallow soil types with a low plant-available moisture capacity. Generally soil moisture holding capacity of soils can be improved with the use of mulch and raising of the soil organic matter content. Nevertheless, in the low, nearly flat areas, which are permanently used for agriculture, irrigation is essential. The following reasons were mentioned by the farmers. Firstly, especially the hard setting clay soils (Quilcas area) need moisture to make land preparation possible. Secondly, irrigation water could make sowing/planting possibly before the start of the rains, which are late in some years. Thirdly, additional irrigation can alleviate the dry spells, which are common during the first part of the rainy season (September to November/December). Fourthly, irrigation water makes a second crop possible during the dry season from May to August. Fifthly, adequate supply of water is required to grow moisture demanding crops such as alfalfa and several horticulture crops.

The construction of an irrigation canal which collects water at a large distance from Quilcas in the upper catchment of the Suitocancha river in the Quilcas area was mentioned earlier and discussed also by Kauffman (1996a).

Soil fertility and crop rotation

A low soil fertility was frequently mentioned by the farmers in both pilot areas as a major production constraint. The fertility assessment of the soil types, briefly described in section 3.2, confirmed the farmers opinion. The following information, based on interviews and discussion at farmers meetings, gives a summary of the fertilization practices in the pilot areas.

It is difficult to obtain quantitative information on yields to verify the declining yields, frequently mentioned by the farmers. The farmers indicates the production in terms of seed/yield ratio, using the *arroba* as weight unit (1 arroba is about 11.5 kg), and bags (*sacos*) as volume unit. For example, the planting of 1 arroba of potatoes results in 18 arrobas yield. However, such seed/yield ratios should be considered as a rough semi-quantitative estimation.

In the Quilcas area corral manure (*guano de corral*) is applied in all altitudinal zones. However, the availability of manure in the low altitude zone is restricted, because the demand of the permanently used agricultural fields is high and heads of cattle in this zone is low. In the high zone corral manure is exclusively applied. This fertilizer type is readily available at this altitude with a dominance of cattle and grazing land.

Especially potatoes, first crop in the rotation, receive manure, other crops less or none. In the low altitudinal zone, on the most intense cultivated land commercial fertilizers (*guano synthetico* or *abonos quimicos*) are used in addition to a limited amount of corral manure.

Several types of crop rotations are used in all altitudinal zones. A common sequence, with several minor variations, of the lower altitude zone includes the following: 1st year potatoes, second broad beans, third Andean tubers (*olluco* and *mashua*), 4th cereals (barley). Mostly the first and rarely the second crop are fertilized with corral manure. Kitchen ash is mainly applied to the second or third crop. In the low altitude zone commercial fertilizers are also used in combination with corral manure. Commercial fertilizers mentioned include ammonium phosphate, urea, and a composite fertilizer 'Indus' 12:12:12. Farmers indicated that, in the

past, more commercial fertilisers were used. However, at present farmers can not afford "as much as they want" this costly external input. Farmers mentioned also the mixing of corral manure with 'decomposed litter' of the Aliso tree (*Alnus acuminata*), which technique is locally called *turba* (literally 'peat'). This technique is also reported by Axmann (1996). Yanapai mentioned that experiments are carried out to test the usefulness of the *turba* technique. Quantities of fertilizers used per ha were seldom reported by the farmer. Farmers knowledge of how to use synthetic fertilizers is often limited (Axmann, 1996). In the high altitudinal zone only tuber crops are grown during a first and sometimes a second year followed by a short or long fallow period. Farmers responses on questions about the length of the fallow period gives a range of 2 to 10 years. The length of the fallow period depends on altitude and fertility status of the soil.
In the San Marcos area, commercial fertilizers are arbitrarily used on the most intensively cultivated, generally, irrigated land (verbal communication, Centro de IDEAS). Farmers indicated the need for soil analysis and soil fertility recommendations to support a more efficient use of (in)organic fertilisers. In the San Marcos area, Centro de IDEAS promotes the use of: i) farm made compost, ii) commercially available worm compost (*humus de lombriz*), which is produced from the biological degradable part of the municipal solid waste of San Marcos, and iii) the inclusion of green fertilizers in the rotation. During an excursion to the municipality compost plant, it was observed that the total production of this compost can serve only a small area.

Land preparation
Mechanized land preparation is mainly restricted to the nearly level land in the low altitude zone. The development of a plough layer in the Quilcas soil type, while using a tractor, and remedies to overcome such a layer as discussed in section 3.2.2. Ploughing with animal traction is used on more sloping land. On strongly sloping land and especially in the high altitude zone, land is prepared with the foot-plough (*chaquitaccla* or *taclla*). This local farm implement is effective to turn natural pasture or grass-fallow on steep sloping land into arable land. In the Quilcas pilot area, especially on soils with restricted root development, farmers construct broad ridges and furrows (*camellones* and *surcos*). On steep sloping land, farmers prefer to have such ridges perpendicular to the contour. Farmers mentioned that the downward slope direction makes construction easier. However, this practice leads to soil erosion and is harmful from a conservation point of view. The construction of such ridges is done to increase the rootable volume and to improve drainage conditions, because even extremely sloping land may have impeded drainage, which is shown by a grey subsoil with reddish/brown mottles (see e.g. Photograph 8). Morales (1987) reports that ridges with a diagonally tilted direction are already effective from soil conservation point of view, especially if mulch is applied. This improved technique was observed in some fields in the Quilcas pilot area (see Photograph 6).

Erosion
Valencia and Kauffman (1996b) prepared water- erosion risk maps of both pilot areas (see Map 7 and 8). The main criterium to estimate the erosion risk is gradient. Land with a very steep slope gradient, forming the major part of both pilot areas, should be used for natural

pasture, forestry land or be protected. However, if arable farming is already chosen by the farmers, the non or insufficiently protected land requires anti-erosion measures.

In the *San Marcos pilot area* water erosion is one of the persistent major problems, especially on shallow soils derived from limestone (e.g. Huayanay soil type). From a large distance the pattern of parcelled land shows a green cover, suggesting a stable situation. However, close inspection of the fields shows clear erosion features (see Photographs 1, 11 and 12). In several locations, a.o. near Ullillin, extremely steep slopes (>50 %) with very shallow stony soils are cultivated. It was asked why farmers are still farming on land with such poor soil conditions, because it was estimated from the very poor stand of cereals (barley and wheat), that yields must be less than 500 kg per hectare. From several interviews it appeared that land pressure is so high that even such low yields are essential for home consumption.
The seriousness of erosion and the need for conservation has been reported over 20 years ago, among others by ONERN (1975). In San Marcos Centro de IDEAS and more recently also the governmental programme PRONAMACHS are (re-)introducing several anti-erosion techniques. For example, it is recommended on strong sloping land to construct contour stone walls (*pircas*) or, if stones are lacking, earth walls reinforced by trees and shrubs (*barreras vivos*). For the latter several native trees and shrubs are promoted. Especially Aliso (*Alnus acuminata*), Sauco (*Sambucus peruviana*) and Quinhual (*Polylepis incana*) are proposed. All these native trees produce a good quality litter, in contrast to the frequently planted Eucalyptus trees, which gives a poor quality litter, and, in addition, is very competitive for soil moisture. In Ullillin, farmers indicated that probably most important factors to (re)introduce soil conservation are: i) training, ii) organization at community level and iii) support in the form of tools and incentives.

