DFID Natural Resources Systems Programme

R7584 Community-led tools for enhancing production and resource conservation

The collection and application of local soils knowledge in southern Bolivia

Technical report

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August 2001

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Summary

This report evaluates soil conditions in the communities of Juntas, Tojo and Chorcoya Avilés in southwest Tarija, southern Bolivia, from the point of view of local people. It determines local knowledge about the different categories of soil or 'land', their preferred uses and the way that the different soils are managed by the inhabitants. People classify soils by way of colour, texture, consistency, topography, soil water conditions and best use. Farmer-conceived soil classifications were established in each community. Soils knowledge varies from household to household, and those who know most have been identified as potential communicators of soils knowledge within the communities. Local people recognise that soil and water can and does carry away earth from their plots, but do not consider soil erosion as a significant constraint affecting production. Whilst there are areas where people have noticed that soil fertility has reduced or 'the earth has become tired' as a result of intensive production, there are also areas where people have perceived improvements in soil quality resulting from application of manure and river sedimentation during floods, particularly in Juntas and Tojo. Areas where soils are under-utilised were identified by local people and technical staff, and adjustments in use suggested – in Chorcoya there is an area of fertile soils formed on recent fluviolacustrine deposits with potential for more cultivation, in Tojo and Juntas there are fluvial soils with the potential for growing trees and producing crops. Soil analyses highlighted low levels of organic matter in most of the cultivated soils. Techniques to raise soil organic matter were identified for discussion in community meetings: better gathering and application of manure, composting, green manuring with local and introduced species.

Resúmen

Este informe evalúa las condiciones del suelo de las comunidades de Juntas, Tojo y Chorcoya Avilés (Tarija) en términos del lenguaje de los pobladores locales, y en términos técnicos. Establece los conocimientos locales de la gente sobre las categorías de 'tierra', y la relación de estas tierras con los usos más adecuados o preferidos, y las formas de manejar las tierras diferentes. La gente clasifica las tierras a base de color, textura, consistencia, topografía y condiciones de agua, y siempre en relación a su uso preferido. Los conocimientos varia de hogar a hogar: se ha reconocido los más expertos para poder comunicar sus conocimientos a los demás en forma comunal. Los agricultores reconocen que el agua y el viento pueden llevar tierra de sus terrenos, pero no reconocen la erosión del suelo como un problema significativo, tanto como otros problemas de la producción (fertilidad y condiciones de agua). La gente percibe que hay lugares donde el suelo ha bajado de calidad, pero también que ha mejorado con el tiempo con la introducción de abono orgánico y sedimentos de los ríos en Juntas y Tojo. Las áreas donde los suelos son infrautilizados fueron identificados y usos alternativos sugeridos – en Chorcoya una zona de suelos buenos en la planicie tiene potencial para la producción, en Tojo y Juntas hay suelos al lecho de los ríos con potencial de reclamar par uso forestal y otros cultivos. Los análisis de suelo identificaron niveles bajos de materia orgánica en casi todos los suelos más usados. Técnicas de enmienda con abono animal, vegetal (compost) y abono verde fueron identificados para iniciar debate sobre el tema en las comunidades.

Glossary of commonly used local soil types and soil/land descriptors

arcilla, arcillosa	clay, clayey
arena, arenosa	sand, sandy
barrial	mire, muddy
caliche	saltpetre, nitre
chacaguano	ant manure
greda, gredosa	clay, clayey
ladera	slope
laja, lajosa	flat-stone (sandstone, shales)
limo, limosa	silt, silty
o'kee	yellowish river sediment
pedregosa	stony
ripio, ripiosa	rubble, rubbly, large pebbles
terraza	terrace
terreno flaco	unproductive land, shallow soils
tierra amarilla, medio amarilla	yellow earth, yellowish earth
tierra blanca	white earth
tierra blanda	soft earth
tierra cascajosa, calicante	gritty earth, stony
tierra castaña	chestnut brown earth
tierra cienegosa	marshland, poorly drained soil
tierra colorada	red earth
tierra de humedad	moisture retaining earth
tierra débil	weak earth, erodible, unproductive
tierra desnuda	eroded earth
tierra liviana	light earth (sandy)
tierra marrona	brown earth
tierra negra, negrusca	black earth, blackish
tierra pegajosa	sticky earth
tierra roja, rojisa	red earth, reddish
tierra salitrosa	salty earth, saltpetre
tierra suave	soft earth, friable
tierra suelta	loose earth, friable
tierrosa	loamy
vallo	reddish river sediment

1. Introduction

The term Ethnopedology was coined by anthropologists. It was used in 1981 in a study of Middle American folk soil taxonomy (Williams and Ortiz Solorio) to denote broad study of local soils knowledge, including folk classifications, perceptions of properties and processes, local soil management, perceptions of soil and plant relations, and links between local and scientific soils knowledge. The work followed earlier anthropological work, largely based on local plant taxonomies (Berlin et al. 1973), though there were isolated early studies that recognized the importance of people's land classifications as a means to better understand local soils (e.g. Conklin 1957).

Since this early work, many studies (largely by anthropologists and geographers) have recognised local soil classes, based on colour, mineralogy, texture, vegetation associations, susceptibility to wind erosion, drainage water colour etc. (Netting 1968, Chambers 1969, Weinstock 1977, Nations and Nigh 1980, Chambers et al. 1991, Tabor 1992, Fairbairn 1993, Sandor & Furbee 1996). Soil scientists have researched ethnopedology infrequently, more recently using local soil knowledge to guide soil surveys (Acres 1984, Tabor 1993). It is probable that the increased use of interdisciplinary teams in research and development has opened the soil scientists' eye to insights that may be obtained by using the alternative approaches of anthropologists, geographers and other social scientists, though the process is a slow one.

Although there is clearly a growing interest in local knowledge, with the emergence of international information centres such as CIKARD (Centre for Indigenous Knowledge for Agriculture and Rural Development) and the Indigenous Knowledge and Development Monitor. Commentators have noticed a reluctance to incorporate local soils knowledge in the actual process of rural research and development (Reij 1991). In addition, comparatively more ethnopedology work has been done in Africa and South East Asia than in Latin America. The result is that technical soil staff who take account of local soil knowledge are still a rarity in research and development projects in Latin America.

What are the advantages of local soil knowledge for research and development initiatives? Chambers (1983) highlighted the complementarity in strengths and weaknesses of local and scientific knowledge for development work in general terms. Local soils knowledge is no exception and has good potential for complementing the technical knowledge of agronomists and soil scientists. The technician can precisely measure soil physical and chemical characteristics, whilst local people have detailed mental maps of soil characteristics in the context of their farm activities and land, especially soil management perspectives and the distribution and uses of different soils. The local information has the advantage of being pertinent to the local social and cultural conditions and contrasts with scientific knowledges, which tend to search for global and generic solutions. In the last fifteen years or so interest in the value of local knowledge has increased, largely based on the perception that the modernization of agriculture techniques has not been particularly effective in reducing poverty in developing countries (Briggs et *al*. 1998), and a parallel belief that land users ought to be more involved in research and development (Critchley 1999). Science and technology has seemed unable to significantly raise living standards for most people in these countries (Blaikie and Brookfield 1987).

In the case of soil science, Sillitoe (1998) goes as far as to say that soil and land surveys have had very little impact on development and almost no impact on subsistence farmers. This is not surprising considering that technical reports and studies have been directed exclusively at planners, administrators and politicians, and are therefore presented in a technical language inappropriate for use at the local level. Reports may not even be produced in the language spoken by local professionals[1].

In soils research, a main blockage in information flow between local people and technical people is jargon (Jones et al 1994). There is a need to establish a common language between technical and local people, based on local terms and phrases, enriched (with time) with useful technical terms and concepts which can improve, not replace, local knowledge. Tabor (1993), a soil scientist, also points out that interviewing farmers and herders can help us to (1) rapidly identify which soils are important to the farmer, (2) determine the relative productivity and value of each soil and their value to agriculture, and (3) locate typical soils of each type and correlate them to other systems both scientific and indigenous.

Soil quality is fundamental in determining crop production levels and the growth of the natural vegetation, especially in areas with severe climatic conditions, where agriculture and livestock rearing are at risk from drought and other environmental hazards (Fairbairn 2000). The management of the soil by the local population determines how effectively and sustainably soils are used. This, in turn, is determined by local people's own accumulated knowledge about soil types, characteristics and optimal uses.

The work presented here aims to identify this local soil knowledge, and use it to initiate debate among local people about beneficial adjustments to soil management in the communities. It also aims to promote debate among local technical professionals, non-government organisations and municipal authorities concerning the value of local knowledge systems in the process of development. It adds to the slow growing body of case studies in Latin America, and the need, identified by Bebbington & Bebbington (2001), for closer engagement of research with the dilemmas encountered in practical attempts to pursue development alternatives.

2. The study area

The study area in southern Bolivia is in the south-west of the Department of Tarija, including the communities of Juntas (mesothermic valley), Chorcoya Avilés (Tarijan altiplano) and Tojo (dry valley associated with the River San Juan del Oro). The different environmental characteristics of the high puna (3,600-4,800m) and the interandean valleys (1,800-3,600m) strongly influence the livelihood strategies of the local people.

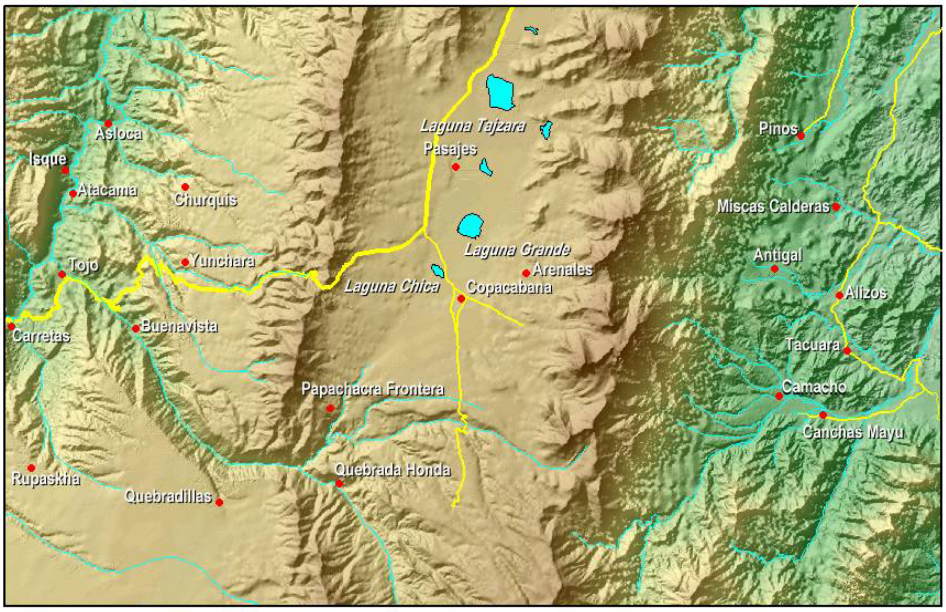
In Juntas local people partly depend on crop production for food and income and maize and potatoes are the most important crops. Fruit trees are also common in the valleys and most households have some peach and quince trees. Vines are grown in the lower part of the valley, producing grapes and wine for home consumption, for sale to local markets and for the production of *singani*. Livestock are important to nearly all households, most having some cows, sheep or goats. Those who have more than 6-10 cows take their animals south eastwards to distant pastures on better-watered low mountain slopes during the dry season (Preston & Punch 1996).

