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Land Use Intensification and Disintensification in the Upper Cañete Valley, Peru

Esther S. Wiegers,[1,2] Robert J. Hijmans,[1] Dominique Hervé,[3] and Louise O. Fresco[2,4]

Farmers in the Upper Cañete valley have both disintensified and intensified land use. The direction of land use change depends on the production zone in which it takes place. Although land in the distant rainfed agropastoral zone is disintensified through land abandonment and an increase of the fallow period, land in the nearby irrigated agropastoral zone is intensified through more frequent cropping, and the use of high-yielding potato varieties, fertilizers, and pesticides. Simultaneous intensification and disintensification contradicts Boserup's theory of agricultural intensification, which predicts unilinear change for all land use systems within a village territory. Population has decreased in the Upper Cañete valley, but this factor alone cannot explain the dynamics of land use. Land use change is also driven by differences and complementarity between production zones, their distance from the villages, and social, economic, and technological change.

KEY WORDS: production zones; land use change; population; ecology; Andes; Peru.

INTRODUCTION

The literature on Andean agriculture often emphasizes that communities and households may have access to different production zones (e.g., Brush, 1977; Mayer, 1979, 1984; Mayer & Fonseca, 1979; Morlon, 1992). Production zones are clearly bounded, locally named sections of a village

[1]International Potato Center (CIP), Apt. 1558, Lima 12, Peru.
[2]Department of Agronomy, Wageningen Agricultural University, The Netherlands.
[3]The French Scientific Institute for Development through Cooperation (IRD), Laboratory of Agrarian Studies (LEA), BP 5045, 34032 Montpellier, France.
[4]Current address: FAO, SDR, Via delle Terme di Caracalla, 00153 Rome, Italy.

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territory, which have a specific land tenure and land use system (Mayer, 1979). Production zones have specific ecological characteristics, and hence provide different production opportunities, but there are also other differences, such as ownership, management, and distance to the town or market. Having access to different production zones, households are generally involved in the production of a relatively high number of different crops, and different kinds of livestock.

Households allocate their labor and other resources among the activities in the production zones. This leads to land use patterns that are specific for each production zone that can only be fully understood when the different zones are studied simultaneously. As households respond to changes in, for example, prices, technology, and population pressure, land use changes over time. In a situation where people have access to several different production zones, land use change can be complex, because a change in management within one production zone can be related to changes in other zones. Land use change is often discussed in the context of Boserup's (1965) theory. Boserup argues that population growth will lead to land use intensification. As a response to a higher population-to-land ratio, farmers will utilize their land more frequently and employ more labor and other inputs to achieve greater production. Boserup's model of agricultural change has been widely debated (e.g., Grigg, 1979; Robinson & Schutjer, 1984; Pingali *et al.,* 1987; Lele & Stone, 1987; Netting, 1993; Turner II *et al.,* 1993). Rarely addressed in this debate is the role of ecological differences within a village territory. In Boserup's model, differences between land use systems within a village territory are attributed to the duration of the transition process from one production system to another. Ecological and other differences between production zones that may explain the co-existence of different land use systems are mostly ignored, and land use systems are assumed to react in an unilinear way to the changing conditions. Under this assumption, population growth should lead to land use intensification in all land use systems within a village territory, and population decline should lead to the reverse.

In this paper, we discuss land use change in two agropastoral communities, Miraflores and Huantan, in the Upper Cañete valley (Fig. 1). Both communities are agropastoral, with rainfed and irrigated agriculture and livestock production. We focus on changes that have occurred in the last 10 to 20 years, as most evidence is taken from fieldwork conducted in 1986 by Hervé and in 1996 by Wiegers. Our results indicate that differences in ecology and location of production zones within a village territory can lead to distinct, but related, patterns of change within these zones.

THE CAÑETE VALLEY

The Cañete valley is located 150 km southeast of Lima, along the western side of the Peruvian Andes (see Fig. 1). The valley is deeply dissected by the Cañete river, which originates above 5000 masl, from the glaciers that peak the upper part of the valley, and flows towards the Pacific