In the *Quilcas pilot area* water erosion is also one of the serious problems. Without being complete some observations are presented here. Severely strongly eroded bare hills strikes the visitor new to the Mantaro Valley. Only a minor part of this land has been reforested in the recent past (through intervention of erosion combatting programme). Two contrasting degrees of erosion were observed during the fieldwork: i) severely eroded land taken out of production, and ii) arable land with slow acting erosion.
Examples of the first type are the eroded bare hills situated around the village of Quilcas (see Photograph 3). According to air-photos taken in 1961, these hills were already heavily eroded 35 years ago, and are at present taken out of agricultural production. This barren land is considered by the farmers as lost agricultural land. The question is when this erosion took place, and how/why did it happen? The heavily eroded hill just opposite (east) of Quilcas shows isolated patches (*mesetas*), which shows the original soil surface, demonstrating that the red soil has been eroded to a depth of 2 to 3 meters! The reddish brown coloured Andamarca and Shuhuanca soils seem to be most sensitive to erosion. Were intensive agriculture and inadequate anti-erosion measures the main cause? During the interviews no clear answers could be obtained from the farmers on this topic. It is noted however, the severely eroded land is recognized by the farmers and depicted on the farmers sketch maps (see photograph 4).
Of the second erosion type, less dramatic erosion features were observed in today's agricultural fields on sloping land. The farmers acknowledge the slow acting water erosion

in these lands, however, insufficient measures are taken yet. The use of broad ridges and its preferred tilted direction was discussed already in section 3.3.2. In both pilot areas several anti-erosion techniques were observed, such as the contour stone-walls or earth-walls, and the so-called slow forming terraces (*terraces de formation lento*). Also some broad terraces were observed. However, for large areas soil protection is considered as below par.

3.4 Socio-economic factors

Population and land use

No census data of the pilot areas are available. In all farmers interviews and plenary meetings it was stated that there is not enough land. Land productivity depends on soil characteristics and on the soil management techniques applied by the farmer. Except for mechanization in the low altitude zone, land preparation is dominantly realized with animal traction and manual labour. Therefore, the area that can be cultivated by a farmer is restricted to a few hectares. There exist a shortage of organic fertilizers to maintain or increase soil fertility. In the low zone, the increase of population has resulted in a shift of pasture land to arable land and fertilization is probably dominated by the use of inorganic fertilizers. However, there are no data available on the use of inorganic and organic fertilizers. In the intermediate and high zones it is assumed that fertilization of the soil is dominated by organic fertilizers.

Infrastructure and transport

The road network in both pilot areas includes a limited length of car roads, but for the greater part it consists of a network of foot tracks, which is used to transport the bulk of agricultural products and other goods, carried by donkeys, to the main market places. In Quilcas also lamas are used, principally in the high zone.

Market

No data on marketed products are available for the pilot areas, but farmers are selling the surplus of the agricultural production at the markets in San Marcos, Quilcas and Huancayo. Farmers mentioned that prices for principal crops are declining over the past years. These observations are confirmed by over-all agro-statistics of the Department of Junin (Ministry of Agriculture, 1995). Figures 5 and 6 show the sharp decreasing trend of both market price of potatoes and the total area of potato production. The correlation of price and land use is obvious, which is stronger than the influence of the rainfall. The annual average potato yield in the Junin Department is between 9 to 11 tons per hectare. Only in very dry years, the reduced rainfall also may limit potato production. For example in 1992, a very dry year, the average potato yield dropped to 7 ton per hectare. Comparable trends can be seen for other principal crops such as maize and broad beans. Only vegetable crops such as carrots show a positive economic picture. Farmers are interested to cultivate new crops in view of the persistent low prices for the present dominantly marked crops (potatoes and maize). Mentioned during the meetings were alfalfa, artichokes, carrots, beets and some other vegetables. A succesful introduction of a new vegetable crop in Mantaro Valley is artichoke (*alcachofe*). For growing such crops, only the low altitudinal zone has a suitable temperature regime, however, irrigation will be essential during dry spells and the dry season.

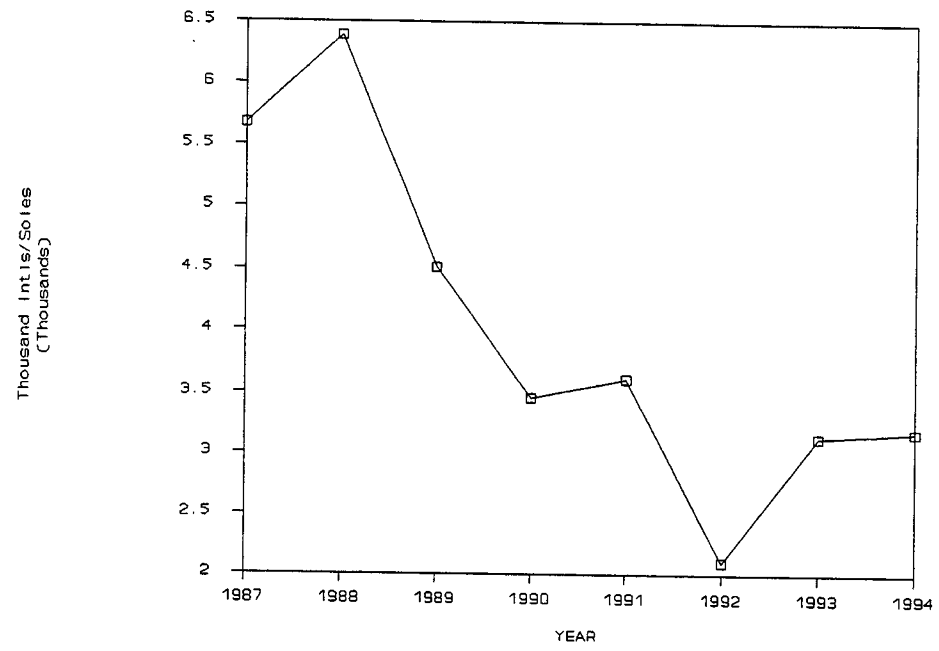


Figure 5 Value of potato production, constant prices (thousand Intis/Soles)