On the Tarija altiplano, poor soils predominate and frosts, drought and variable rainfall limit what can be grown. Households in the communities depend on small

[1]For equivalent technical report in Spanish see Fairbairn & Morales (2000), available on website www.geog.leeds.ac.uk/research/andes/fragenv.htm

cultivated plots for their own consumption and for the exchange of highland crops for fruit and maize from the valleys. The principal crops are potatoes and broad beans, and some households grow garlic for external markets. Most of the land, however, is used for rough grazing of natural pastureland, and sheep are vital for most households, for both meat and wool. Some households also have some cattle, which graze the higher pastures on the slopes behind the houses.

Figure 1. The study area in SW Tarija – main project communities circled



Around Tojo, in the catchment of the River San Juan del Oro, the climate is warmer allowing a larger range of crops to be grown - maize, fruit such as quinces, peaches, figs and grapes, forage crops such as alfalfa, and vegetables such as onions, cabbage, tomatoes, squash and carrots. The valleys are typically narrow and deep, so that the communities are widely separated and riverside plots are sometimes far from the houses of those who cultivate them. Most households have some animals, from 10 to 40 sheep and goats. Livestock management practices vary from family to family. Sheep either stay in pens all year round eating forage crops (alfalfa), or they are taken to the richer pasture of the *pampa* to the south, cared for by shepherds in the communities of Peloj or Rupashka.

Parts of this paper draw on previous reports that contain more detail about rural livelihoods (Preston & Punch 1996, Fairbairn 1999), vegetation (Beck et al. 1999) and grazing (Fairbairn et al. 2000) in the study area.

3. Previous soils work in the study area

Various technical soils studies have been carried out in the study area, largely descriptive and employing the FAO and USDA soil classification systems. Galarza Castillo (1997) classified and mapped the soils of the Tarija altiplano at a general scale. The study generated useful technical data, and classified the soils as Typic and Lithic Calciorthids – Aridosols, dry for most of the year, which have a layer of secondary accumulation of calcium carbonate and neutral to slightly alkaline pHs. The work has not been utilised for the development of the area, but provides some useful baseline data. A study completed in 2001 by ZONISIG mapped the soils of the Department of Tarija at the general scale of 1:250,000, accompanied by a computerized database of soil profile and site information (Appendix 5), although it is unclear whether this database will be maintained, and what the degree of access of development projects or communities to the data will be. Beyond descriptive studies, the plant-soil relationships in some agricultural soils have been investigated (Salm 1996), as well as the impacts of land management on soil stability (Cerdá 1995). Barring Salm's study, which considers the management of individual farmers' fields by way of a combination of interviews and sampling, there are no studies in the area which consider the soils knowledge of local people. A study in Santa Cruz (Lawrence 1997) looks at what local people know about soil and water management in order to shed light on the opinion prevalent among development professionals that 'farmers have done nothing to prevent soil erosion'. The study shows that the local population do possess detailed knowledge about types, best uses, fertility and management of soils and employ locally generated soil conservation practices. Although logically the depth of soils knowledge will vary from place to place, it is likely that there is similar knowledge in the study area.

4. Methods

In contrast to other local knowledge work, there is almost no published work on ethnopedological methods, which straddle the disciplines of anthropology, geography and soil science, and techniques tend to reflect the researchers' background. Two of the major ethnopedological studies carried out in Latin America, in Mexico (Williams & Ortiz Solorio 1981) and Peru (Sandor & Furbee 1996), have employed an anthropologist and a soil scientist, using sampling and analytical techniques from soil science and social enquiry techniques from anthropology. Many of the recent studies of local soils knowledge have borrowed rural development methods arising from paradigms such as Farmer First (Chambers et al. 1989), including interviewing, group meetings, diagramming and transects with local people (Conway 1989, 77). In one of the few articles concerning local soil knowledge methods, Birmingham (1998) highlights the need for methods which are flexible, responsive and creative, so that they can be adapted to cultural preferences and village priorities, enabling researchers to make optimal use of the available time. A combination of individual and semi-structured interviews was found to be most effective in the Ivory Coast study, and the best information was gathered when observing the soils in situ with local people and participating in soil management with farmers (ibid.)

In this study a combination of three methods was used: informal interviews with local people, group work in community workshops and transects accompanied by community experts. In the case of Juntas the experts were a group of youngsters who accompanied us on a reconnaissance of the soils of the community. In Tojo those who cultivate each holding explained what they knew about the soils in their plots, as we made a transect of the community, combined with other project activities (pruning practice). In Chorcoya Avilés three local adult experts (one with a detailed knowledge of each ecological micro-area) accompanied us on a soils evaluation, and it was possible to construct a map of locally named soils together with local people. Where possible the local experts drew the boundaries between the different soil types. A farmer-conceived classification system of local soils was constructed in each community.

Soil samples (0-15cm) were taken to represent the local soils identified in the first phase of the work, and were analysed to determine their physical and chemical characteristics (21 samples in Tojo, 13 samples in Chorcoya, and data from the Salm (1996) study in Juntas – see Appendices 2-4). These data allowed local soil type characteristics to be determined for communication back to local people. Based on the data collected, areas with potential for modification in soil management were identified.

5. Local perception of soil characteristics and management

Local people often consider soils, crops and livestock together in their discussions, since these are integrated strands of their livelihoods. They recognise that soils play an integrated part of their activities and often refer to soils (earth) in terms of their characteristics related to plants – crops, trees and pasture. This study also shows that people are aware of changes in soil productivity. In contrast to observations in Santa Cruz (Lawrence 1997), where local people noticed decreasing soil productivity due to 'the tiredness of the earth', in Tarija people also noticed improvements in soil productivity over time.

People distinguished different soil types, classified by texture, structure, stoniness, soil water conditions and suitability for different uses, based on direct experiences and collected knowledge over generations. In the three communities, in general terms, the least fertile and shallowest soils are used for grazing, mainly on slopes; soils on the footslopes are slightly deeper and are used for rainfed crops, in places irrigated with water from seasonal streams; bottomland riverside soils are used for irrigated crops and fruit trees. The soils of the high plains are used for grazing sheep, llamas and donkeys.

Juntas

Juntas is located in a zone of transition between the semiarid climate of the Central Valley of Tarija and a more humid area in the higher part of the watershed, and also has a broad range of physiographic units (Salm 1996). Soil conditions therefore vary greatly within a fairly small area. Local people identified yellow earths (*tierras amarillas*); black earths (*tierras negras*); brown earths (*tierras marronas* or *castañas*), understood to be a fortunate mixture of yellow and black earths, and on the slopes, white earths (*tierras blancas*) and flat-stone earths (*lajas, lajosas*) (Table 1). Yellow earths are found on slopes, terraces and bottomland in the western part of the community and black earths on the bottomland to the east.

Soil types

Local soil types in Juntas are shown in Table 1 and in the neighbouring community of Barvascuyo in Table 2. Black earths are mainly clayey and produce potatoes, vegetables, fruit and irrigated maize. They are located in the eastern section of the community, in the bottomland to the north of the River Alizos, between the riverbank and the road. This is the most intensively farmed area, with access to irrigation water, relatively flat and easily accessible from the most populated area. The fine clayey texture of the black earths is seen both as an advantage and a disadvantage by local people. The black earths are fertile ('stronger' and more 'earthy' than the 'lighter' yellow earths), but some observe that 'when dry, the plough won't go in'. They require sufficient moisture, but 'with too much water they become muddy and you can't get onto the land'. Despite these difficulties, farmers cultivating these soils are able to produce a wide range of crops, and have the security of available water for irrigation. A perceived disadvantage of clayey soils for potato production is that the soil 'imposes on the potato', resisting free growth of the tuber particularly in dry years. After floods the clayey soils take longer to dry, which can result in crop damage. Pedro Aparicio notices that 'after the floods, you lose less potatoes in sandy soils'. There is a common perception that sandy soils are better for producing potatoes, since they are a more suitable medium for tuber growth and are better drained and less inclined to waterlogging following the common hazard of floods.

Farmers observe that the black earths become ‘lighter’ (less heavy) towards the slopes where the yellow earths begin. The yellow earths are the most heterogeneous group of soils, occurring on bottomland, terrace and sloping land.

Table 1: Locally conceived soil classes in Juntas, Tarija.

Soil type	Topography	Texture	Phases	Farmers' comments	Perceived best use
Yellow earth, yellowish earth	Slope	Sandy	Stony	• Maize grows beautifully on the yellow earth. It's the best for maize • Yellow earth with stones conserves more moisture. Where there are no stones you get great clods on the surface when you plough • Earth with small stones is looser and easier to prepare • On dryland fields, maize helps to conserve moisture, because it throws more shadow than other crops • Clayey earth is best for making adobe • The clayey earth is hard to manage. When it rains, it grabs the moisture, gets sticky and doesn't dry. When it doesn't rain it's hard and compact • Even when it rains a lot you can always plough the sandy earth. It wets quickly and you can sow earlier, but it dries more quickly too. • Sandy earth is better for tatties, because it's not as stiff as the clay (it doesn't 'impose itself' on the potato) • The earth further down near the river is weaker – the river's higher, there's more water and the plants get more plagued • Maize grows more quickly on the dryland slopes than on the flat irrigated land – there's more height, more air and less frost……that is, when it rains • The terrace earths are soft and easy to manage – they have less rubbly stone than the irrigated riverbank earths	Dryland maize, grazing
			Not stony		Irrigated wheat and potatoes
		Silty	Stony		
			Not stony		
		Clayey 'Earth'	Stony		
			Not stony		
	Terrace, flatland	Sandy	Stony		
			Not stony		
		Silty	Stony		
			Not stony		
		Clayey, 'earth'	Stony		
			Not stony		
	Riverbank '*banda*'	Sandy	Rubbly		
			Not rubbly		
		Silty	Rubbly		
			Not rubbly		
		Clayey, 'earth'	Rubbly		
			Not rubbly		
Red earth	Riverbank	Sandy	Not stony	• Red earth's better than the yellow – it comes from river deposits, it was the riverbank 100 years ago	Potatoes, maize
Chestnut earth	Flatland			• Good for grapes	Vines
Black earth	Riverbank			• Black clay isn't easy to cultivate, it needs a lot of manure. If it doesn't rain it's very hard, if it rains a lot it becomes mud and you can't get onto the land. In normal years it yields well • With irrigation it gives good yields, it's reliable	Potatoes, maize, irrigated vegetables
White earth	Slope	Soft		• We use it to whitewash our houses	
Flat-stone earth	Slope	Clayey	Stony	• Very little pasture, bare earth in places	Grazing, goats

Source: Survey, August 2000.