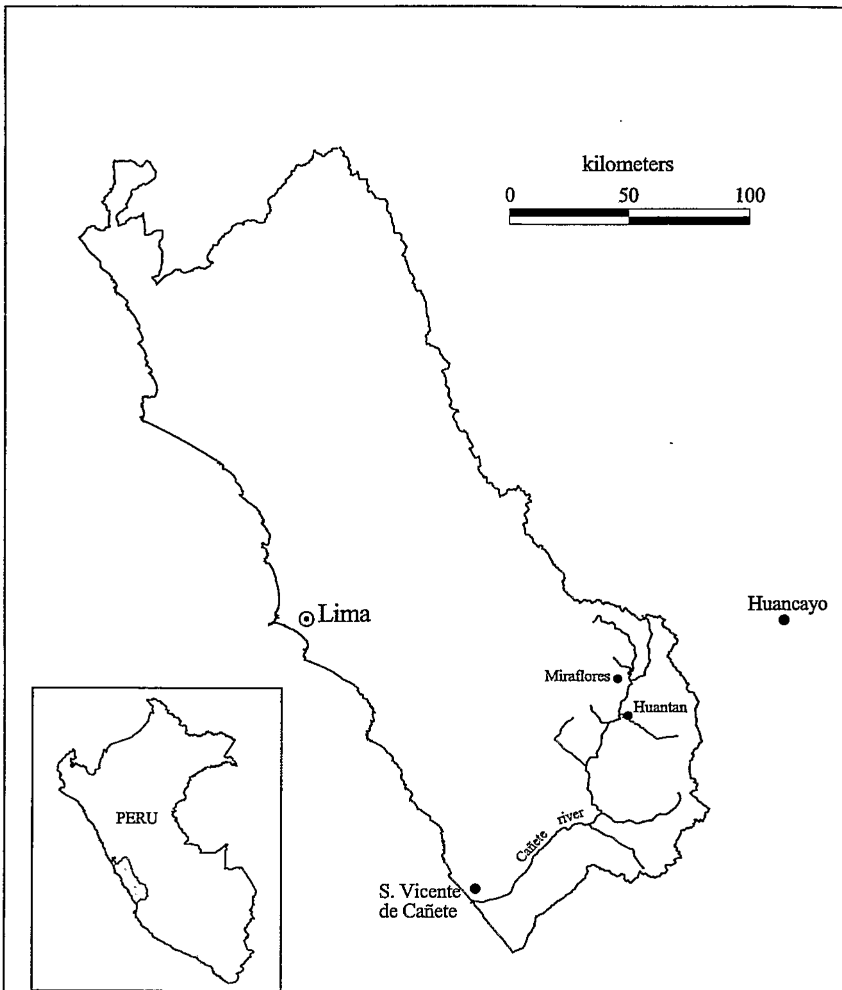

Fig. 1. Location of study area: Peru, Lima department, major towns and the towns where the fieldwork was conducted (Miraflores and Huantan).

Ocean. The valley has a length of 220 km and an area of 6,114 km^2, of which 84% is located above 2000 masl (ONERN, 1970). This article focuses on the Upper Cañete valley, roughly defined as the area above 2000 masl, and mostly in the province of Yauyos.

Precipitation is concentrated in a distinct wet season that lasts from October through March (ONERN, 1970). Precipitation increases with altitude, from less than 200 mm in the lower part of the valley, to about 500 mm at 3000 masl and 1000 mm at 4000 masl. Variation in annual precipitation and in the onset and duration of the rainy season is great. Temperature decreases with altitude. The mean minimum monthly temperature varies between 13° and 20°C at 150 masl; between −2° and 4°C at 3790 masl; and between −4° and 3°C at 4050 masl (Huerta, 1988). Night frost is common during the dry season in the upper part of the valley, but it may occur at any time of the year.

With the exception of the coastal area, the Cañete valley is sparsely populated. The province of Yauyos, that comprises most of the upper valley, has a population density of only 4.1 persons per km^2 (INEI, 1993). This low population density is related to a process of out-migration. Migration to mining centers, the coast, and especially to Lima started early this century and accelerated due to the violence of the *Sendero Luminoso* movement in the late 1980s. According to Brougère (1988), both men (60% of the migrants) and women of the Upper Cañete valley migrate, primarily motivated by employment, education, and marriage. If a community has secondary education, people tend to migrate above the age of 19, if no secondary school is present within a reasonable distance, migration will begin from the age of 12. Out-migration has resulted in a steady population decline in Miraflores and Huantan (Table I). In the province of Yauyos, population has declined at an annual rate of 1.5% between 1961 and 1993

Table I. Population Decline Over the Last Three Decades in the Miraflores and Huantan Communities (Upper Cañete valley, Peru)

	Population size		Population density (per km^2 of agropastoral land)[a]	
Year	Miraflores	Huantan	Miraflores	Huantan
1961	781	1231	13.1	16.1
1972	740	1076	12.4	14.0
1981	547	1091	9.2	14.2
1993	453	929	7.6	12.1

Source: INEI (1995a).
[a]Following Boserup (1981), we eliminated unusable land for the calculation of population density.

(INEI, 1993). Population decline is not unique to the study area but is common for large parts of the western Peruvian Andes (Fig. 2). Because mainly young people between the ages of 12 and 24 have been migrating over the years to the urban areas, the middle-age group of the resident population is now missing. Migration of this age bracket affects social organization within households, as it constitutes the loss of an important part of the family labor resource. As a consequence of migration, households are facing labor shortages, and, within a decade, the wage of daily laborers has doubled or even tripled in some communities.

Out-migration continues despite the end of the political violence and regardless of some improvements in living conditions. Roads have been improved, public bus transport has increased, and many communities have recently obtained electricity, tap water, and television reception via satellite. These changes and school expenditures, which loom large in household budgets (Bey, 1994), have increased the need for cash. Limited access restricts movement of goods to and from the more economically developed coastal regions. Most towns in the Upper Cañete valley are connected with the coast by an unpaved road over which buses travel for about 15 hours one way. Because the communities are not on the main road following the river, buses visit each community only once or twice a week, on their market days. People from the lower parts of the valley use the bus to carry fruits and vegetables to these markets, where they are exchanged for potatoes. Farmers barter their surplus of potatoes in small quantities on a one-to-one ratio; a basket of potatoes for a basket of apples. However, many of the fruits and vegetables, such as mango, tomatoes, and carrots, are no longer bartered and have to be bought. Cheese is the main product sold for cash in these markets. Selling livestock is also an important source of cash.