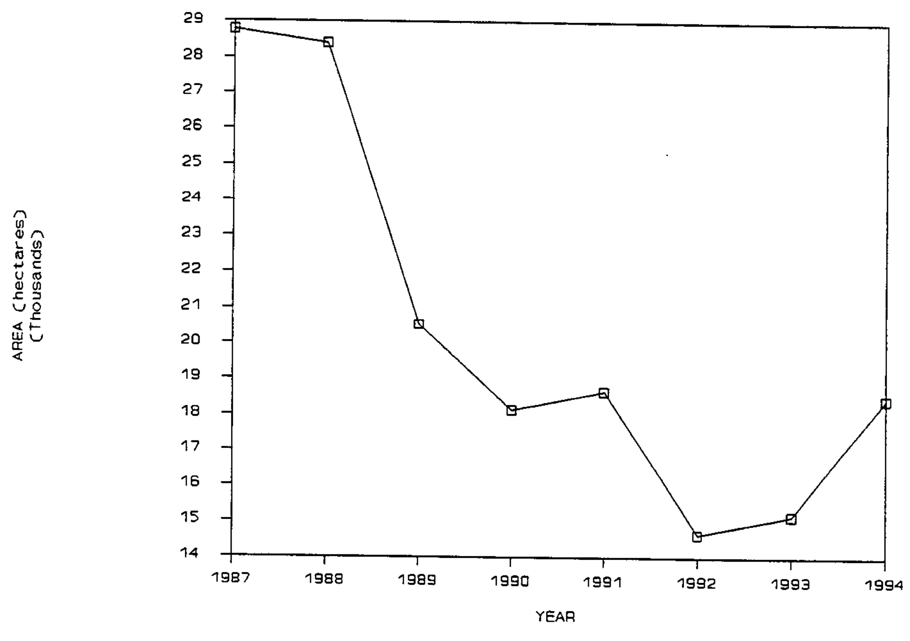


Figure 6 Area of Potato production, Dept. Junin (hectares)

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

1 The San Marcos pilot areas is considered representative for the southern part of the department of Cajamarca (ONERN, 1975), and the Quilcas pilot area for the eastern mountainous land of the Mantaro Valley (Ministerio de Agricultura, 1956; ONERN, 1976).

2 The two ILEIA project pilot areas show a great range of soil types, which is recognized by both farmers and scientists. A correlation between the farmers soil names and the scientific soil classification system could not be made, because no consistent soil naming system was used by the farmers. Farmers have detailed soil knowledge, which is focused on soil management practices, while the scientists focus is on so-called diagnostic properties.

3. There is a large discrepancy between the present-day land use and the recommended science-based land capability classification. In both pilot areas arable and pasture land use exceeds grossly the available suitable land for these kinds of land use. Land pressure is main cause of this situation. Land protection against water erosion in arable and pasture land is below par.

4 Farmers and scientists agree on the most important soil-related production constraints, which are:
   a Shortage of moisture during the growing season, especially in the low, but also in the intermediate zone.
   b Decreasing soil fertility. Farmers mentioned that yields are declining because soils are exhausted (*cansado*). Determining factors are i) the low natural fertility of most soil types, ii) a reduced length of the fallow period which is needed to maintain/restore soil fertility, iii) the insufficient availability of corral manure, especially in the low and intermediate zones, and iv) the high cost of inorganic fertilizers.
   c Soil degradation dominated by water erosion. Early soil survey reports already indicated the risk of water erosion and the urgent need for conservation. Continuing soil erosion will decrease the soil moisture capacity and plant nutrient supply, especially for shallow soils. Farmers are aware of the problem, but because it is a long-term process it is overshadowed by the immediate food production needs.

5 To overcome the three major soil-related production constraints, farmers should aim simultaneously at: improved organic matter management; optimizing plant nutrient cycles; soil and water conservation; and an ecological and economic use of soil amendments and fertilizers. Such a package of soil management techniques, or "Integrated Soil Management" approach, is needed to develop an ecological sound agriculture.

6 Farmers indicated the following other production limitations: i) shortage of land, ii) difficult transport of agricultural products to the markets, and iii) low prices for the principal crops at the local markets.

7 There is much published information on natural resources, soils and soil conservation of the Peruvian Andes; however, it is insufficiently accessible to the farmer communities. The meeting and the discussions/interviews in the field showed the interest of the farmers to initiate solutions at an experimental scale.

4.2 Recommendations

The following recommendations are made to support a future ecological sound and economically viable agriculture:

1 Possibilities for a more efficient use of the present irrigation systems in the low and intermediate altitudinal zone of San Marcos should be investigated. Furthermore, the potential for further development of irrigation systems should be investigated. As immediate action, the feasibility of the irrigation canal in the Quilcas pilot area should be evaluated, which should focus on the quantity of water presently captured and the kind of water distribution system for the farmers communities of Quilcas, Colpar and Llacta.

2 The possibilities of increasing the soil organic matter content should be studied for the soils in the lower and intermediate zones. Local higher biomass production seems to be the most efficient way. However, especially in the low zone, shortage of soil moisture and low soil fertility are limiting such a higher bio-mass production.

3 An improved use of local available organic fertilizer types (*guano organico, guano de corral, estiércol, compos, humus, turva*) should be evaluated with the farmers.

4 The high zone of Quilcas, at present increasingly used for arable land, should be reserved for natural pasture land. The growing of potatoes should be reduced in order to prevent the degradation of the land by water erosion and soil mining.

5 In large parts of the pilot areas, anti-erosion measures are an obligation for the insufficiently protected agricultural fields. A (re)introduction of proven 'traditional' techniques should be maximally supported by governmental and non-governmental programmes.

6 More quantitative information should be collected on the history, causes, the degree of the eroded surfaces and present day erosion in the agricultural fields, in order to make projections for presently cultivated endangered land. Such information can be collected by systematizing oral information of the farmers ('back-tracking'), in addition with a

correlation of the 1961 air-photos with recently taken satellite images and field observations during the rainy season.

7 In the Quilcas pilot area the elimination of the machinery-induced hard pan at shallow depth in the subsoil of the Quilcas soils by biological techniques should be studied in a series of farmer experiments.

8 Quantitative monitoring of agricultural production is needed. Farmers should be assisted to introduce easy ways of quantifying the productivity of their lands by measuring annually the yield of small areas.

9 Agro-statistics discussed indicate the dominant influence of market prices on land use. An agro-economic study is needed to verify the economic feasibility of the above mentioned recommendations and to develop future economic strategies. The latter should include recommendations on promising (new) crops, such as for example the artichoke (*alcachofe*), but also on improved marketing and transport alternatives.

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Valencia R.M. and S. Kauffman (1996b). Caracterization y evaluacion de los suelos de la zona piloto de ILEIA: Quilcas - Nahuinpuquio. Universidad Nacional Agraria de la Molina, Peru.

Annex 1 - Correlation between the local soil name, the FAO-Unesco Revised Legend (1988), and the Soil Taxonomy (Soil Survey Staff, 1994) for the San Marcos pilot area.

Soil name	FAO-Unesco (1988)	Soil Taxonomy (1994)
Penipampa	Dystric Fluvisol	(...?) Ustifluvent
Ideas	Eutric Leptosol (Regosol)	Lithic Ustorthent
Huayanay	Rendzic Leptosol (calcaric Cambisol)	Lithic Ustorthent
San Nicolas	Calcaric Phaeozem	Entic Haplustoll
Ullillin	Gleyic Phaeozem (Mollic Gleysol)	Aquic Ustochrept (>Udochrept)
Poroporo	Dystric Cambisol	Typic Ustochrept
El Cruce	Cambic Arenosol	Typic Ustipsamment
Alimarca	Humic Alisol	(Ultisol)

Annex 2 - Correlation between the local soil name, the FAO-Unesco Revised Legend (1988), and the 1994 Soil Taxonomy (Soil Survey Staff, 1994) for the Quilcas pilot area.