Table 2. Local soil classes in Barvascuyo, Tarija.

Soil type	Comments by informants
Yellow earth	Maize grows beautifully Good for building houses The best earth for maize
Black earth	Not very productive Good soil Found on the slopes
Clay, clayey earth	Not very good. If it rains a lot you can't prepare the earth If it doesn't rain it's very hard Not good for maize
Muddy earth	In a normal year for rain it yields well If it's dry you can't sow. If it rains a lot it becomes mud Hard – doesn't conserve the moisture
Sandy earth, sand	It needs more manure than other earths, but yields well Good earth In a dry year it doesn't do anything, with lots of rain the maize grows well It's found on the mid-height terraces
Loose earth	The best, easy to plough
Flat-stone earth	Earth on steep slopes

Source: Survey, July 1999.

Because of the variability, people classify the yellow earths according to their texture and topographic position (Table 1). The yellow earths are generally considered to be 'weaker' than the black soils, but are easier to cultivate and more suitable for dryland maize production on the slopes and high terraces 'they let you cultivate them – the first plough is deep and forms ridges, whilst the black doesn't break up – it's compact and hard' (Carlos, Juntas). The faster preparation of the dryland yellow soils appears advantageous, although farmers need to respond quickly to the first rains for ploughing, without access to irrigation water. They are 'fast' soils in many respects – they wet and dry quickly, and in a wet year farmers comment that maize matures more quickly than on the irrigated lowland black earths. Irrigation provides less risk, but farmers observe that in a wet year irrigated soils produce less. Other reasons given for better yields on dryland slopes in a wet year were the lower incidence of pests, disease and frost damage when compared to the bottomland, which is also at risk of flooding. Overall, despite the semiarid conditions and lack of irrigation, the well drained yellow soils on slopes or terraces are considered best for maize production. Work in Mexico (Fairbairn 1993) in a similar semiarid environment, showed that the less fertile soils (sandy and silty loams), manageable in both dry and wet years, were preferred to the more fertile clayey soils, which were difficult to manage in a particularly dry or wet year. The same is likely in Juntas – the less risky soils are considered best for dryland maize production, in conditions which vary significantly from year to year.

Stoniness

For a farmer using a tractor, stones are logically viewed as an impediment to land preparation. In the classic land capability classifications for agriculture (Bibby and Macknay 1969, Klingebiel and Montgomery 1961), the presence of stones is seen only as a limitation to agricultural land use. For the people of Juntas (and in another study area in Mexico – Fairbairn 1993) there are cases where the presence of stones is a distinct advantage. In the Mexican case, farmers regarded stones as good for retaining moisture and warming the soil. In Juntas, a similar semiarid region, people commented that stones maintain soil humidity, especially important in the dryland yellow soils. The inconvenience of ploughing among the stones appears less important that the loss of soil moisture which occurs when the stones are removed – 'the dryland soils for maize and other crops need stones to conserve the moisture' (Carlos, Juntas). Furthermore, in clayey soils, stones help to break up the large clods of earth when ploughing – 'where there are no stones, you lift up great clods' Señor Robles, Juntas.

Manure

Some farmers use chemical fertilisers (18:46:00 NPK) and organic manures, though on dryland soils farmers use only organic manures, collected from cattle, goats (considered the best), sheep and occasionally donkeys, though this is considered the 'weakest'. People clearly understand the value of organic manure for maintaining soil fertility and humidity. Where there are chickens their droppings are collected, and, in the vegetable plots, ant nest manure is traditionally used as a fertiliser. A group of youngsters explained how the ants come up and throw the manure outside the nest, which is gathered and placed between the onions in the vegetable plots. 'We mix it with earth because otherwise the *chacaguano* can burn the plants, it's so strong – you can't put it on any old plant'.

Most people bring manure from the livestock pens to the fields, though some employ moveable pens in the actual fields. 'We manure the fields, moving a livestock pen constructed from *churqui* branches every 20 days, until the whole field is manured. The earth here is as good as when I was a lad (50 years ago) – it yields well'. (Rene Mendoza Cardosa). In some cases there is only sufficient manure to cover half of the land one year, the remainder is manured the following year. Continued use of organic manures maintains nutrient levels and improves soil structure and soil moisture retention. Farmers perceive these change in practical terms – the earth becomes softer, easier to manage; without manure the earth doesn't give etc. Whether the interpretation is technical or local, maintaining the practice of adding large amounts of animal manure, and possessing livestock (or the means to obtain manure) is key if crop production and soil fertility are to be maintained in Juntas and other communities. Farmers themselves regard organic manure as superior to chemical fertilizers.

'The chemicals are pure fantasy – they weaken the soil, make it more compact and they don't last – they wash away, slip through' (Sr. Robles, Juntas).

Strategies that could best sustain soil productivity in the zone would involve the optimal capture and efficient incorporation of organic manures.

Some farmers in Juntas use green manures to improve soil structure and maintain soil moisture, but the practice is not common. The reasons for this appear to relate to the labour involved and the nature of the task – 'there is loads of green manure in Juntas, but it is a lot of work, it's costly to gather and it's dirty work' (Sr Robles, Juntas). In future debates on the possible benefits of green manure in the community it will be important to arrive at ways to reduce the work load. In addition, it is necessary to be aware of the perception in the community that the preparation of green manures, like compost, involves 'dirty work' and may initially be resisted.

Erosion

In other areas of Bolivia it was recognised that farmers perceive lack of water and the consequences of the lack of sufficient pasture as more important than the problems associated with soil erosion (Lawrence et al. 1997). Rural people are sensitized to those factors which have perceived direct effects on livestock and crops, in other words things which affect livelihood strategies from one year to the next, such as drought, frosts, pests and diseases. Soil erosion is perceived as less important, since it is a process rather than a particular event. This is not to say that farmers never think about erosion, especially when floods remove soils and land from riverbank fields. Some farmers do relate soil erosion to vegetation cover and identify a relationship between the level of organic material in the soil (the amount of manure applied) and soil stability.

'The earth is eroded because people remove trees, the earth dries and when it rains it takes the earth away. There is more erosion where the earth is soft, further downriver. Up here, where there is more rock, it doesn't erode so much. As long as I have known the land, the earth has been more or less as it is now, but the gullies have grown a little as the rain has taken away the soil. Before, the churqui trees were big and the earth was not so dry. The plots do not erode because we put manure on the earth – the earth is always covered and it becomes fixed; the water doesn't remove it.' (Roberto Vega).

Riverbanks and islands
One often overlooked consequence of erosion is deposition. The local people in Juntas understand the value of sediments deposited by the Rivers Camacho and Alizos, and have been successful in converting sediments into cultivated fields (described in Liberman 1993). During large and rapid floods the rivers deposit large amounts of sediment in certain parts of the river course, often forming islands. People protect these islands with stone walls and *churqui* branches (*Acacia caven*). They then allow the natural vegetation to grow, typically bushy species such as *chilca* (Baccharis sp.), then *romerillo* and *churqui*, and after a few years wait for a large flood. When this happens, the vegetation slows the flood waters so that only fine sediments (fine sands and silts) are deposited. When, after several floods farmers judge that enough sediment has accumulated, the bush cover is cleared and crops such as potato and maize are grown. For the farmers it is worth taking the risk of losing these reclaimed plots (and the crops) in subsequent floods, to obtain the potential benefits of new land and good yields, at least in the first years of cultivation.

In Juntas, the late Dionicio Mejía had two hectares of cultivated land on islands in the course of the River Camacho, where he cultivated potatoes, maize, sometimes wheat, peas and peanuts (Salm 1996). The benefit of this new land was significant for his household, but the risk was high. After sowing 3.5 tonnes of potato in September 1994, Dionicio obtained 10 tonnes, but could only harvest half, because the land was flooded and the potatoes rotted before they could be lifted (ibid.)

The island resource, pioneered from the necessity, curiosity and experimentation of previous generations, is important for improving household productivity in the community.

Tojo

In the community of Tojo most agricultural fields are situated on fluvial terraces close to the River San Juan del Oro (SJO) and the lower reaches of the Honda valley. The landscape is characterised by deeply incised valleys and the steep slopes limit cultivation to the narrow valley floors. The River SJO flows all year round, and every years there is flooding which damages irrigation channels. Big floods which cause significant damage to cropland occur every 4-8 years (Fairbairn 2000). The river deposits vary in texture from sands, silts and sometimes finer material, but stone deposition is less common than in the seasonal River Tojo, whose stony bed provides materials for building foundations.

The rivers dominate the discussions with local people about the local soils, and they are very aware of the variation in soil texture, related to the types of materials laid down during floods. Don Cipriano Tejerino, from the neighbouring community of Carretas, has land on the River SJO close to Tojo, where he has observed that:
'The earth is characterised by the nature of the sediments the river brings when there are floods – fine or coarse. The river changes colour during the year depending on the sediments'.

In Tojo there are local terms used to distinguish river sediments. If the river is 'very *vallo*' the sediments are reddish or the 'colour of blood', and the word *o'kee* describes yellowish sediments.

Don Cipriano distinguished three types of soil: red earth, sandy earth and soft earth. His main classes are defined by different criteria – colour, texture and consistency. It is not a systematic classification in the scientific sense, but is pragmatic, using those criteria by which he most easily distinguishes one soil from the other, when he observes it and uses it. The 'soft earths' are at the footslopes – 'the earth falls from the mountainslopes and is badly drained and *salitrosa* (like saltpetre, nitre). The 'sandy earths' are typical of the alluvial terraces – 'the most common earth, well drained, but needs manure', and the 'reddish earths' are located close to the riverbanks and 'are the sediments dragged by the river, they bring good nutrients'.

Other soils identified by local people in Tojo (Table 3) include *tierra cascajosa* (gritty earths), yellow clayey earths and marshy earth.

Table 3 Local soil classes in Tojo, Tarija.