In addition, there are exchange relations with herders from pastoral communities from the remote highest parts of the valley. Pastoral communities, which do not have agricultural land, secure their access to agricultural products, such as potatoes and oca (*Oxalis tuberosa*), by exchanging their products (wool, meat, blankets, bags, and ropes), and by transporting harvested potatoes from the fields to the town with their llamas.

Land use in the Cañete valley has been studied extensively over the last decades (e.g., ONERN, 1970; Mayer & Fonseca, 1979; Fonseca & Mayer, 1988; Hervé, 1996). The Cañete valley can be subdivided in three main regions: the Desert, the Andean, and the High Plateau Regions (Fonseca & Mayer, 1988). The Desert Region is located between the Pacific coast and about 2000 masl (see Fig. 1). Crops include cotton, maize, sweet-potato, and potato (in winter) and fruit crops like avocado, mango, grapes, and apple in the higher parts. In the Andean Region, between 2000 and

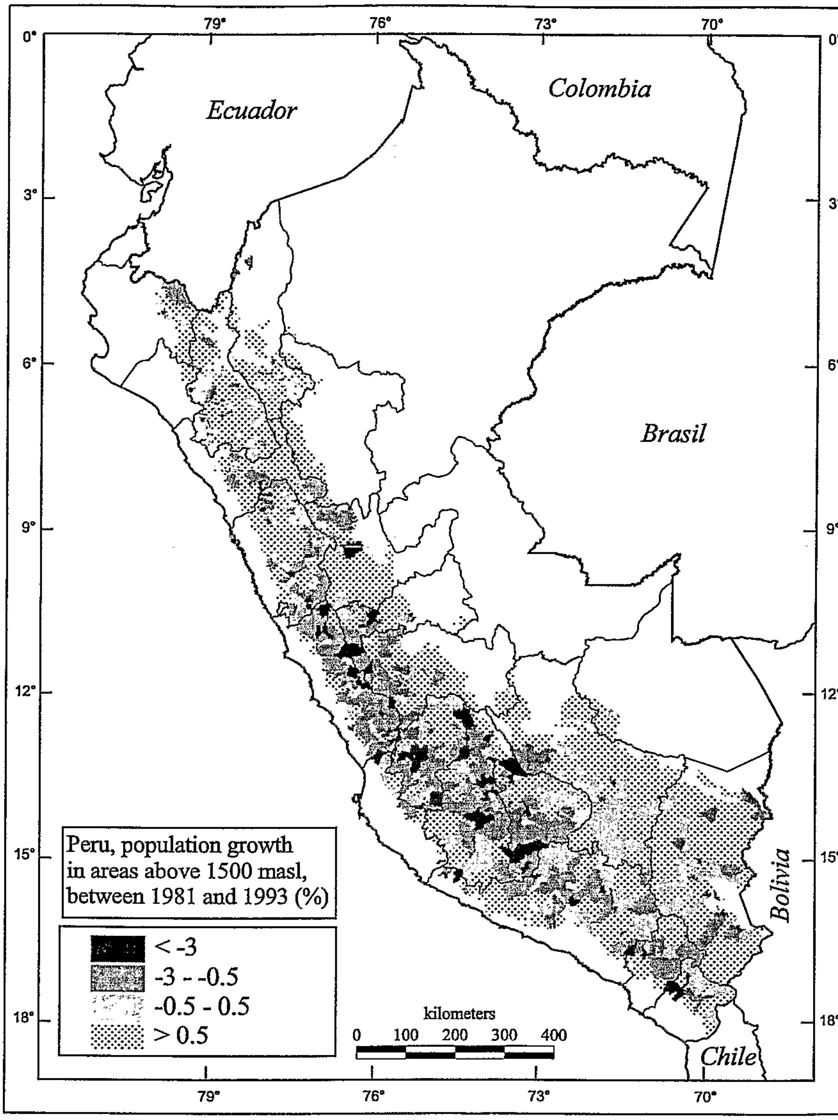

Fig. 2. Population growth and decline in the Peruvian Andes. (Source: INEI, 1995b.)

4000 masl, crops like maize, potato, oca, and barley dominate, and dairy cows are common. The High Plateau Region is above the limits of agriculture and camelids and sheep are the dominant livestock (Fonseca & Mayer, 1988). In general, agricultural land in the Upper Cañete valley is scarce; 40% of the total land is covered by deserts, glaciers, and lakes (Hervé *et al.*, 1989). Most agricultural land is located on steep slopes that are partially covered by small terraces.

Mayer and Fonseca (1979) distinguish 10 production zones in the Cañete valley. The number of production zones a community has access to depends on its location. In the Desert Region, a community may have access to only one zone (irrigated cropland). Communities in the High Plateau Region only have grazing lands. The community limits in the Andean Region are similar to the catchment limits of the Cañete river's tributaries. The territories are perpendicular to the main valley and, owing to the steep gradient of the terrain and subsequent climate, they comprise many different production zones. These may include high areas that are too cold for crops that can only be used for grazing, rainfed and irrigated cropland for potatoes and maize, and areas with tropical fruit trees. Most of these zones are also used for grazing and are surrounded by zones exclusively used for grazing. However, there has been a tendency of these communities to break up into more specialized, smaller communities, with control over fewer production zones (Fonseca & Mayer, 1988; Mayer, 1984).