Soil name	FAO-Unesco (1988)	Soil Taxonomy (1994)
Quilcas	Eutric Fluvisol	Typic Ustifluvent
Colpar	Dystric Cambisol	Fluventic Ustochrept
Andamarca	Dystric Cambisol	Typic Ustochrept
Shuhuanca	Dystric Regosol	Lithic Ustortent
Calaloma	Dystric Cambisol (Regosol)	(lithic) Ustorthent
Rangra	Dystric Cambisol	Typic Ustochrept
Rachacpata	Humic Alisol	Typic (Haplumbrept) bordering to Ultisol
Nahuinpuquio	Dystric Cambisol	Lithic Ustochrept

Annex 3 - Local names of soils and soil management (provisional)

The following list the various local names in Quechua and Spanish mentioned by the farmers during the fieldwork and the corresponding English equivalent.

San Marcos pilot area

SOIL CONSERVATION

Local	**English**
Pirca	stone wall on the contourline
Andenes	man-made terraces

SOILS

Mitoso	clay soil
Shilloso	gravelly soil

PHYSIOGRAPHIC UNITS

Huayllas	grazing land in the high altitude zone
Playa	lowest, more level part in steep valley

Quilcas pilot area

SOILS

Local	**Spanish**	**English**
Allpa	tierra	earth/soil
Anta*)	suelos colorados	coloured soil
Puka	suelos roja	reddish soil
Greda	suelos blancas	white or light grey soil
Yula	tierra blanca	white soil
Cascajo	pedrogoso	stony soil
Latigoso	arciloso resbaloso	slippery clay when wet, very hard when dry
Gredoso	arciloso	clay soil
Shali/srala	cascajal	gravelly land

*) The term anta was frequently mentioned. Although the 'suelos colorados' literally refers to colour, according to the farmers of the low zones, it factually refers to a combination of texture and consistency, indicating a clayey soil which hardens when dry and becomes a clay past when wet. The soil colour of the 'suelos colorados' includes a rather large range of colours, from yellowish red to reddish brown.

LAND PREPARATION

Local	**Spanish**	**English**
Polón	tierra bien descansado	soil after a long fallow period, ready for new crops
Ticpa	siembra con labranza minima	sowing with minimum tillage
Chaquitaclla (or taclla)		foot-plough
Waru-Waru	camellones y surcos	(broad)ridges and furrows