Soil type	**Other names**	**Topography**	**Farmers' comments**	**Perceived best uses**
Yellow earth, Whitish	Sandy earth	Riverbank, flat, terrace	Need to irrigate the sandy earth Thin earth needs more manure Good for growing garlic	Maize, potato, vegetables, garlic, quince, grapes
	Clay	Riverbank, flat, terrace	The clay is harder More productive The best for maize Needs irrigation to cultivate	Maize
Red earth, Reddish		Riverbank, flat, terrace	Red earth produces most beautifully – for tomatoes and vegetables Has no river salts Used to be redder, but is losing its blood colour with irrigation Without irrigation it doesn't produce – only prickly pear cactus grow.	Maize, broad beans, vegetables, quince, grapes
Black earth		Slope	Pure stones	Prickly pear
Gritty earth	Footslope black earth Soft earth	Slopes, footslopes	Saltpetre	Citric fruits, grapefruit, mandarins, prickly pear
Tierra Cienegosa	Moist earth	Flat	OK with lime or ash	Trees
O'kee			Yellow river sediments	
Vallo			Reddish river sediments	

Source: Survey, August 2000

Preferred uses
The crops grown depend in part on the type of soil, but also the availability of organic manure. Maize is regarded as a low risk crop, which needs less manure than potatoes and vegetables, and grows well in sandy soils, although it can yield better clayey soils. The clay soils are regarded as more fertile, but require more work to prepare. Local people recommend the following preparation – irrigate, cultivate, leave two months (to 'ferment'), cultivate twice (perpendicular), plough to 30 cm, and sow. This task is particularly difficult in clayey soils.

Farmers in Tojo prefer to use sandy soils for those crops which require good drainage, such as fruit crops, vegetables, potatoes and garlic, but they are conscious that whilst the physical medium is favourable, sandy soils contain few nutrients and need a lot of manure.

Manure
Farmers in Tojo, like those in Juntas, notice a relationship between the type of fertilizer used and the consistency of the soil:

'The soil was more fertile when we all used organic manure. They introduced chemical fertilizers eight years ago. But the chemicals need a lot of water, which we don't have. The earth became hard and didn't produce. Now only a few people use chemical fertilizers' (Gertrudes Maraz).

They conclude that fertilizers harden the soil, and are not suited to their particular soil conditions. The number of animals that a household can maintain is thus very important for soil conditions. Until last year, Tojo households sent sheep (and some goats) to shepherds in the communities of Rupashka and Peloj in the pampa to the south, from November to May, and in some cases all year round. This freed Tojo people from the daily chore of grazing the animals so that they could engage in other activities like what?, but during this time manure was not collected. The future of this practice is now uncertain because the highland communities are less willing to accept the valley livestock partly because payment is unreliable or even absent but also because there is a generalised feeling that they should keep their resources for their own animals.. If the animals are no longer to be sent to the pampa, this implies changes in the amount of manure available during the summer in Tojo, and could even have a positive effect on soil conditions. A potential problem is the generation of enough forage for livestock feed during this period.

There is little use of green manures in Tojo, though some farmers incorporate a mixture of *molle* leaves and organic manure in their vegetable patches, principally for growing onions. These farmers recognise the beneficial effects of organic material for improving the structure of the soil, maintaining soil moisture and increasing nutrients available to the plants. Farmers in the neighbouring community of Buenavista appear to use molle leaves regularly to improve their soil and they accumulate leaf litter for use in improving the soil in seedbeds. These practices could be discussed with others in the community and more widely diffused. Technical assistance could be offered to those who wish to evaluate the different types of green manure and compost for their fields.

Some communities along the River SJO use red rock (Molino & Santa Rosa formation) from nearby cliffs. These high-phosphate rocks are removed, crushed and applied to the soil to improve fertility. In some communities a section of cliff is sold together with a plot of land (personal communication David Paredes). In Tojo this practice has not been observed, probably since soil phosphorus levels are fairly high

(Appendix 2). There is the potential for such rock phosphate to be collected for exchange with products from communities with low soil phosphorus, such as Juntas.

Minimizing river damage
Near the river banks, local people sow *caña hueca*, a sturdy bamboo-like plant, and sometimes plant poplars close together. These plants act as a physical barrier against floodwaters and protect the crops and fruit from being damaged by fast-flowing water during floods. Water passes between the plants, which slows the flow leading to sediment deposition reducing the load of sediments reaching the cropland. In this way farmers can take advantage of the nutrients in a manageable amount of sediment, avoiding the damage which large amounts of sediment would cause.

Soil use sustainability
The work in Tojo indicates that the riverine agricultural systems produce sustainable yields of maize, fruit and vegetables, given the continued addition of organic manure, which is the current practice. On these coarse-textured, well to excessively drained soils, the effect of organic manure in increasing soil moisture holding capacity is particularly important. Annual yield variations are probably caused by variations in annual rainfall and the incidence of pests and diseases. As seen in other semiarid areas (Mexico, Fairbairn 1993), the inherent fertility and sensible soil husbandry of local people makes it possible to sustain households whose livelihood in part depends on agriculture . The soils around Tojo are susceptible to water and wind erosion, and it is sound resource management by local people, and the intelligent use of microenvironments which has allowed reasonable crop yields to be achieved, despite the lack of water and prevalent environmental hazards (Fairbairn 2000). The *campesinos* tell us that the ‘river can take earth, but can also bring new earth’, actually improving the quality of the soil by introducing little-weathered minerals into the system.

For example, a man respected in the communities for his knowledge (Cipriano Tejerino), judges that the condition of the soil has improved in the time he has been a farmer (50 years). ‘The earth is better than before, if you work it, bringing the sweeter earth from below and adding organic manure’. Other farmers agree that the beach and island soils can improve after flooding, though some add that this implies a great deal of extra work and can take a long time, in extreme cases up to three years.

The sustainability of adequate yields from these Soils will depend on the continued availability and application of organic manure. The soils are moderately fertile, but quite erodable, with relatively low organic matter content. Farmers know the value of manure, but know less about other ways of incorporating organic matter, such as green manures and composts, which have proved successful in other parts of the world.

Chorcoya Avilés

The farmers and herders in Chorcoya Avilés distinguish about nine different types of soil, mainly by differences in colour and texture (Table 4). The colour criterion is often used because it is convenient and visual. It doesn’t say anything in itself about the soil characteristics, which are learned by association, but it does offer a useful label. When a farmer thinks of a ‘blackish earth’ s(he) thinks about ease of ploughing, how it maintains the moisture, its suitability for different crops and pastures, and the yields s(he) can hope for in a wet, ‘normal’ or dry year.

Soil types

In Chorcoya people speak of black earths, red earths, yellowish earths and chestnut brown earths, and have also identified areas of reddish sands. The sands are found in the south of the community in the lower part of two valleys which drain the eastern section of the community. The shallowest soils are found on the slopes – red rubble soils (*ripios colorados*), gritty soils (*tierras cascajiales*) and flat-stone soils (*lajosas*) – and grow natural pastures. Slightly deeper soils are found in the seasonal river valleys – the stony blackish earths, the main agricultural soils, and the marshy earths. Black clay earths are found on the plains, as well as chestnut brown earths and red clays. The plains are used very little for agriculture because of the uneven distribution of soil water conditions throughout the year (either dry or flooded), and the high incidence of frosts in the low lying land. With the help of four people with knowledge about different zones of the community, a map was constructed showing the most important soils in Chorcoya Avilés, using local terms (Figure 2). The map will help local people and professionals to communicate about the different soils in the community, their location and areas with potential for management adjustments. It serves as a tool to aid debate in community meetings.

Soils that are best for agriculture and grazing are clearly identified, on the basis of soil depth, water conditions and topographic position. The stony blackish soils are considered the best for crops, perceived as an intergrade between the dark clays in the lowlands and the reddish soils on the slopes, and importantly with a supply of water for irrigation.
'The stone is good – it gives air to the earth and makes it easier to prepare'. (Angel Sanchez). In Chorcoya, as in Juntas, stoniness, for those who plough using oxen, is seen as an advantage in soils which can become very dry and difficult to prepare.

It is common in Chorcoya Avilés to hear people use the adjective *tierra* or *tierrosa* to describe soils that are 'neither clay nor sand' or 'sandy clay'. In this context *tierra* refers to loamy soils which have similar proportions of fine and coarser particles, usually sandy clay loams or sandy loams. These soils are considered easy to plough. The use of the term varies from community to community – in Juntas *tierra* refers to soils which are clayey and have a strong consistency.

The red stony earths on the slopes are used for rough grazing, and are not considered suitable for crop production – 'they are weak, they don't yield well, you have to put on a great deal of manure'. This comment suggests that some have experimented with crops on these soils, where access to the blackish soils is limited.

The black clays and chestnut brown earths are found on the plain (Figure 2). From a pedological point of view, the black clays are well developed, receiving downwashed materials from the higher slopes in the watershed. They are deep and well structured. Their main use is for grazing and the dominant vegetation is *paja* (*Stipa leptostachya*). There is little cultivation on these soils because there is insufficient water for most of the year and flooding is common during November and December. Farmers comment that the lower lying areas receive more frosts than the higher valleys, limiting which crops can be grown. Without fencing it is also for people to prevent grazing animals from damaging crops. In the lowest and wettest parts of the plain (to the south of the community), where springs emerge, some small fenced paddocks are protected from grazing and pasture is allowed to grow up to provide feed for lambs. In contrast to other altiplano communities, sheep are not sent from Chorcoya to other communities for grazing during the dry season, and herds depend entirely on the pastures within the community boundary. The paddocks are therefore important, but although they are in theory communal, in reality only a few households have access to them.

The chestnut brown earths (Figure 2), located to the north of the area of black clays, have a coarser texture, and are generally sandy loams and loamy sands. They are referred to as earthy (*tierrosa*) by local people. They are less stony than the blackish soils, deep and well structured, and have significant potential for the growth of frost resistant crops. Some farmers have noticed the potential of these chestnut soils and are evaluating garlic production in small plots. It is important that organisations are quick to respond to the initiatives of experimenting farmers and offer support in their evaluation and development.