Land use in the Cañete valley is dynamic. Major changes that have taken place this century include a conversion of maize terraces to alfalfa meadows, on which cows graze for cheese production in the Desert and Andean Regions; a strong expansion of irrigated commercial fruit production in the higher parts of the Desert Region; and a decline of rainfed agriculture in the Andean Region (Fonseca & Mayer, 1988; Mayer, 1984). These changes are similar to those in the Chancay valley, north of Lima (Greslou & Ney, 1986; Lausent, 1983).

CURRENT LAND USE

The two communities studied, Miraflores and Huantan, are agropastoral communities in the Upper Cañete valley. Miraflores is located at 3660 masl, and its agricultural land is distributed over an altitude range of 3200 to 4000 masl. Its agropastoral land area is 5957 hectares, of which 103 are irrigated. Huantan is located at 3290 masl and has its agricultural land distributed over a range of 2530 to 3980 masl. This community occupies an agropastoral territory of 7658 hectares, of which 184 are irrigated (Hervé, 1996). Both Miraflores and Huantan have access to four main production zones: (1) pastoral; (2) rainfed agropastoral; (3) maize; and (4) irrigated agropastoral. The production zones differ in altitude, climate, slope, and soil characteristics, and availability of irrigation water (Fig. 3). Land tenure and degree of communal control also differ between the zones. Community control is especially strong in the rainfed agropastoral zone and in the maize zone. The characteristics of each zone are described below and have been summarized in Table II.

Pastoral Zone

The pastoral zone is located above the climatic limits of agriculture and in lower areas that are not suited for agriculture. In Miraflores and Huantan, pastoral zones occupy 5266 and 6723 ha, respectively (Hervé, 1996). Pasture land consists of *puna* and sub-*puna.* The *puna* is land above 4000 masl, where vegetation is dominated by *gramineacea,* and where camelids (llamas and alpacas), sheep, and some beef cattle are grazed. The best *puna* lands are the *bofedales,* which remain moist due to snowmelts

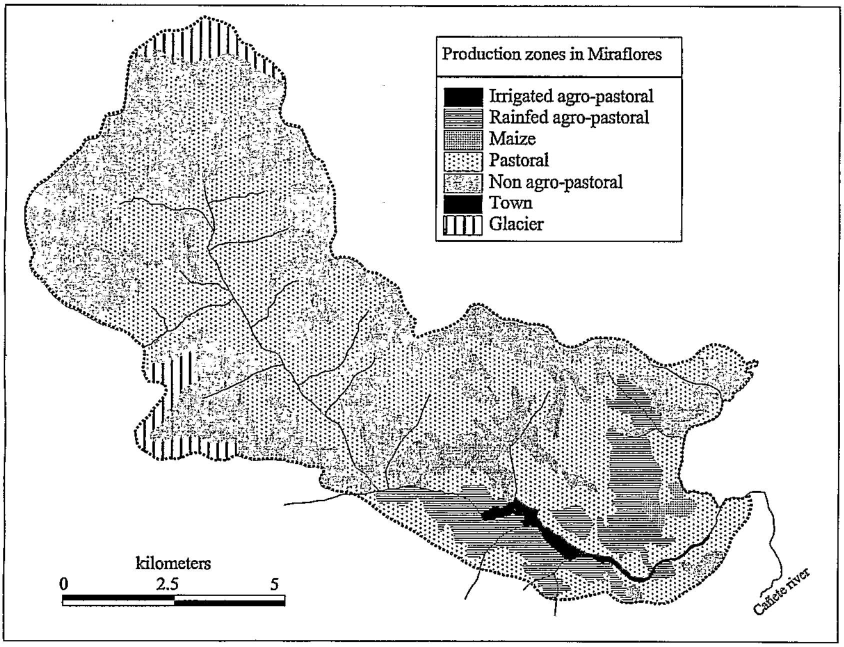

Fig. 3. Production zones in Miraflores. (Source: Hervé, 1996.)

Table II. Characteristics of the Production Zones in Miraflores and Huantan

	Pastoral production zone	Rainfed agropastoral zone	Maize zone	Irrigated agropastoral zone
Local name	(Sub) *Puna*	*Aisha*	*Maizal*	*Potrero*
Altitude (masl)	3000–4800	3400–4000	3000–3600	3000–3800
Walking time to village (hr)	3–4	1–3	0.1–0.2	0.1–0.2[a]
Land use system	Grazing of goats, cattle, sheep, alpaca and llamas	Sectoral fallowing with 3 years of annual crops and 6 to 9 fallow years	Dominantly irrigated maize cultivation	Irrigated annual crops rotated with about 5 years of alfalfa
Infrastructure	Corral, cattle/sheep dip	Earth terraces	Stone terraces, irrigation system	Fenced stone terraces, irrigation system
Land tenure	Communal	Communal and private	Communal and private	Private
Decison-making	Individual	Communal and individual	Communal and individual	Individual

Source: Hervé (1988a), Wiegers (1996).
[a]The section of the irrigated agropastoral zone in which annuals are rotated with a fallow period of alfalfa is at 0.1 to 0.2 hours walking time from the town, the section with only alfalfa is at 0.2 to 0.75 hours.

and provide grasses of good quality throughout the year. They are used during the dry season, especially for alpacas. *Puna* land is located at 3 to 4 hours walking distance from the towns. The lower sub-*puna,* consisting of shrubs and *cactaceae,* is mainly used for wet season grazing by goats and dairy cows. In the *puna* and the sub-*puna,* land is communal property, and the right to use the zones is granted with a payment of a fee per animal. Herding is managed by individual households, reciprocally helping each other in grazing activities, and represents the main source of income for many households.