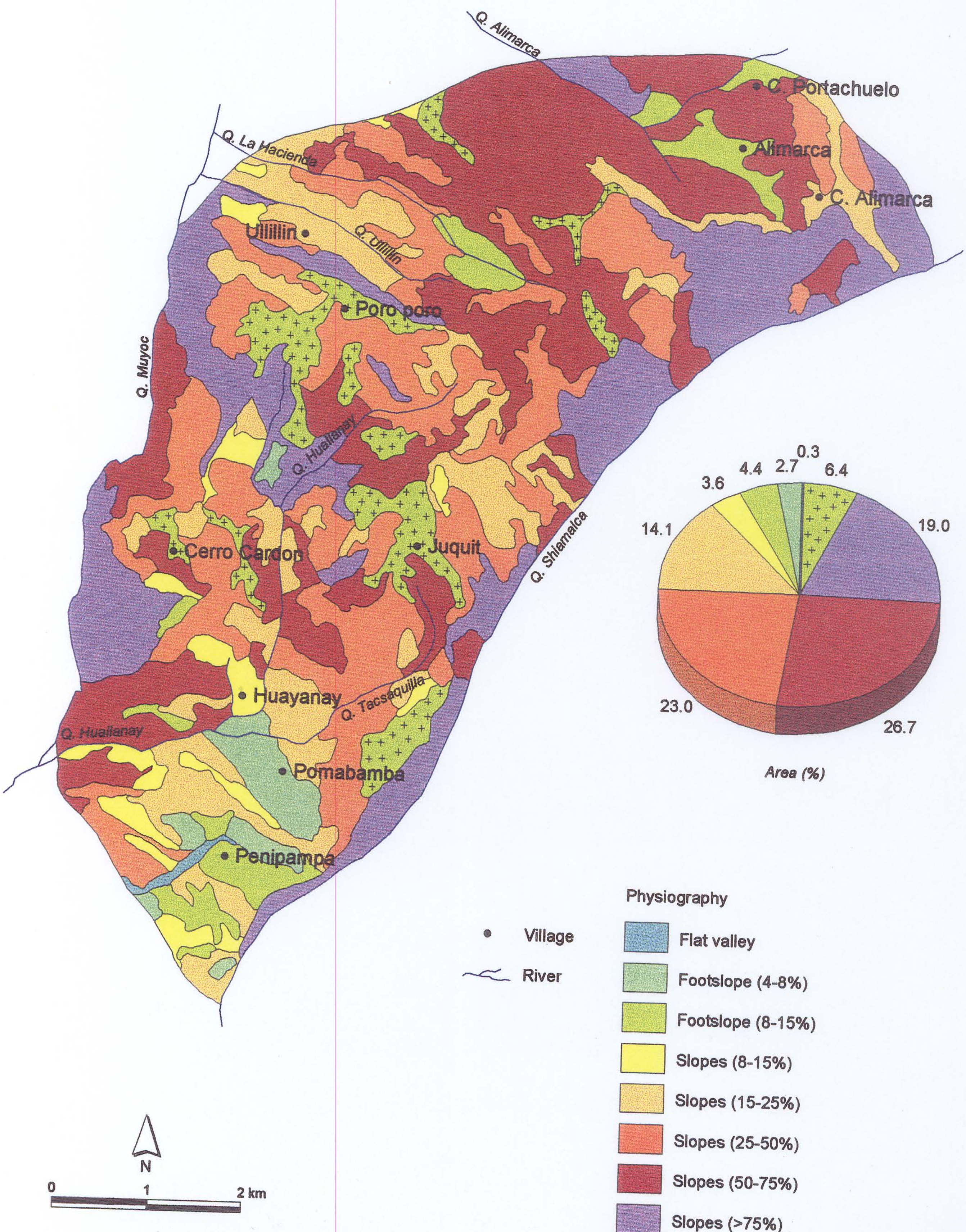
SOIL CONSERVATION

Pirca		stone wall on the contourline
Andenes		man made terraces

TOPOGRAPHY

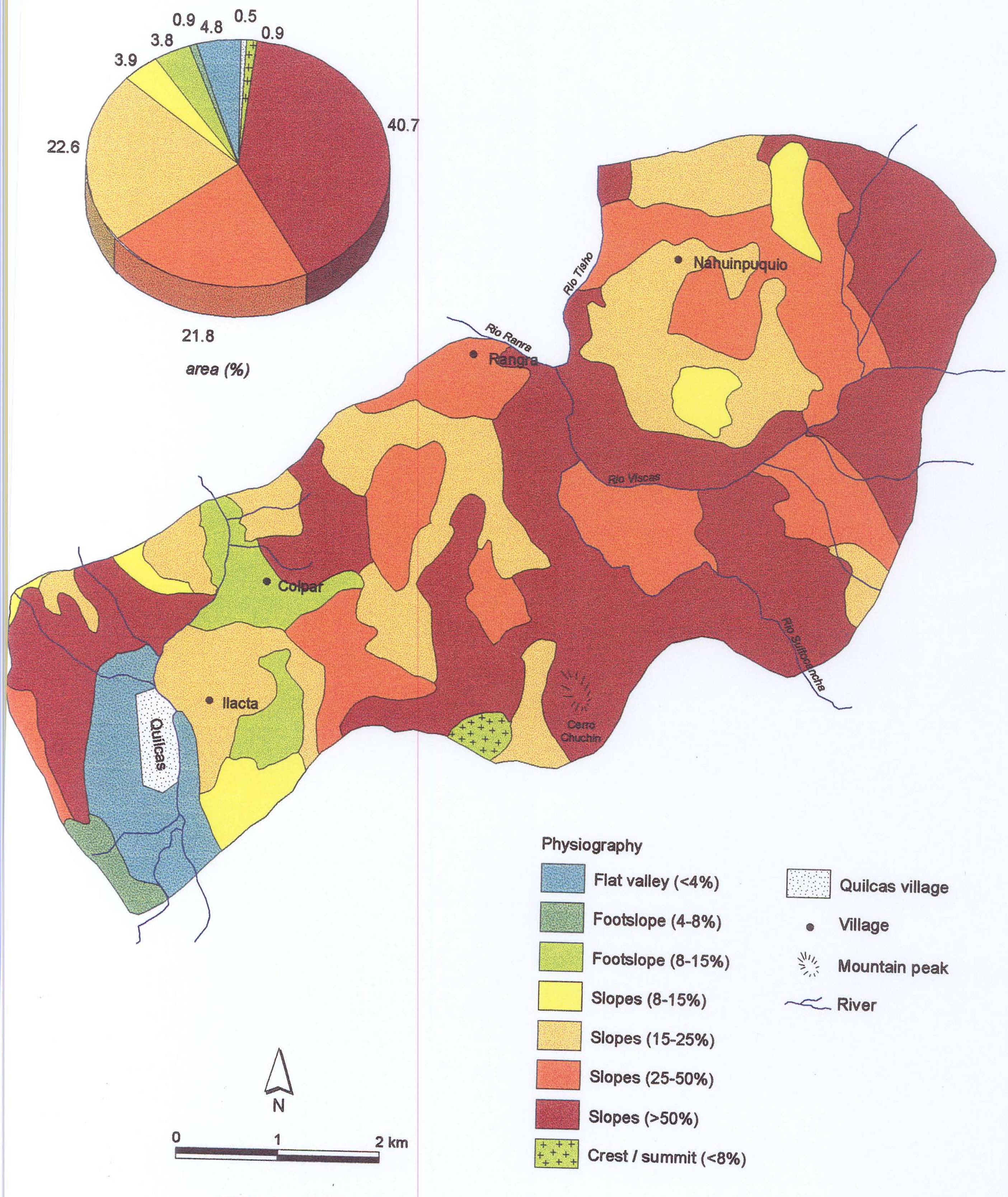
Cancha	campo de pastoreio	pasture
Nahuipuquio	ojo de agua	lake (lit. eye of water)
Quilcas	chilcas	(medicinal plant)
Rangra	pedras/pedragal	stones/stony place
Rachac patac	Lomado de sapos	hill of the toads
Rimay	conversar	conversation
Shuito	largo	large
Tingo	junto de rios	meeting (of rivers)