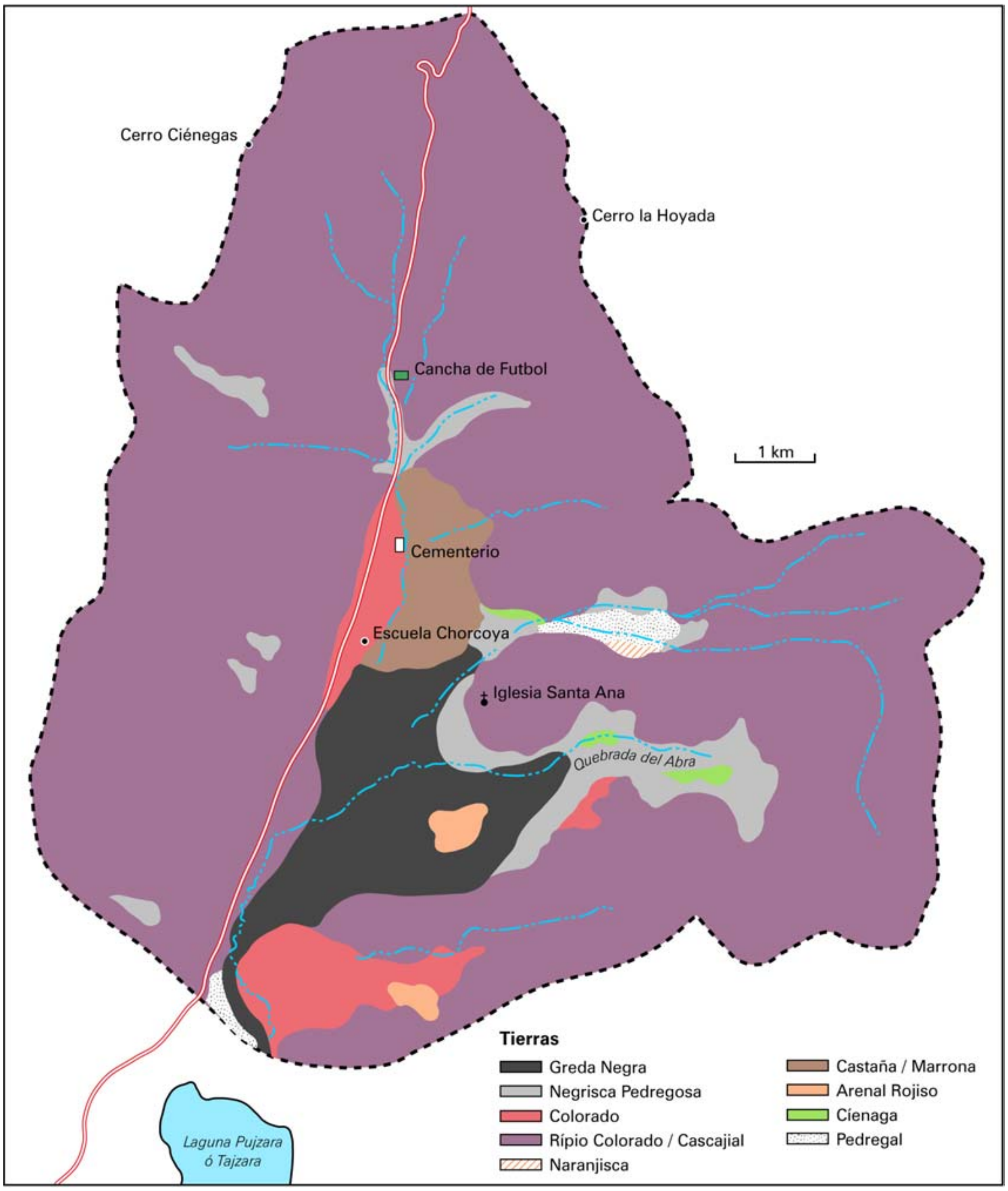
Table 4. Local soil classes in Chorcoya Avilés

Soil type	Other names	Topographic position	Farmers' comments	Preferred use
Black clay	Lowland black earth	Plain, lowland	They could produce well, but lack water and suffer frosts	Rough grazing
Stony blackish earth		Base of seasonal river valleys Lower slopes	The best for crops Yields well, manuring well The darker the better Loose, friable, the wind lifts it With four to five ploughings and lots of manure it will produce anything	Broad beans, potatoes, wheat, onions, vegetables
Reddish earth	Red clay, red mud	Plain, gentle slopes		Rough grazing
Red rubble	*Cascajial*, muddy red earth	Slopes	The most common land Poor grasses grow – sometimes even they won't grow Weak earths, they don't produce	Rough grazing
Orangey earth	Yellowish earths	Lower slopes		Broad bean, potato
Chestnut earth	Brown earth, ''earthy''	Plain, lowland	'Tierrosa' – neither clay nor sand	Grazing, some garlic
Marshy earth	Wet earth			Rough grazing
Stonefield		Seasonal river channels Lowland		Material for stone dykes and house building
Calicante	*Caliche*	Laderas altas		None

Source: Survey, August 2000

Figure 2. Local soils in Chorcoya Avilés, Tarija

Cuadro 5: Chorcoya Avilés : Suelos Locales de la Comunidad



6. Soil characteristics and potential management adjustments

This section considers the physical and chemical characteristics of the sampled local soil types in Juntas, Tojo and Chorcoya Avilés (Appendices 2-6), identifies under-utilised soils and suggests adjustments in the management of more intensively utilised soils. Under-utilised soils include those under natural vegetation with the potential for crop production, riverbank soils which could be reclaimed. The protection of land from environmental hazards is also considered.

Juntas

The soils in Juntas are generally weakly to moderately acid, with few constraints for the production of locally produced crops. Salm's data (Salm 1996) show that hillside soils contain moderate to high levels of calcium, magnesium, potassium and nitrogen, but low organic matter levels and low to very low levels of phosphorus. These are the locally named yellow earths used for dryland maize production.

The alluvial soils on the floodplain of the River Camacho also have moderate levels of calcium, magnesium and nitrogen, but available phosphorus is lower than on the slopes. Phosphorus levels vary according to input levels, but on average alluvial soils contain more phosphorus than on slopes and island soils. On a very old terrace now cultivated by Sergio Amador, phosphorus levels are very high, reaching 100 ppm, and organic matter levels are higher than the average in Juntas. Low organic matter is a constraint that is common in all three communities. The highest levels in Juntas are found under *churqui* trees (*Acacia caven*), on the slopes and also footslope land owned by Felipe Castillo. He owns more livestock than others and this might be a factor that explains the soil quality.

The analyses show that the more intensively utilised soils could be improved by incorporating more organic matter into the soil. On the less intensively used dryland terraces acceptable yields of maize can be achieved without further addition of manure, although the long term sustainability of the soils will depend on regular addition of organic manure. On land fertilized with chemical fertilizers (18:46:00, i.e. no added potassium) levels of potassium are much lower than the dryland soils where only organic manure is used.

In the three communities little-utilised soils were identified which would be suitable for reclamation and potentially more intensive use. In Juntas there are areas along the course of the River Camacho with stony, sandy and silty soils, and scrub vegetation including *churqui*. Although there is a risk of flooding in this area, local people have expressed a desire for help in evaluation of local and introduced tree species in order to create woods to provide feed for goats and sheep, and conserve existing *churqui* trees which also provide leaves and fruits for goats, improve soil stability (Cerdá 1995) and increase soil organic matter and nitrogen (Salm 1996). At the same time branches could be harvested for use as green manures and compost, building on the efforts of some farmers who currently use *molle* (*Schinus molle*) leaves in their vegetable plots. I suggest we initiate debate at community meetings concerning the utility of a tree nursery to evaluate species such as *chacotea*, *Acacia cianofila* and *Eucalyptus rostrata* (as a protective curtain at river margins).

Tojo

The predominant agricultural soils of Tojo are Class II (Appendix 7), according to the FAO land capability classification system. They are moderately deep (>50cm) with some physical and chemical constraints. They are susceptible to flooding since fields are close to the river channel and not raised much higher than the riverbanks.

A smaller area of soils belongs to Class IV, shallow soils which restrict what can be grown and require careful management. Other soils are Class III, with saline deposits that restrict crop growth. They are mainly found close to the river bank, where the phreatic surface is within 30-40cm of the soil surface. Very shallow soils, the *cascajales*, are used to cultivate prickly pear cacti. According to the 21 soil samples taken in Tojo (Appendix 2), the pH does not constrain the cultivable soils close to the riverbanks. The soils in the south-east of the community, near the mouth of the Quebrada Honda, are slightly acid. In the central part of the community where most of the cultivated land lies, soils are neutral and in the north of the community, by the River SJO, they are slightly alkaline.

NPK – The soils have moderate to high contents of total nitrogen, high to very high phosphorus contents (associated with parent material) and are moderate to high in potassium. Nutrient levels appear suitable for the crops produced, but soil organic matter content is low despite the constant addition of organic manures by the farmers.

In Tojo some farmers cultivate land in the sandy beaches (Plate 1) in an opportunistic effort to increase household production. This is a high-risk strategy, but the high value of the crop (broad beans) is considered worth the risk of crop failure.

A priority for those with land next to the River SJO (and some parts of the Quebrada Honda valley) is the protection of the land from floods. We have described how plants are used as a protective curtain, but in some locations stronger constructed river defences are needed. Protection can also be provided with trees and shrubs. ‘Winning back land from the river’ is a topic commonly debated in the community of Buena Vista, higher up in the Quebrada Honda, but less so in Tojo. Land reclamation is recommended as a topic to be suggested for debate at a Tojo community meeting, preferably with a representative of Buena Vista who could present the activities carried out in his/her community.

Plate 1. Broad beans sown on the beach by the River San Juan del Oro, Tojo.

Tojo people have been unable to use patches of poorly drained wet soils next to the River SJO and are anxious to plant trees in these areas to reduce the humidity of the soil. They couldalso use or sell the wood, use the leaves and branches for livestock feed, and they could provide some protection from floods. A possible intervention would be to help local people organise a tree nursery in combination with their fruit tree nursery in order to evaluate different tree species for this purpose.

Irrigation

Information about local soils knowledge in Tojo shows that farmers have broad knowledge about soil management. One area in which there is probably misunderstanding is the effect of irrigation. When asked why there were salty white patches on the soil surface, some farmers replied that this was due to the lack of irrigation to wash them down. It is more likely that the high frequency of irrigation has encouraged the accumulation of salts on the surface, common in arid and semiarid soils. It is important, to include the topic of irrigation methods and timing in a community meeting, to evaluate knowledge on the effects of irrigation, and react by providing assistance to reduce salts' accumulation.

Chorcoya Avilés

Little-utilised soils

The soils of the plains are developed on fluviolacustrine deposits of differing ages. According to Galarza Castillo (1997) the most recent deposits are in the north of the plain and the ‘sub-recent’ deposits are located to the south, towards the Laguna Pujzara and the Laguna Grande. The farmers’ black clays coincide with these older deposits and the more recent deposits are overlain by the chestnut brown soils, developed on limestone, sandstone and fluviolacustrine lutites. They are deep soils with slopes of 0-3%, moderately well drained, little evidence of erosion by water, not saline, not stony, loamy textures, commonly sandy clay loams. Physically they are good soils for crop production. They are also quite fertile (Appendix 6): they have high contents of calcium, magnesium and potassium, high cation exchange capacity, very high base saturation and adequate amounts of total nitrogen. In contrast to the other soils of the region which, like many Andean soils, are low in organic matter, these soils, which Galarza Castillo terms ‘Copper Series’, and the local people call chestnut brown earths, contain moderate amounts of organic matter. According to our analysis (Appendix 3) these soils, like other soils in Chorcoya, are high in phosphorus. They are used for grazing not crop production. These chestnut brown soils (Figure 2) can be used more intensively. In the previous section we saw that some farmers recognise this potential and are experimenting with garlic. Acknowledging the frost problem in these lower lying plains, it would be worth triggering debate at community meetings on the potential of evaluating frost resistant crops and varieties, such as garlic and short cycle (90 days) potatoes such as the Desirée variety. The local experimenters can discuss their evaluations of the advantages and potential problems of cultivating the chestnut brown earths.