Rainfed Agropastoral Zone

Land use in the rainfed agropastoral zone, locally referred to as *Aisha,* is organized in a sectoral fallowing system. In this system, land is divided into a number (6 to 12) of large sectors, which are subdivided into small individual plots. Each sector has the same crop rotation and fallow period, but no two sectors begin the cropping sequence in the same year. Hence, the number of sectors equals the number of years with crops and fallow within each sector (Mayer & Fonseca, 1979; Orlove & Godoy, 1986). Decision-making is both at the community and household level. The community regulates the agricultural calendar, mainly by setting the first sowing and last harvest dates. When the ownership of the sectoral fallowing land has remained communal, as in Miraflores, the community authorities annually assign parcels to the households. The households are the actual units of production, which organize and execute the various agricultural tasks according to gender and age.

In Miraflores and Huantan, the total land area within this zone is divided into, respectively, 11 and 9 sectors, which all pass through the same sequence of 3-year crop cultivation. At the end of the rainy season, the soil in one of the fallow sectors is broken (*barbecho*) using an Andean footplough (*chaquitaclla, huiso*). At the beginning of the next season, potato (mainly native varieties) is grown in that sector, followed the next year by Andean tubers (oca, mashua, and olluco), and by barley the third year. After the cultivation period, the sectors in Miraflores and Huantan enter a 9- and 6-year fallow period, respectively, during which all the members of the community can use the plots as pasture land.

Sectoral fallowing systems in the Upper Cañete valley are restricted to an area with an elevation from 3000 masl to the upper limits of agriculture at 4000 masl (Mayer & Fonseca, 1979). Within Miraflores and Huantan, sectoral fallowing systems occupied, in 1986, 589 ha and 751 ha, respectively (Hervé, 1996). The distance of the towns to the sectors varies over a range of 30 minutes to more than 3 hours walking time. Most of the transport of the potato harvest from the fields to the town is done with llamas, by herders from pastoral communities, who receive 1 load out of 10 in return.

Irrigated Agropastoral Zone

The irrigated agropastoal zone (*potrero*) consists of privately owned, stone-fenced parcels, between 3000 and 3800 masl. Potatoes and other annual crops are rotated with a 5- to 10-year alfalfa crop. Alfalfa is used as forage through cutting and direct grazing. Contrary to the rainfed agropastoral zone, in the irrigated agropastoral zone high-yielding potato varieties are grown, sometimes with fertilizers and pesticides. In both communities, the irrigated agropastoral zone is located along the river and road, within 5 to 40 minutes walking distance from the village. Most annual crops are grown within 20 minutes walking time from the village. The more distant part of this zone is primarily used for alfalfa.

Maize Zone

The dominant crop in the maize zone, or *maizal,* is irrigated maize, sometimes in association with other crops, such as beans. During maize cultivation, the production zone is closed to animals, but it is opened after harvest for communal cattle grazing. In fact, the maize zone is a special kind of irrigated agropastoral zone, but it needs to be treated separately because of its different location, crops, management, and local name. The plots in the maize zone are privately owned and managed but the community determines the dates sowing can begin and harvest should have ended, to allow communal stubble grazing by sheep and goats.

The maize zone is generally located along a river and near the village. Miraflores is an exception. Its maize zone is located on a steep slope, approximately 2.5 hours walking time from the village, because this is the only irrigated location within the village territory where maize can be grown without major frost risk.

Cattle Management

All production zones within the Upper Cañete valley are used for cattle grazing. During the rainy season, cattle mainly pastures in the *puna* and sub-*puna* of the pastoral zone, and in the fallow sectors of the rainfed agropastoral zone. During the dry season, when rainfed pasture is not available, cattle graze in the harvested sectors of the sectoral fallowing system, and in the maize zone. After the stubble grazing, cows may graze in the irrigated agropastoral zones. People without access to the irrigated agropastoral production zone send their cattle to the *hechaderos,* free-grazing zones located 3 to 4 hours walking distance from the village, and temporarily suspend dairy production.

The price of fresh cheese varies with the availability of pasture land. During the wet season, when there is sufficient pasture, cheese is sold for the equivalent of about U.S. $2 per kg. During the dry season, when only those households with access to the irrigated agro-pastoral zone can produce cheese, the price rises to U.S. $3 per kg. Cheese sales are an important source of cash income, which is used to meet expenses such as electricity bills or to purchase consumption goods and alcohol. The average yearly surplus production per family is about 210 kg, or U.S. $475. The earnings from cheese production are supplemented with the sale of wool and meat from alpaca and sheep. Cattle provide a form of savings that bear the costs of funeral and wedding expenses and schooling of the children.