MAP 1: PHYSIOGRAPHY OF SAN MARCOS PILOT AREA



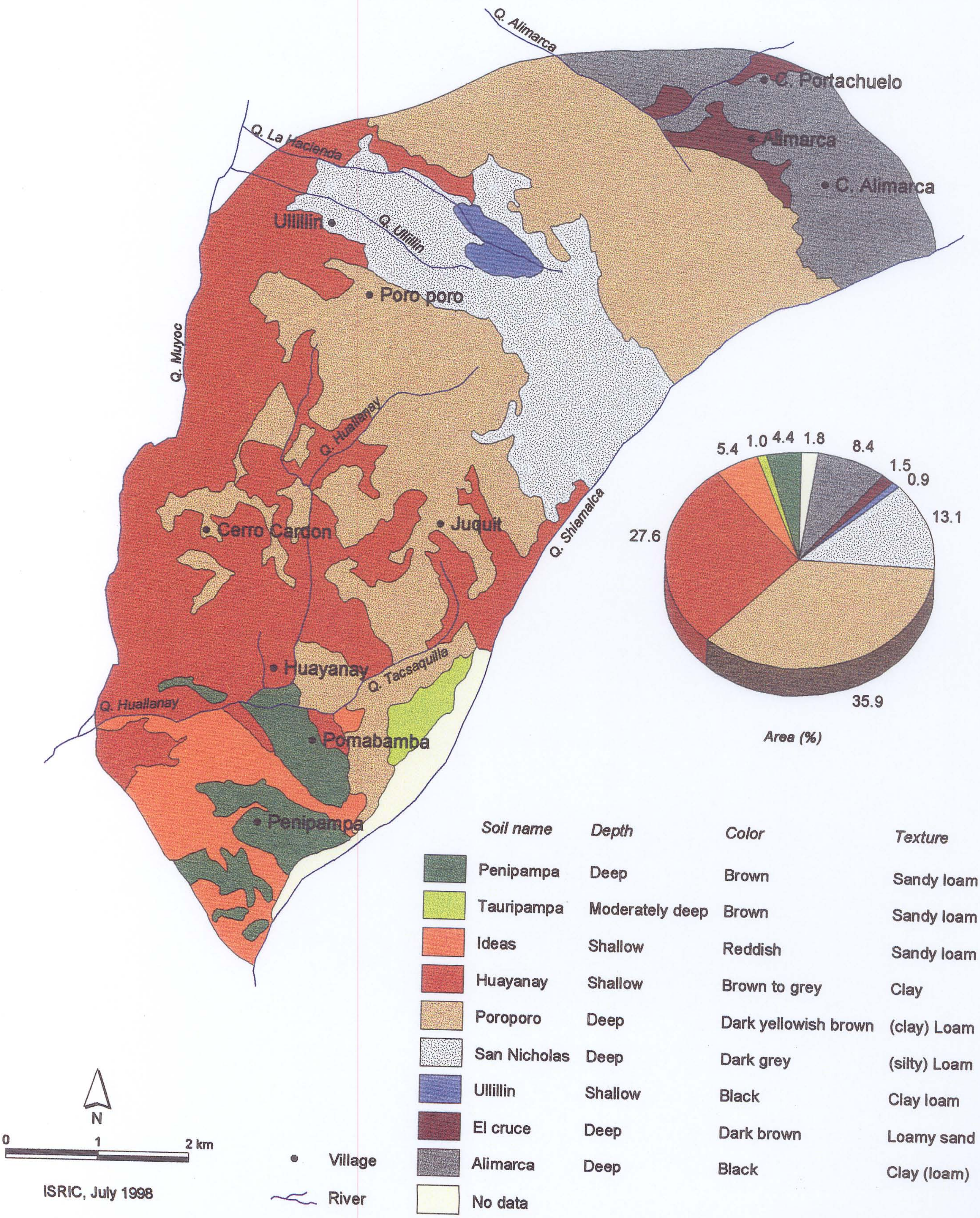
ISRIC, July 1998

MAP 2: PHYSIOGRAPHY OF QUILCAS PILOT AREA



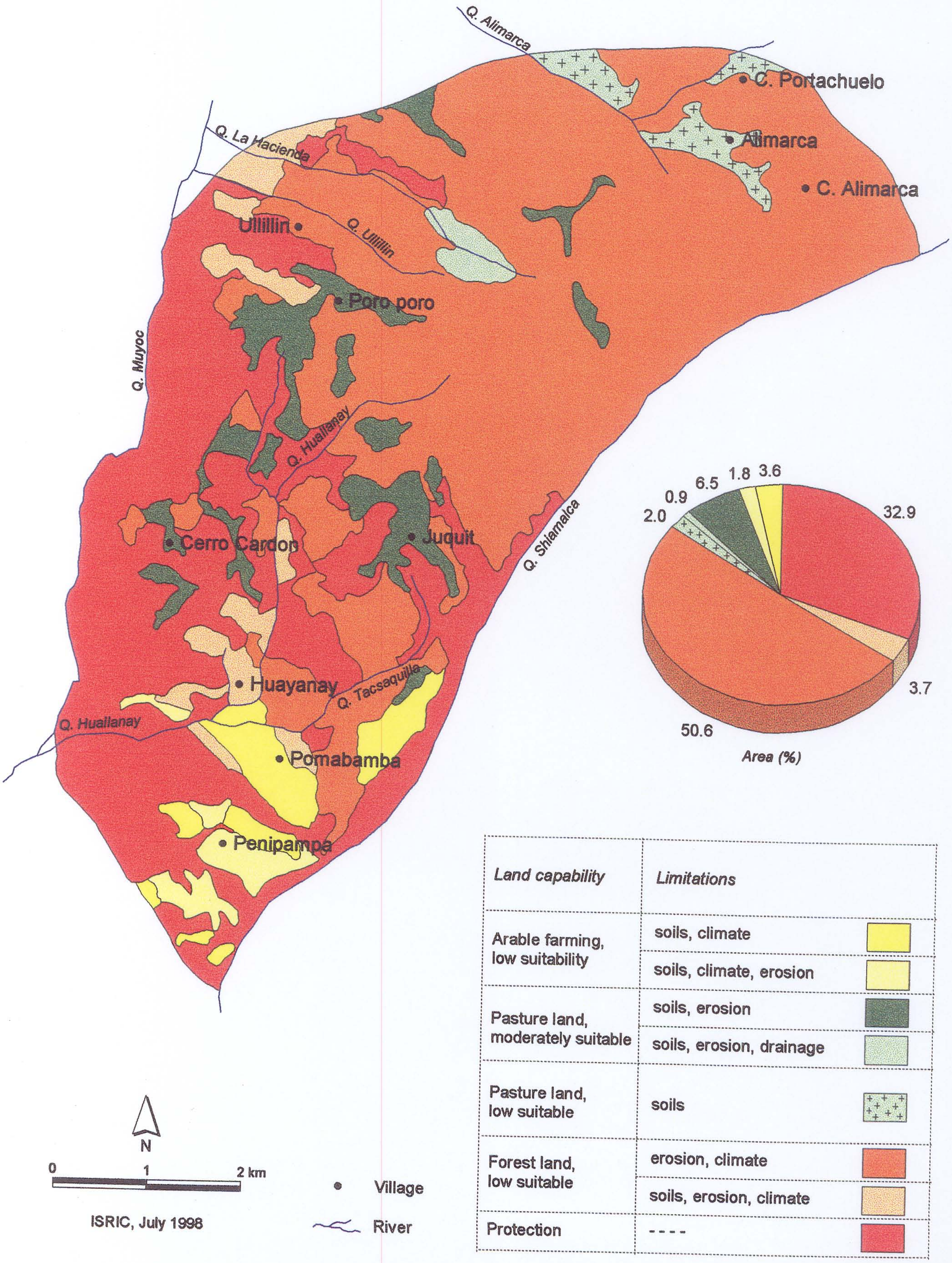
ISRIC, July 1998

MAP 3: SOILS OF SAN MARCOS PILOT AREA

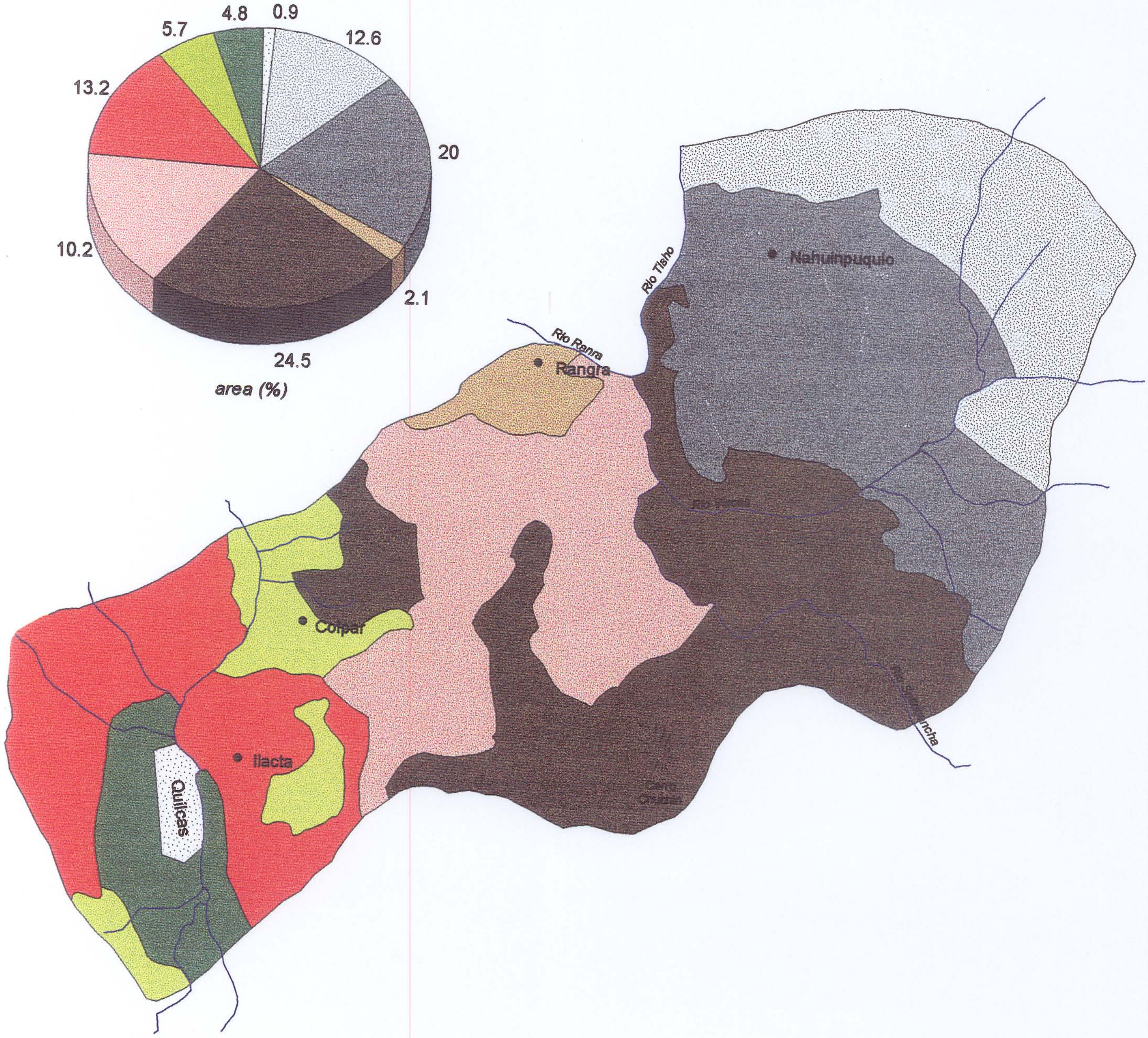


ISRIC, July 1998

MAP 4: LAND CAPABILITY OF SAN MARCOS PILOT AREA



MAP 5: SOILS OF QUILCAS PILOT AREA



Soil name	Depth	Color	Texture
Quilcas	Deep	Yellowish brown	(clay) Loam
Colpar	Deep	Brown	Clay loam
Andamarca	Deep	Reddish brown	(clay) Loam
Shuhuanca	Shallow	Dark brown	Sandy loam
Calaloma	Moderately deep	Brown/grey	Gravelly loam