Intensively use soils – stony blackish earths

The stony blackish earths (Figure 2) are the most intensively cultivated soils in Chorcoya Avilés. Galarza Castillo’s soils map of the Tajzara watershed does not distinguish these darker, deeper soils from the shallow red rubble soils on the slopes, collectively naming them footslope soils (Series Quewiñal), but the differences noted by local people are significant. The analyses of local soils show that they have moderate amounts of nitrogen and potassium and are high in available phosphorus (Appendix 3). They are generally low in organic matter (around 0.2%), despite the efforts of people who manure the soils each year with sheep dung collected from the pens.

7. Soil improvement techniques

Soil analyses show that there is a problem common to all three communities – low levels of organic matter in the soils. Both socioeconomic and edaphic evidence suggests that current production levels can be maintained providing that the current practice of capture and incorporation of medium to large amounts of organic manure continues. To improve organic matter levels in the soils (recognised by the local population as beneficial for improving how much moisture the soil can hold and how easy it is to cultivate) the following techniques could be evaluated to identify those which would be best adapted to each community and those which the communities would be willing to pursue.

i-Management and improvement of organic manure

Without the current practice of organic manuring, soil quality would be much worse and the soils would not be able to achieve the yields reached by the farmers. The manure not only increases organic matter in the soils but also increases and balances the reserve of nutrients available to plants. The loss of nutrients can be minimized by improving the collection, mixture, storage and transport of dung **and the use of urine**. In Juntas and Tojo the seasonal migration of animals to distant pastures in winter limits the gathering of dung during this period and nutrients are lost from the system. When the animals return, they graze among the maize crop residues (*chala*) during the day and stay in the corrals at night, facilitating the collection of dung. In Chorcoya the sheep are in pens at night all year round, allowing continual accumulation of manure for distribution over the fields. Some farmers in Juntas avoid the need to move dung from pens to field by constructing moveable pens from *churqui* branches, thereby regulating the distribution of manure over the field. .Animals remain collected over one patch for around twenty days before the pen is moved on. This practice is now less common, but has potential for widespread use in Tojo and Juntas, where animals are only present in the community for parts of the year.

A technique used successfully in Bhutan and other locations (Reijntjes et al. 1992), which has not been used extensively in the Tarija communities is the use of litter or bedding in the pens to increase the nutrients of the manure and more importantly to retain the nutrients in the urine which can otherwise be lost. In Tojo some farmers incorporate *molle* leaves mixed with manure into the soil. These farmers could evaluate the benefits of putting the leaves in animal enclosures, capturing the urine and increasing the nutrient level of the final manure

Ash from bread ovens and wood burning stoves could be used to add nutrients to vegetable garden soils. Good practices which were probably more prevalent in the past (incorporation of molle leaves in Tojo, use of ant nest manure in Juntas) could be promoted in all communities by those who maintain them by way of workshops or community meetings. Nitrogen levels in the soils of Juntas, Tojo and Chorcoya vary from low to moderate, in places adequate. The soils could benefit from an increase in nitrogen levels, not only by addition of organic manures but also the cultivation of nitrogen fixing legumes such as peas, alfalfa and beans, intercropped with maize. Climbing bean varieties, well known in Mexico and Central America, are sown together with maize and are harvested some weeks before the maize. They provide food, animal forage, organic matter and improved soil fertility.

ii-Compost

Composting is the breakdown of organic material by micro-organisms and soil fauna to give a humus end product called compost. Recycling of wastes and residues (weeds, crop residues, waste from postharvest processing, dung, nightsoil and urine) can improve the quality and quantity of organic manures. The conversion of organic wastes into humus slowly releases nutrients over time and stimulates microbial activity, improves soil structure and improves the resistance of plants to pests and diseases. Given the low levels of organic matter in Juntas, Tojo and Chorcoya the method could provide important benefits for increasing production and conserving soil quality. There is more potential in Juntas and Tojo, where residues are most abundant. What is less certain is the willingness of local people to spend additional time in the gathering of wastes and residues and the preparation of composts. The attitude among some farmers is that it is ‘dirty work’. The technique can be adapted according to local preferences and soil moisture contents. Compost can be prepared in heaps, or under dry conditions in shaded pits. The process involves labour for digging and turning the compost, but it is also possible to prepare compost *in situ*, working the material into ridges.

iii-Green manures

Trees, bushes, cover crops, grain legumes, grasses, weeds, ferns and even algae can be used as a cheap source of organic fertiliser to build up or maintain soil organic matter and fertility. Green manures add organic matter and nitrogen to the soil accumulatively, and in the short term improve the mobility of phosphates and microelements (such as calcium and magnesium) in the topsoils for plant uptake. Deep rooting green manures can also help recover nutrients leached to the subsoil, and cover crops can appeal to farmers because they help to control weeds. Some potential techniques include the following (adapted from Reijntjes et al. 1992):

- Improved fallow – replacing natural fallow vegetation with green manure crops (e.g. legumes) to speed up the regeneration of soil fertility, for one year, several years or only during the dry season
- Alley cropping – introducing simultaneous fallow in which quick growing trees, shrubs (legumes) or grasses are planted in rows and are regularly cut back; the prunings are used as mulch or worked into the soil in the alleys between the rows. Additionally the material can be used for livestock feed or bedding
- Integration of trees into cropland – cutting tree legumes for mulch material or fodder
- Relay fallowing – sowing bush legumes among food crops after these have established, and, in the dry season using the cut green biomass as mulch or working it into the soil
- Live mulching – maintaining a low, dense cover of grasses or legumes. Removing the strips of cover crop by hand when the food crops are to be sown, reducing soil tillage.
- Shaded green manures – sowing green manures in shade under fruit trees in Tojo and Juntas

In Chorcoya Avilés the lack of suitable vegetation limits the use of these techniques, although the presence of quewiña trees (*Polylepis sp.*) in some walled fields shows a potential to increase their number in the community. The soils in Chorcoya are susceptible to wind erosion and would benefit from an increase in organic matter and soil cover. In Tojo and Juntas there is more potential for using these techniques. In Juntas we already know that the soils under *churqui* trees are higher in organic matter than the soils under crops (Salm 1996). Combined with its important role in soil conservation, *churqui*, a tree well known to local people and used for posts, fuel and feed, has good potential for enhanced use as a source of green manure.

8. Use of the data to benefit communities

The purpose of this and other project reports is to enrich the debate, planning and evaluation of appropriate rural development activities in the communities of Juntas, Chorcoya Avilés, Tojo and other neighbouring communities that wish to take part in project activities (Buena Vista, Atacama, Charaja). The data and information gathered for this report will be presented to the communities in an easily-understood format, to aid informed discussions about new natural resource management techniques can be developed by farmers.

Analytical data

The physical and chemical data for sampled soils will be presented to the communities in visual form, and individually to those whose land was sampled. The technical team will be available to explain the interpretation of the laboratory results for production and the implications for soil conservation. All relevant soils information is to be incorporated into community folders, which are being developed with project assistance. These community databases contain information about the community – lists of families, climate, crops, production problems, crop and animal pests and diseases and remediation methods and other information emerging from project activities.

Together with climatic data collected by schoolchildren, the soils data and maps of soils and grazing areas will contribute to the generation of materials on local geography which, as well as adding to the community database can also contribute directly to the school curriculum.

Maps
Together with maps of vegetation, generated by the project, maps of soils and grazing areas will be presented to the communities via a workshop or community meeting. People will then have the opportunity to suggest modifications to the maps, discuss the mapping units and debate the preferred uses of the different soils. Using the maps as a tool for focusing debate, ideas can be exchanged about the possible uses of identified under-utilised soils, and how to improve the condition of more intensively used soils.

Techniques
The soil improvement techniques identified (green manure, compost, legumes) build on current local knowledge and management techniques. Practical workshops, involving children who can evaluate the techniques via school classes on environmental topics, will be run to assess which techniques could work best in which locations and for which households. People from Buena Vista (where more success has been achieved in land reclamation next to the River Honda than in Tojo) will be asked to explain the techniques, successes and problems they have encountered at a Tojo community meeting. Similarly local experimenters will be invited to share their methods with the community. For example, those who use green manure or anthill manure could rekindle the interest of other farmers in the community. We have identified a lack of understanding about the effects of continual irrigation on salts accumulation, which could be explained within a workshop or community meeting.

9. Conclusions

Building on existing knowledge is likely to be more successful than introducing alien or unknown concepts or technologies into rural communities, particularly if improved sustainability is to be achieved. This is common sense, but it has not been widely adopted by development organisations. The importance of local knowledge permeates the rural development literature but organisations have not widely translated the ideas into practice. This report adds to the small body of case studies on local environmental knowledge in Tarija and attempts to use the approach for practical solutions on the ground.

In the study area, locally conceived soil classifications have been established in order to facilitate communication within communities and between local people, technical professionals, researchers and municipal functionaries. The level of local soil knowledge in the study area is high, and the communities use microenvironments which are important for maintaining or improving livelihood strategies, such as the islands and beaches of Juntas and Tojo and marshy soils for grazing in Chorcoya Avilés. Farmers recognize that water and wind can erode the soils, but soil erosion is not considered as significant a problem as productivity ?? since erosion is a process rather than an event.
Soil organic matter is recognised by local people as important for maintaining soil fertility and soil moisture. Most farmers use dung collected from cattle, sheep, goats and sometimes chickens and recognise that dung from horses and donkeys has fewer nutrients. Chemical fertilisers are not broadly used, except by some farmers in Juntas, and people regard them as inferior to dung, since they are short lived and harden the soil.

In the three communities little-utilised areas have been identified which are suitable for reclamation or more intensive use. These areas will form the basis of discussions in the communities to evaluate the advantages and disadvantages of alternative uses. These include reclaiming riverine soils in Juntas and Tojo for crop production and using useful tree species. In Chorcoya, a large area of fertile soils has been identified with potential for growing frost resistant crops such as garlic and short cycle potatoes.