LAND USE CHANGE

Land use in the Upper Cañete valley is changing owing to a decrease of the availability of labor because of population decline, an increase in the need for cash and of the influence of the market, and the introduction of high-yielding potato varieties, fertilizers, and pesticides. During the 1986 to 1996 period, in Miraflores and Huantan, land was abandoned, and land use disintensified in the rainfed agropastoral zone and in the maize zone, and the number of cattle declined. During the same time period, however, land use intensified the irrigated agropastoral zone.

Land Use Disintensification in the Rainfed Agropastoral Zone

In the rainfed agropastoral zone, a considerable amount of land has been abandoned and is no longer considered as part of the production zone. Most abandoned terraces are located above the current limits of the production zone. It is not clear what caused the long-term land abandonment, or when it started.

In addition to long-term land abandonment, farmers do not plant crops on all fields within the production zone. In Miraflores, the amount of land that is assigned to individual households has not increased, despite the increasing land-to-people ratio. Thus, as population declines, more land in the rainfed agropastoral zone remains fallow. In Huantan, where land in this zone is private, farmers are not that interested in gaining access to additional land in this production zone, and many fields are left fallow. In Miraflores in 1996, only 40% of the fields in the sector with potato, and 55% of the fields in the sector with Andean tubers, were used, whereas in 1986, 65% of the fields were still used. In Huantan, only 15% of the fields in the potato sector and 10% of the fields in the Andean tubers sector, were used in 1996.

The potato area in Miraflores was unusually small in 1996 as a consequence of the early end of the rains in 1995 that left too little time for field preparation. In a normal climatic situation, the potato area in the rainfed zone would have been 55%, equal to the area cultivated with Andean tubers in 1996, the second crop in the rotation. The relatively strong decrease in Huantan is partly due to the very long distance from the village: 2 or more hours walking for most of the rainfed production zones. In Miraflores the rainfed zones are on average about 1.5 hours away.

In the rainfed agropastoral zone in Miraflores, barley was only grown 4 times during the last 11 years. This relatively strong decrease of barley production can be attributed to decreased barley consumption, labor shortage, and the distance of some sectors. In the years when only a small number of people wanted to grow barley, the community of Miraflores decided to use the sectors for cattle grazing. This did not happen in Huantan. However, few households grew barley in the rainfed zone in 1996 in Huantan, and 90% of the barley sector remained fallow.

The decline of the area with barley leads to an increased fallow period and, together with the stable input use and yields for the other crops, to land use disintensification (Table III). The effect of the increase of the fallow period on livestock production is complex. More land becomes available for grazing at the cost of the loss of barley straw as fodder, and the community may lease its grazing rights in a sector that would otherwise have had barley to an individual household. Nevertheless, the increased fallow period and

Table III. Land Abandonment (Area not Cultivated) in the Rainfed Agropastoral Zones in 1996

	Miraflores	Huantan
Potato sector	45%	85%
Andean tubers sector	45%	90%
Barley sector	100%	90%
Barley sector: average 1986–1996	36%	100%

Source: Hervé (1988b), Wiegers (1996).

Table IV. Cattle Decline in the Upper Cañete Valley, 1986–1996

	Total		Average per household		Number of households with cattle		Fraction of households with cattle	
	1986	1996	1986	1996	1986	1996	1986	1996
Miraflores	791	520	11.8	10.2	67	51	0.40	0.43
Huantan	846	761	10.1	8.1	85	94	0.64	0.78

Source: Hervé (1988a), Wiegers (1996).

the decrease in the number of cattle (Table IV) lead to a decrease in the number of animals per unit of grazing land, i.e., disintensification of the pastoral component of land use in the rainfed agropastoral zone.

Reduction of the Maize Zone

From the beginning of this century, an increased demand for cheese in both urban areas and regional mining centers has resulted in an expansion of livestock production (Mayer & Fonseca, 1979). Irrigated alfalfa production became important, and the need for irrigated land increased. As a consequence, maize land was converted into irrigated agropastoral land, resulting in a reduction and fragmentation of the maize zone (Fonseca & Mayer, 1988; Mayer, 1984). Especially in Huantan, the irrigated agropastoral zone expanded at the expense of the maize zone. In addition to the decrease in area, maize zone agriculture has disintensified. There has been a notable decrease in labor input for weeding, a woman's task. In Miraflores, weeding two times per season was common in 1986, but nowadays people weed only once a season. The decline in labor input is higher in Miraflores than in Huantan, because its maize zone is a 2.5 hour walk from the village, whereas Huantan's maize zone is located only 5 to 10 minutes away. The people of Miraflores used to live just above the maize zone, in a town called Huaquis. However, that location was abandoned in the 1920s when milk production became important, and the town is now located closer to the areas where the cows graze.

Miraflores is the only community where land abandonment within the maize zone has taken place over the last decade. Approximately 35% of the total land available in this zone was not used for crop cultivation in 1996; in 1986 it was 29% (Hervé, 1988a). This decline in the Miraflores maize zone is explained by its location, far away from the town, at the upper limit of maize production, where yields are limited. Moreover, the slopes are very steep for cattle and irrigation water is limited, impeding transformation to alfalfa or potato production.