Rangra	Shallow	Yellowish brown	Gravelly loam
Rachacpata	Deep	Dark brown (black topsoil)	Loam
Nahuinpuquio	Shallow	Brown	Loam

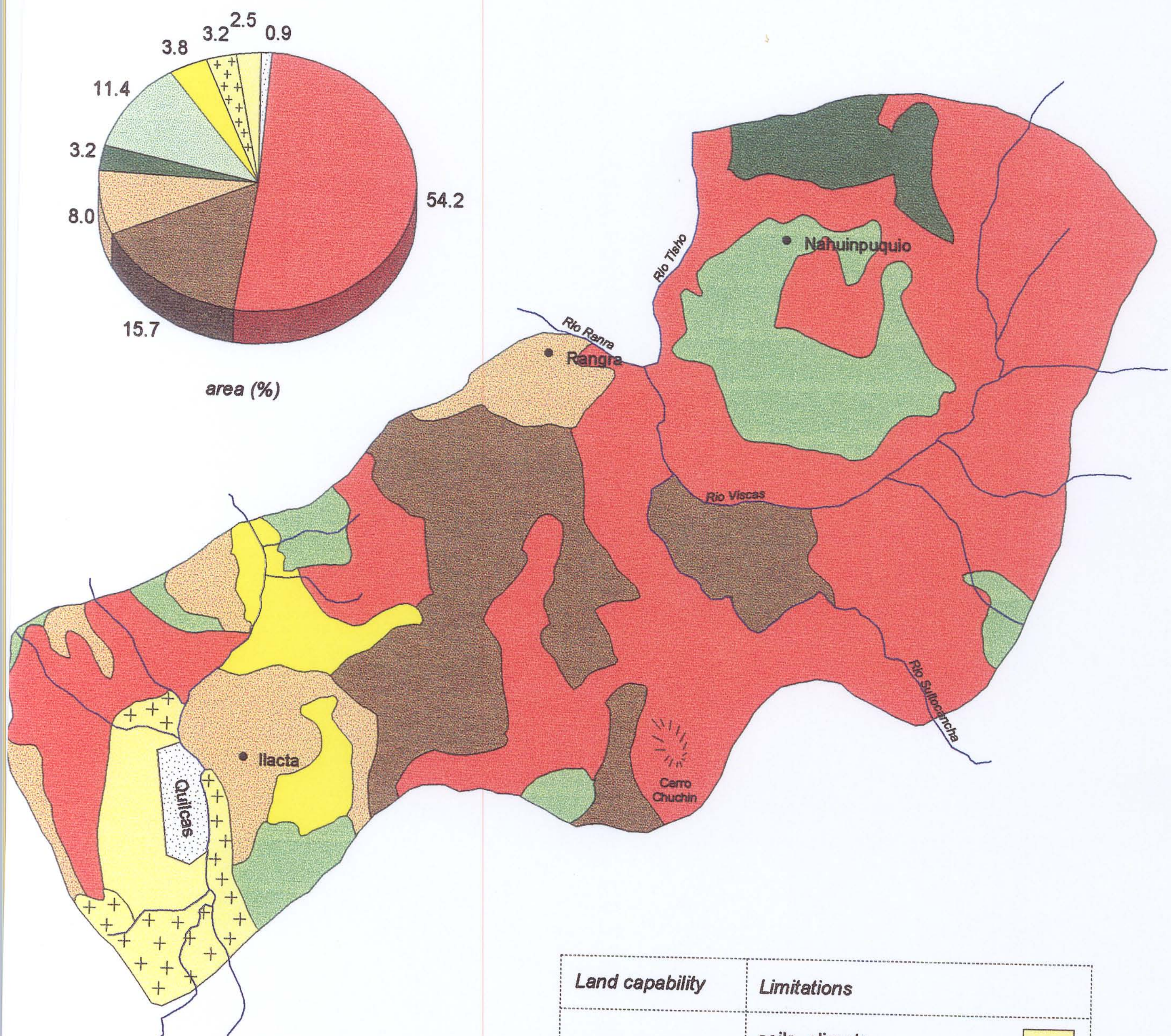
Quilcas village
Village
Mountain peak
River

N

0 1 2 km

ISRIC, July 1998

MAP 6: LAND CAPABILITY OF QUILCAS PILOT AREA



Land capability	Limitations	
Arable farming, moderate suitability	soils, climate	
	soils, climate, erosion	
Arable farming, low suitability	soils, climate, erosion	
Pasture land, moderate suitability	soils, climate	
Pasture land, low suitability	soils, climate	
Forest land, low suitable	erosion, climate	
	soils, erosion, climate	
Protection	- - - -	