The agricultural soils of the three communities are moderately fertile. They are neutral soils with high base saturation and adequate levels of nutrients important for the crops grown in the study area. The principal problem is low organic matter. The amount of organic manure people can put on their fields depends largely on the animals owned by the household and the proximity of those animals to the fields during the year. The use of cheap and simple techniques of green manuring, composting and capture of urine as well as dung in enclosures is recommended for improving the sustainability of the more intensively used soils in the three communities.

Local soil knowledge varies significantly from place to place, and within communities. These differences can be partly explained by differences in ecosystems (e.g. soil variability differences, rivers vs. high plains), activities (crop production and livestock rearing) and individual interest, but the story is clearly more complex and may incorporate language and cultural elements. In the early Mexican study, for example, Williams and Ortiz-Solorio (1981) give the example of three Mexicans responding to the question: what kind of soil is this? The Popoluca campesino replies with a vegetation term, the Nahuatl speaker with a term denoting alluvium and the Spanish speaker with a colour or texture label. Ugh, try again.

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Appendices

Appendix 1. Group work results on local soils in Arenales

Group 1.

Soil	**Commentary**
tierra negra	ladera, con abono es util
greda (arcilla) negra	con abono da
piedra con greda colorada	no se usa para cultivos
tierra colorada	planicie, no muy fertil
tierra arenal	pajales
tierra cascajial	mucha piedra, poco profundo
tierra menudita	menos piedra
tierra salada negra greda	no tiene remedio (solo cerca de las lagunas)
tierra gredosa	con guano de oveja sirve
	conserva la humedad
	necesita mucho abono
	no la levanta el viento, sentadito, ni con el agua se va

Grupo 2.

Suelo	**Comentario**
tierra ripiosa	sirve para plantas naturales, y
	alfalfa pega mucho tambien
tierra gredosa -barro colorado	no sirve para cultivos
-barro negro	con mucho abono muy lindo para el cultivo
tierra arenosa	en el pueblo y las laderas
	sirve para paja brava y thola
tierra salitrosa	no sirve para el cultivo,
	brama crece hermoso

Apéndice 2

TOJO: INTERPRETACION DEL ANALISIS FISICO-QUIMICO DEL SUELO

N° DE LAB.	NOMBRE DE LA MUESTRA	N° de M.	Prof	PH	CE	K	CIC	MO	NT	P
00603	GETRUDIS MARAS	T1	010	suavemente acido	no salino	moderado	bajo	bajo	moderado	muy alto
00605		T2	025	suavente acido	no sailno	alto	bajo	bajo	moderado	muy alto
00606	OCTAVIO CRUZ	T3	020	suavemte acido	no salino	alto	bajo			
00607	AIDA VDA DE ARROYO	T4	025	suavemente alcalino	ligeramente salino	muy alto	bajo	muy alto	alto	alto
00608	MATERIA ORGANICA	T4					bajo			
006025	SEBERO TACACHO	T5	0,25	suavemente alcalino	no salino	alto	bajo	bajo	adecuado alto	muy alto
00609	EMILDA MARAS	T6	0,25	suavemente alcalino	no salino	moderado	bajo	bajo	moderado	alto
00610	MARIO ALEAN	T7	020	Neutro	no salino	alto	bajo	bajo	moderado	muy alto
00611	HERNÁN SORUCO	T8	0,25	Neutro	no salino	adcuaod	bajo	bajo	moderado	alto
00612	ROBERTA VIUDA DE SALAZAR	T9	0,30	Neutro	no salino	moderado	bajo	bajo	moderado	alto
00613	MARIO ALEMÁN	T10	0,25	Neutro	no salino	adecuado	muy bajo	bajo	adecuado	alto
00614	LUISA CAMPERO	T11	0,25	Neutro	no salino	moderado	bajo	bajo	adecuado	alto
00615	OCTAVIO CRUZ	T12	0,25	Neutro	no salino	alto	bajo	bajo	bajo	muy alto
00616	ABDON SORUCO	T13	0,25	Neutro	no salino	moderado	bajo	bajo	bajo	muy alto
00617	FELIZA MAMANI VICTORIA SORUCO	T14	0,25	Neutro	no salino	muy alto	bajo	bajo	adecuado	muy alto
00618	ALICIA GUTIERRES	T16	0,30	Neutro	no salino	adecuado	bajo	bajo	moderado	alto
0061900620	HIPOLITO TOCONAS	T17	0,25	suavemente alcalino	no salino	moderado	bajo	bajo	moderado	alto
0060	ALICIA GUTIERRES	T18	0,30	suavemente alcalino	no salino	alto	bajo	bajo	moderado	muy alto
0060	AGUSTIN GUTIERRE	T19	0,25	suavemente alcalino	no salino	adecuado	bajo	bajo	moderado	alto
0060	SEGUNDO ANPUERO	T20	0,30	suavemente acido	no salino	alto	bajo	moderamente alto	adecuado	muy alto
0060	FELIX GUTIERREZ	T21	0,25	suavemente	no salino	alto	bajo	bajo	moderado	alto
0060	ATACAMA RIVERO	A-1	0,25	suavemente acido	no salino	alto	bajo	bajo	adecuado	muy alto

Muestreo por Cristina Morales y Jamie Fairbairn Agosto 2000.

Apéndice 3

CHORCOYA AVILES: INTERPRETACIÓN DEL ANALISIS QUIMICO DE SUELOS

N°	N° DE LAB.	NOMBRE DE LA MUESTRA	N | DE LA NUESTRA	PROF	PH	CE (MMMHS/CM)	CATIONES DE CAMBIO K	CIC	MO%	NT%	POSEN (PPM)
1	00630	GUMERCINDO JURADO	C-4 (G –L)	0,20	suavemente acido	No salino	muy alto	bajo	Bajo	Adecuado	muy alto
2	0631	CLEMENTE ABAN	C-5(C-B)	0,25	Alcalino	-	Alto				
3	00632	JUSTINO CONDORI	C-6 (J-C)	0,25	Neutro	No salino	Bajo	bajo	Moderado	muy alto	
4	00633	ANGEL SANCHES	C-7 (A-S)	0,25	suavementeacido	No salino	Moderado	bajo	Moderadamente alto	Adecuado	muy alto
5	00641	FELIPE SANCHES	C-8 (F-S)	0,20	fuertemente alcalino	No salino	Moderado	bajo	Bajo	Moderado	muy alto
6	00639	FRANSISCO SANCHES	C-9 (F-S)	0,20	suavemente acido	No salino	Moderado	bajo	Bajo	Adecuado	muy alto
7	0038	TIERRAS NEGRAS Y PLANAS DEL BOFEDAL	C-10 (S/N)	0,20	Neutro	No salino	Adecuado		Bajo	Adecuado	muy alto
8	00637	FELIPE COLQUE	C-X= C3	0,15	moderadamente alcalino	salino	muy bajo	bajo	Bajo	Bajo	muy alto
9	00636	FELIPE COLQUE BIEN CULTIVADAS	C-2 (L P)	0,20	suavemente alcalino	No salino	Alto	bajo	Moderado	Moderado	muy alto
10	00639	HORIZONTE A	C-1 (PA)	0,20	suavemente acalino						
11	00640	HORIZONTE B	C1 (P B)	0,35	Alcalino	No salino	Alto	bajo	Bajo	Adecuado	muy alto
12	00641	HORIZONTE C	C1 (PC)	045	Suavemeta	No salino	Alto	muy bajo	muy bajo	Moderado	muy alto
13	00642	PASTOS COMUNALES	C13 PC	035	suavemente acido	nosalino	Adecuado	bajo	Bajo	Adecuado	muy alto

Muestreo por Cristina Morales y Jamie Fairbairn, Agosto 2000.

Apéndice 4. Analisis fisicoquímico de los suelos de Juntas, Tarija.

Dueño	Uso	Riego Si/no	Ubicación	Pendiente %	Arena %	Arcilla %	Limo %	PH KCl 1.5	CE Mmho/cm	Cationes de cambio meq/100g suelo					Sat Bas %	MO %	N tot %	P disponible ppm
										Ca	Mg	Na	K	CIC				
Sergio Amador	Maíz	No	Terraza	0	35	29	36	6.01	0.087	7.38	2.06	0.04	0.95	10.47	99.6	3.18	0.29	31.64
Sergio Amador	Barbecho	No	Terraza	0	38	28	34	5.88	0.074	7.96	2.13	0.05	1.66	11.89	99.2	3.04	0.31	31.17
Sergio Amador	Papa	Si	Terraza	0	-	-	-	6.00	109.00	5.34	1.84	0.14	0.25	-	-	1.55	0.10	30.20
Adolfo Cruz	Falta arar	No	Ladera	15	51	26	23	6.49	0.044	8.09	4.57	0.06	0.28	13.10	99.2	1.66	0.13	5.51
Adolfo Cruz	Churqui	No	Ladera	50	27	31	42	6.16	0.074	7.98	5.02	0.05	0.56	13.66	99.6	4.21	0.26	5.87
Asunción Ruiz	Papa	Si	Terraza	1	28	32	40	6.21	0.069	6.24	3.69	0.10	0.31	10.45	98.9	1.16	0.15	15.74
Asunción Ruiz	Papa	Si	Terraza	1	22	32	46	6.77	0.076	8.94	3.70	0.13	0.34	13.21	99.2	1.94	0.19	14.06
Silverio Mejía	Descanso	Si	Ladera	20	42	34	24	5.44	0.044	7.37	2.79	0.05	0.96	11.26	92.2	2.34	0.25	2.92
Silverio Mejía	Maíz	No	Isla	0	36	22	42	7.03	0.038	4.09	2.82	0.09	0.19	7.30	98.5	0.72	0.13	0.07
Zenon Ferreira	Churqui	Si	Terraza	3	47	24	29	6.62	0.025	7.66	2.57	0.05	0.60	10.96	99.3	1.61	0.08	6.29
Zenon Ferreira	Papa	No	Terraza	6	52	23	25	6.26	0.150	3.80	2.89	0.06	0.46	7.26	99.3	1.24	0.12	27.82
Zenon Ferreira	Arveja	Si	Terraza	1	23	32	45	5.50	0.021	4.16	2.93	0.09	0.26	7.49	99.3	2.80	0.39	19.42
Felipe Castillo	Churqui	No	Ladera	40	-	-	-	5.30	184.00	8.33	1.82	0.04	0.74	-	-	7.76	0.36	8.08
Felipe Castillo	Maíz	Si	Piedemonte	6	45	22	33	5.92	0.057	6.19	2.86	0.06	0.31	9.47	99.5	5.98	0.31	19.35

Fuente: Adaptado de datos en Salm (1996), datos de 1993-1995.