Land Use Intensification in the Irrigated Agropastoral Zone

In the nineteenth century, land use in the irrigated agropastoral zone consisted of a rotation of annual crops and perhaps a fallow period. In the lower parts, maize was probably the dominant crop. The increasing importance of livestock production from the beginning of this century led to the introduction of alfalfa as a fodder crop. Alfalfa is rotated with potato, *faba* bean, barley, and other annual crops. The shift to alfalfa production has led to changes in community control. Before the introduction of alfalfa, the community set the date for the initiation of the period that plots were open for communal grazing. Now, management reverts to individual households. Farmers constructed walls around private plots to hold in grazing cattle, and there are no more communal grazing periods.

The duration of the alfalfa crop decreased from about 20 years in the 1920s to 10 years in the 1980s. Nowadays, alfalfa only lasts for approximately five years. Farmers attribute this to an increased competition with kikuyo grass (*Pennisetum clandestinum*), considered a weed, that overgrows the alfalfa (Mayer & Fonseca, 1979), perhaps because of declining soil fertility. This has led to more intensive agriculture, where the number of crops have increased and have shifted from alfalfa to more labor demanding crops.

The importance of annual crops in this zone, and especially of potato, has increased. In the 1980s a local development organization introduced modern potato varieties, fertilizers, and pesticides to be used in the irrigated agropastoral zone (Baumann, 1988). Initially, these short-cycle and commercial varieties were introduced to produce potato seed for the lower parts of the valley, but most produce seems to be used for consumption. Miraflores and Huantan's response to the new technology differed. Huantan farmers were assisted by the local development organization in selling potatoes for the Lima market and in managing a seed bank. Farmers in Miraflores opposed commercial potato production in their territory. They argued that the use of improved varieties, chemical fertilizers, and pesticides produce potatoes with high water content and less taste than native varieties. As a result, in 1996 this new technology was used by 18% of the households in Miraflores but by 49% of the households in Huantan (Table V). Adoption is linked to wealth. Households that apply fertilizers and pesticides have at least one member with off-farm employment, or have access to at least five plots in the irrigated agropastoral zone.

Table V. Land Use Change in the Irrigated Agropastoral Zone of Miraflores and Huantan

Attributes	Miraflores			Huantan	
	1976	1986	1996	1986	1996
Land abandonment (%)	0	0	0	0	0
Fallow period (y)	16	10	5	10	4
Cultivation period (y)	2	3	4	3	4
Fallow ratio	0.89	0.71	0.55	0.71	0.43
Households using fertilizers and pesticides in irrigated potato (%)	0	8	18	21	49

Source: Aerial photographs (6-8-1976), Hervé (1988a, 1996), Wiegers (1996).

From Rainfed to Irrigated Potato Production

In both communities, the traditional low-input potato cultivation in the rainfed agropastoral zone is slowly being replaced by more capital-intensive irrigated potato cultivation. The irrigated and the rainfed agropastoral zone are competing for households' labor resources. The irrigated agropastoral zone is located near the village and thus agricultural field labor does not entail long hours of walking and carrying. Despite the increased time needed for irrigating and fertilizing, the total agricultural labor input, that is, time required for agricultural field activities including walking, is lower than in the rainfed agropastoral zone. Lower total labor input and higher production result in higher labor efficiency for the irrigated potato cultivation (Table VI). This difference is even more pronounced when the cost of the llama transport of the rainfed potatoes (i.e., 10% of the produce) is taken into account. Moreover, yield of irrigated potato is more stable as rainfed potato yields may strongly decrease due to frost and drought stress in dry years.

Table VI. Differences in Labor Input, Yield, and Labor Efficiency Between Potato Cultivation in the Irrigated Agropastoral Zone and the Rainfed Agropastoral Zone[a]

	Rainfed	Irrigated, with fertilizers and pesticides
Labor input (hr/ha)	1194	1448
Labor input including hours spent walking to the fields (hr/ha)	1791	1689
Yield (t/ha)	16	24
Labor efficiency without walking (kg/hr)	13.8	16.6
Labor efficiency including walking (kg/hr)	9.2	14.3

Source: Wiegers (1996).

[a]Labor input data is obtained through interviews and observations ($n = 10$) during the entire growing season. Yield data was obtained through crop cuts of small areas ($n = 10$) at harvesting time.

There is, however, a remarkable difference in this transition between Miraflores and Huantan. In Miraflores, in 1996, 21 ha of the total land cultivated with potatoes was located in the rainfed zone with only 6 ha in the irrigated zone. In Huantan, farmers cultivated 13 ha with potato in the rainfed area and 24 ha in the irrigated agropastoral area. This contrast between Miraflores and Huantan is strengthened by differences in the application of modern inputs: 18% of the households in Miraflores versus 49% of the households in Huantan apply chemical fertilizers and pesticides. This difference is related to the fact that Huantan has more dairy production and thus more wealth, and the fact that the development organization had more impact in Huantan.

DISCUSSION AND CONCLUSION

In Miraflores and Huantan land use disintensification exists alongside intensification. There is land use disintensification in the rainfed agropastoral and the maize zones, but land use has intensified in the irrigated agropastoral zone. At the community level, there is a shift of labor input from the rainfed agropastoral zone towards the irrigated agropastoral zone.