N

0 1 2 km

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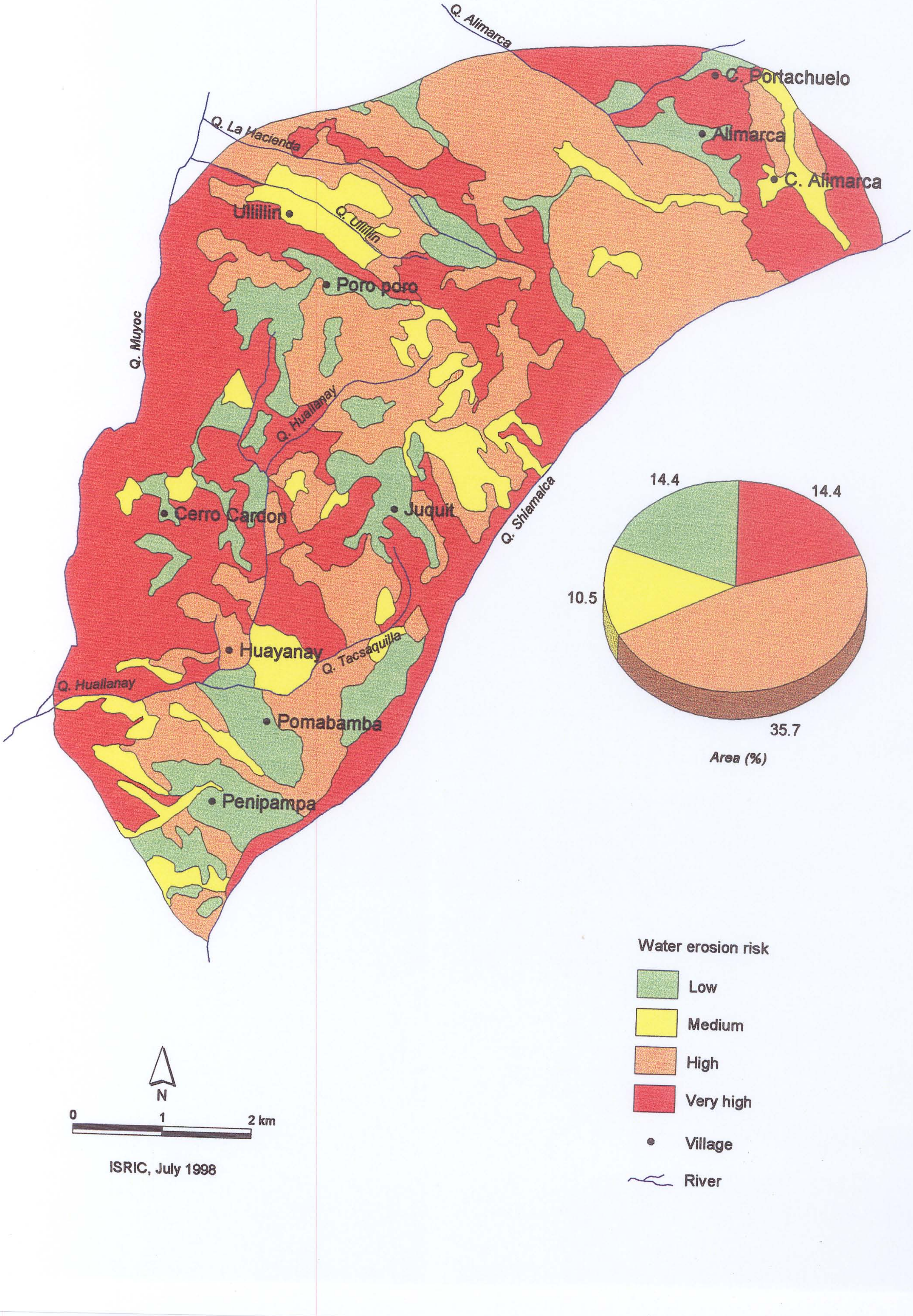
Quilcas village

Village

Mountain peak

River

MAP 7: WATER EROSION RISK OF SAN MARCOS PILOT AREA



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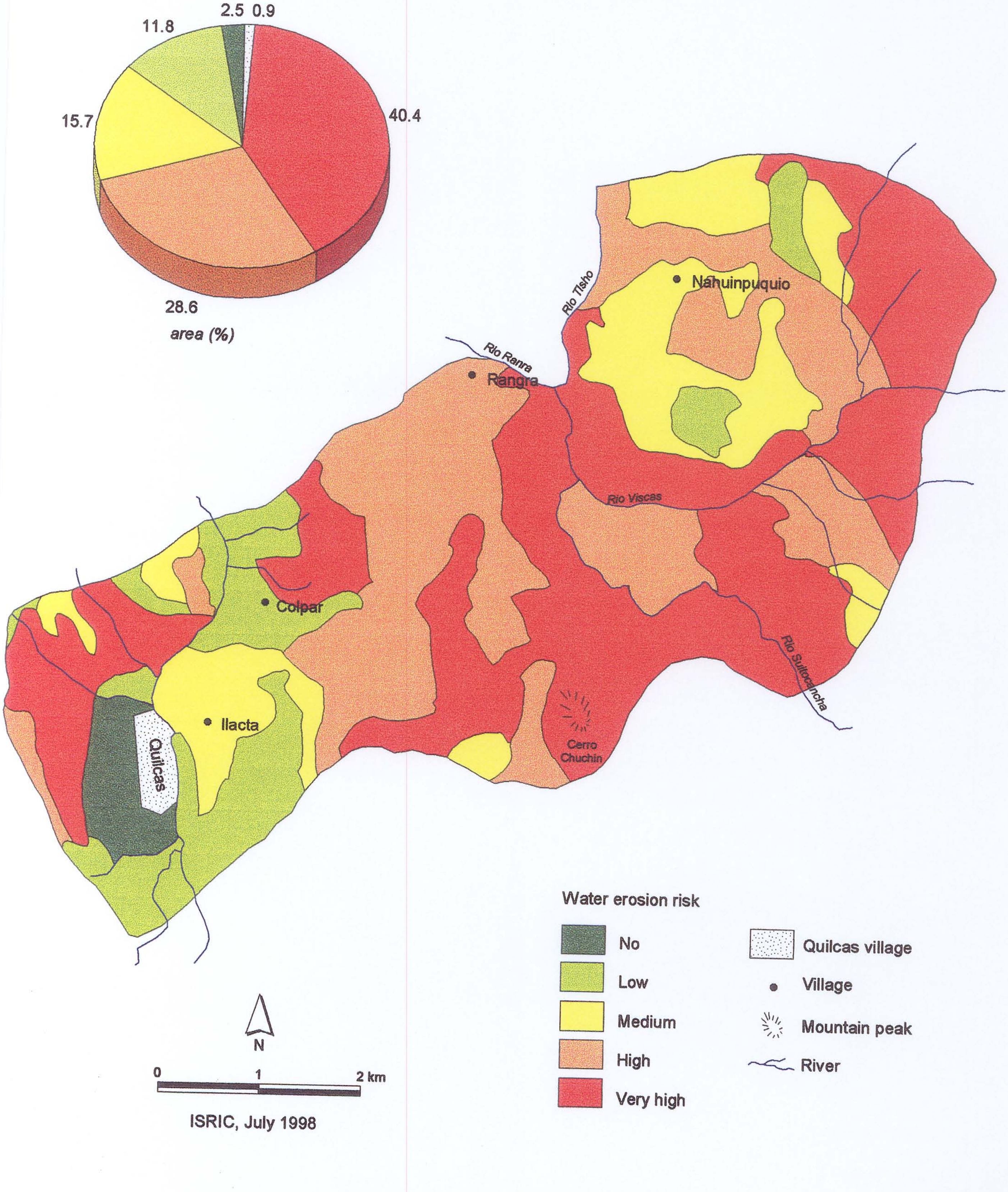
MAP 8: WATER EROSION RISK OF QUILCAS PILOT AREA



ISRIC, July 1998