Bajo/muy bajo	

Apéndice 5

Ejemplar de los datos de suelos de ZONISIG-Tarija (pers. Comm. David Paredes)

UNI_TER_ID	PERFIL_ID	HORIZON	pH	COND_ELEC	Ca	Mg	Na	K	N_TOT	P	ARENA	LIMO	ARCILLA	LAT	LONG	CL_FAO	PEN-DIEN	ELEV (m)	LOC_PERFIL
97	672	1	6.0	0.69	5.50	4.00	0.08	0.21	0.22	1.0	54	31	15	7592818	318723	CMe	40	1900	5km AL SW DE LA ESCUELA DE CHOCLOCA
97	672	2	6.4	0.33	6.50	4.80	0.08	0.20	0.15	0.0	43	36	21	7592818	318723	CMe	40	1900	5km AL SW DE LA ESCUELA DE CHOCLOCA
97	673	1	6.0	0.53	5.10	5.80	0.09	0.23	0.14	2.0	60	28	12	7593298	317943	CMe	8	1907	5km AL SO DE LA ESCUELA DE CHOCLOCA
97	673	2	6.1	0.27	5.60	6.20	0.10	0.20	0.22	0.0	61	26	13	7593298	317943	CMe	8	1907	5km AL SO DE LA ESCUELA DE CHOCLOCA
97	674	1	5.6	0.67	3.80	5.20	0.08	0.19	0.13	2.0	65	24	11	7591558	316803	FLe	4	1900	5km SW DE LA ESCUELA DE CHOCLOCA
97	674	2	6.3	0.38	3.90	4.80	0.25	0.15	0.07	0.0	68	20	12	7591558	316803	FLe	4	1900	5km SW DE LA ESCUELA DE CHOCLOCA
95	710	1	4.9	0.60	3.70	2.20	0.08	0.20	0.14	2.0	51	31	18	7591588	309903	CMe	10	2050	CAMINO EL TUNAL JUNTAS
95	710	2	5.4	0.16	4.00	3.00	0.13	0.25	0.07	1.0	32	36	32	7591588	309903	CMe	10	2050	CAMINO EL TUNAL JUNTAS
308	737	1	7.1	1.22	7.10	6.80	2.16	0.58	0.06	5.0	6	39	55	7614178	318003	RGe	65	1900	TABLADA TOLOMOSITA
308	739	1	6.1	5.80	3.00	2.50	0.46	0.09	0.03	24.0	37	45	18	7613702	319672	RGe	37	1895	300mts AL E. DEL CAMINO PRINCIPAL
308	739	2	6.2	8.01	1.00	3.70	1.77	0.11	0.02	17.0	67	20	13	7613702	319672	RGe	37	1895	300mts AL E. DEL CAMINO PRINCIPAL
111	806	1	8.0	2.96	11.80	7.30	0.27	0.44	0.22	4.0	20	47	33	7626373	267888	FLc	1	2400	500mts NORTE DE LA ESCUELA DE SAN PEDRO
111	806	2	8.3	2.04	5.60	4.80	0.57	0.42	0.10	1.0	63	16	21	7626373	267888	FLc	1	2400	500mts NORTE DE LA ESCUELA DE SAN PEDRO
111	806	3	8.2	1.26	3.90	3.60	0.48	0.36	0.06	1.0	60	24	16	7626373	267888	FLc	1	2400	500mts NORTE DE LA ESCUELA DE SAN PEDRO

118	843	1	8.0	1.81	10.20	2.10	0.29	0.93	0.18	26.0	60	30	10	7591903	287328	CMe	2	3700	A 300mts NE DE VICUĐAYO
118	843	2	7.0	0.73	4.00	1.70	0.16	0.55	0.08	7.0	65	22	13	7591903	287328	CMe	2	3700	A 300mts NE DE VICUĐAYO
118	843	3	6.6	0.63	3.30	1.60	0.15	0.46	0.04	4.0	65	20	15	7591903	287328	CMe	2	3700	A 300mts NE DE VICUĐAYO
118	850	1	4.0	2.95	4.00	0.30	0.18	0.59	0.92	10.0	13	79	8	7594363	293238	PHh	8	3800	100mts AL NORTE CAMINO DEL INCA
118	850	2	3.9	2.89	3.60	0.90	0.30	0.46	1.48	5.0	5	87	8	7594363	293238	PHh	8	3800	100mts AL NORTE CAMINO DEL INCA
118	850	3	4.4	0.30	1.40	0.60	0.17	0.41	0.42	2.0	27	58	15	7594363	293238	PHh	8	3800	100mts AL NORTE CAMINO DEL INCA
111	858	1	8.0	37.06	26.60	1.20	5.60	0.26	0.12	4.0	48	24	28	7646728	271353	CMe	2	2400	400mts AL N. CAMINO A POMPEYA
111	858	2	8.2	38.34	28.80	1.20	6.33	0.21	0.06	3.0	50	37	13	7646728	271353	CMe	2	2400	400mts AL N. CAMINO A POMPEYA
111	858	3	9.2	12.05	30.60	1.30	3.19	0.31	0.04	4.0	49	41	10	7646728	271353	CMe	2	2400	400mts AL N. CAMINO A POMPEYA
111	860	1	8.7	0.65	15.20	1.00	0.16	0.57	0.06	2.0	74	14	12	7646503	270843	RGc	47	2389	200mts AL N. CAMINO A POMPEYA
111	885	1	8.8	12.80	9.40	2.80	1.60	0.28	0.02	4.0	30	61	9	7644493	270783	FLe	2	2387	A 1km N.W. DE PIRWA PAMPA M.I. DEL RIO S.J.DEL ORO
111	885	2	8.6	1.11	3.50	1.20	0.40	0.17	0.01	2.0	89	2	9	7644493	270783	FLe	2	2387	A 1km N.W. DE PIRWA PAMPA M.I. DEL RIO S.J.DEL ORO
111	887	1	7.8	16.64	18.20	0.04	0.14	0.48	0.01	1.0	80	11	9	7644898	271008	LPq	55	2393	A 700mts N. DE LA ESCUELA DE POMPEYA M.I. DEL CAMI
115	888	1	8.2	3.43	9.40	3.90	0.42	0.54	0.15	36.0	24	60	16	7586728	259338	CLh	3	2600	100mts AL N. DEL RIO DE TOJO
115	888	2	8.4	2.10	13.80	5.00	0.54	0.77	0.09	14.0	25	59	16	7586728	259338	CLh	3	2600	100mts AL N. DEL RIO DE TOJO
115	888	3	7.9	5.98	12.70	4.40	0.36	0.34	0.25	15.0	23	56	21	7586728	259338	CLh	3	2600	100mts AL N. DEL RIO DE TOJO

Apéndice 6. Características físicoquímicos del suelo concociación Cobre (Typic Calciorthid), Chorcoya Avilés.

Profundidad (cm)	0-46	Interpretación	46-75	Interpretación
% Arena	50.3		36.5	
% Limo	20.7		25.8	
% Arcilla	29.0		37.7	
Textura	Franco arcilla arenoso		Franco arcilloso	
pH (1:5 agua)	8.1	Muy alcalino	7.8	Moderadamente alcalino
CE Mmhos/cm 1:5 suelo	0.347	No salino	0.144	No salino
Cationes intercambiables Meq/100g de suelo				
Calcio	29.50	Muy alto	31.25	Muy alto
Magnesio	5.25	Alto	6.00	Alto
Sodio	2.00	Alto	1.50	Alto
Potasio	2.83	Muy alto	3.00	Muy alto
CIC (meq/100g suelo)	35.73	Alto	41.81	Muy alto
Saturación de bases %	99.58	Muy alto	99.85	Muy alto
Materia orgánica %	3.17	Moderado	2.01	Bajo
Nitrógeno total %	0.22	Adecuado	0.14	Moderado
Fósforo asimible (ppm)	4.75	Bajo	5.00	Bajo

CE – conductividad eléctrica
TBI – Total de Bases Intercambiables
CIC – Capacidad de Intercambio Catiónico

Apéndice 7. CRITERIOS DIAGNOSTICOS DE LA CLASIFICACION DE TIERRAS POR SU CAPACIDAD DE USO

Características de la tierra	*Clase I*	*Clase II*	*Clase III*	*Clase IV*	*Clase V-VIII*
Textura del suelo (del horizonte b o en caso del perfil AC , de la capa entre 20-70 cm)	Moderadamente gruesa moderadamente fina	Fina	Muy gruesa o muy fina	Gruesa o muy fina	Muy gruesa
Profundidad efectiva del suelo (cm.) a materiales simples como claypans	Profundo mayor a 90cm	Mod. Profundo 90-50 cm.	Superficial 50-30 cm.	Muy superficial 30-10 cm.	Extremadamente superficial 10 cm.
A materiales muy permeables como: arenas y gravas	Profundo mayor a 90	Mod. Profundo 90-50	Superficial50-30	Muy superficial 30-10	-
Capacidad de retención de humedad mm/120 cm.	Muy alta 120	Alta 120-100	Moderada 100-70	Baja 70-40	Muy baja 40
Permeabilidad (m/24 hr.)	Moderada 0.3-0.8	Mod. Rápida 0.82.0 Mod. Lenta 0.1-0.3	Rápida 2.0-3.0 Lenta 0.5-0.1	Muy rápida 3.0-4.0 Muy lenta 0.2-0.5	Extremadamente r{apida >4.0 Extremadamente lenta <0.2
Fertilidad (apreciación de todas las características físicas químicas	Alta a mod. alta	Moderada	Baja	Muy baja	Muy fuerte Salino >3000
Salinidad(C E micro mhos/ cm. Cuando ocurre por debajo o encima de 60cm	No salino 0 - 400	Lig. Salino 400 – 800	Mod. Salino 800 – 1500	Fuerte. Salino 1500 - 3000	Muy fuerte salino >3000
Microrelieve : desniveles En cm.	Casi plano A moderado	Pronunciadoa30a 60cm las diferencias en elevaciones ocurren sobre distancias horizontales >10 m	Pronunciado 30 a 60cm las diferencias en elevaciones ocurren sobre distancias horizontales >10 m		
Mesorelieve Desniveles en m	Muy débil 0.6-1,0	Débil 1.0 –2.0	Moderado 2.0 – 6.0	Fuerte > a 6. 0	
Mocro relieve (pendiente %) Disección	Plano casi Plano (0 – 1) No disectado	Lig. Ondulado (1 – 3) No disectado	Mod. Alto (3 – 5) Lig. Disectado	Alto (5 – 10) Mod. Disectado	Muy alto (> 10) Fuert. Disectado

Susceptibilidad a la erosión	Ninguno o solo Lig.	Moderada	Alta	Severa	Muy severa
Drenaje interno	Favorable	Algo desfavorable	Marginal	Excesivo	Insuficiente
Peligro de inundaciones	Ninguno	Ocasional	Frecuentes	Anuales	

Fuente. FAO/ NICARAGUA MANUAL 210