Out-migration has led to a strong population decline in the communities of the Upper Cañete valley. According to Boserup, depopulation results in land use disintensification, in all land use systems within a village territory. This shift to less intensive systems of land use is supported by various case studies from different continents (Conelly, 1994; Netting, 1968; Stone *et al.*, 1990; Templeton & Scherr, 1997). However, land use intensification and disintensification occurring at the same time in a village territory cannot be explained by the change in population density alone. The ecological differences between production zones, their spatial distribution, as well as technological and economic change, need to be considered.

In both Miraflores and Huantan, the low input rainfed potato cropping system is being partly replaced by more capital-intensive potato cropping in the irrigated zone. This transition has been stimulated by a local development organization that provided support for the use of more productive potato varieties and inputs for use in the irrigated zone (Bauman, 1988). Boserup (1965) argues that in situations with low and declining population densities, farmers that use shifting cultivation techniques will not shift to irrigated agriculture because the reward of the high labor cost is too small. It may indeed be unlikely that farmers would construct an irrigation system as food demand declines. However, when people already have an irrigation system, they may continue using it, as it allows production of crops that cannot be grown otherwise, or with less production risk or higher yields.

With the increased need for cash and cattle production as the dominant source of income, year-round forage production is of great importance and offsets the high labor cost of irrigation. Having the irrigated alfalfa production system in place, and the need to rotate it with other crops, irrigated potato production is attractive. Yields are more stable and higher, and, because walking distances are short, this compensates for the labor input needed for irrigation and for the use of fertilizers and pesticides. Because of the location of the production zone, irrigated agriculture does not have a lower return to labor than rainfed agriculture. The presence of intensive irrigated agriculture, despite low population densities has also been described by Padoch (1985) for an area of low population density in Kalimantan, where farmers practice intensive rice cultivation because of its high labor efficiency.

The shift from rainfed to irrigated potato cultivation illustrates the importance of the spatial distribution of production zones over a community's territory. According to Von Thünen (1842; *cf.* Netting, 1993), the further from the area of settlement, the less intensive land use tends to be. Although this general rule is confirmed by the land use patterns in the Cañete valley, it is modified by ecology. In Miraflores, the maize zone is far away, and has a relatively intensive land use (i.e., no fallow). This is explained by its location on a relatively low, irrigated, and east-facing slope; it is the only location in Miraflores where maize can be produced without major climate risks.

A major ecological difference between Miraflores and Huantan is the relative extent of their production zones. In Huantan there is more irrigable land and land abandonment in its very distant rainfed zones is substantially greater than in Miraflores. The sharp decrease in importance of the rainfed zone in Huantan is reflected by the fact that there is not much left of the communal control over the sectoral fallowing system. In Miraflores, the irrigable area is smaller. Moreover, the Miraflorinos have a stronger preference for native potatoes and Andean tubers that can only be grown in the higher parts. This preference for specific crops or varieties over caloric efficiency implies that the production zones will continue to co-exist. Further disintensification of the rainfed potato production system is hardly feasible because, apart from a minimum amount of labor and seed, there are no external inputs. The fallow period could be extended by not growing the Andean tubers, but this seems unattractive because it would make the labor demanding soil tillage after the fallow period less labor efficient as only the potato crop would benefit. More land abandonment is likely to occur and barley may disappear altogether from the rainfed zones; in the local diet, it is increasingly replaced by rice (Sautier & Amemiya, 1986).

Given the growing importance of cash, the decrease of the number of cattle is somewhat surprising. Perhaps it is related to the competition with potato production in the irrigated agropastoral zone. Probably more important is the out-migration of youngsters. Children help in the daily herding of the cows, and in the milking and cheese processing. The women who take over the work would have difficulties in increasing the number of cows, as they are already involved in all agricultural field activities and marketing, and are responsible for all household tasks.

The case of the Upper Cañete valley indicates that changes in population density are clearly relevant to an explanation of agricultural change. Labor scarcity is reflected in land abandonment and land use disintensification, and the high wages of day laborers, which are twice that of the coast. This study also illustrates the importance of other factors that determine land use change. By taking these factors into account, one can elucidate why farmers shift potato production from the rainfed towards the irrigated agropastoral zone. They responded to population decline, increasing their labor efficiency by optimizing their labor allocation at the village level, as determined by ecology, distance, economy, and consumption patterns. As many other areas in the Andes with similar land use patterns have a declining or stable population (see Fig. 2), the findings of this paper might be a valid representation of large areas in the high western Peruvian Andes.

The case of the Upper Cañete valley is not unique. Similar changes have been described for other areas in the western Peruvian Andes by Lausent (1983) and Greslou and Ney (1986) for the Chancay valley, and by Guillet (1987), who describes intensification alongside disintensification as a result of the interaction between land use zones in the Colca valley. It can, therefore, be concluded that research on land use change needs to consider environmental differences within a village territory. The environment of different zones within a village territory provides specific opportunities and constraints that may prevent the introduction of a single land use system. Especially in highly variable mountainous environments such as the Andes, that are characterized by exploitation of different production zones, ecological differences among land use zones within community territory need to be taken into account.

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