Land-Use Change in the Cajamarca Catchment, Peru, 1975-1996

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We used land-use maps for different years and areas in the Cajamarca catchment in the northern Peruvian Andes to study changes in land use between 1975 and 1996. Despite population growth, agriculture has not been intensified nor extensified. Neither did we find evidence for crop encroachment into the higher parts of the catchment. The agricultural area has decreased and the proportion of fallow land has increased. There has been a significant increase of shrubs and bare soil at the expense of natural pastures, perhaps indicating overgrazing. The area planted to specific crops has fluctuated, but there has been a clear decrease in the area planted to barley and an increase in wheat. The area with exotic tree species has also increased.

The global increase in population has led to important changes in agriculture, through both intensification and extensification of production. Extensification refers to the use of more land for agriculture, while intensification refers to using agricultural land more intensively, e.g., with shorter fallow periods. Both processes can have a significant negative impact on the environment. Agricultural extensification leads to the loss of natural habitats, and intensification can lead to the loss of biodiversity as well as to environmental pollution, as it often goes hand in hand with increased pesticide and fertilizer use. However, intensification may also lead to increased economic land value and incentives to conserve land resources through such measures as soil conservation (Tiffen and Mortimore, 1994).

It is important to note, however, that patterns of land use change can be rather different between regions and countries, within countries, and even within village territories. Particularly in areas of heterogeneous terrain, such as the Andes, different patterns of land-use change are likely to occur simultaneously; there are reports of intensification as well as abandonment from different parts of the Andes (e.g., Mayer, 1979; Hervé and Ayangma, 2000; Wiegers et al., 1999). Understanding the patterns and causes of land-use change in the Andes could lead to the development of policies that would help avoid some of the more negative consequences of these changes. Insight into the current processes of change could also help in the design of development interventions.

In the present study, we describe land-use change in the Cajamarca catchment between 1975-1996. We used a geographic information system (GIS) to compare a number of large-scale maps (1:25,000) from different years and zones. The Cajamarca catchment is in the northern Peruvian Andes (Figure 1). It is regarded as a region with a distinct ecology, characterized by the jalca or grassland vegetation, in the highest areas, being a transition zone between the more humid paramo Andes in the north and the drier puna Andes in the south (Troll, 1968).
Near Cajamarca town, at 2650 m, average daily temperature is about 13°C and yearly precipitation is 720 mm. The temperature is rather constant over the year, while diurnal differences are about 17°C. There is a clear rainy season between October and April (De la Cruz et al., 1999). The altitude in the catchment is between 2000 m to 4200 m, with about 79% between 2600 m and 3800 m. The distribution of crops by altitude has been used to distinguish main agroecological zones: the cultivated pasture zone (irrigated valley bottoms), the maize zone (lower slopes), the tuber zone (higher slopes), and the natural pasture zone (jalca) (Kohler, 1986; Kohler and Tillman, 1988; Seifert, 1990; Tapia, 1996). Land-use systems in this area are different from those found in the central and southern Andes of Peru (see, e.g., Mayer, 1979; Morlon, 1992). For example, there is not much communally managed land in Cajamarca, and household access to different production zones is limited.

Between 1940 and 1993, the Cajamarca Department had an annual population growth rate of about 1.5%, and the smaller Cajamarca Province (which roughly coincides with the Cajamarca catchment) had a growth rate of 1.7%. Although this is below the national average (2.2% for the same period), Cajamarca has a high

Figure 1. Location of the Cajamarca catchment in Peru and the study areas: 1975/78 (the whole catchment), 1991 (A), 1992/1993 (B), 1996 (C), and the zone with three studies (D).
growth rate for areas in the Peruvian Andes (INEI and UNFPA, 1996; INEI, 1995; Seifert, 1990; Wiegers et al., 1999).

Materials and methods

Land use

Our point of reference is a series of three land-use maps for 1975, 1977, and 1978. Together, these maps cover the whole Cajamarca catchment (211,854 ha), except for a small part in the southwest (25,932 ha). They also cover some areas outside the catchment, which we excluded from our study. We compared these maps with six land-use maps of smaller zones within the Cajamarca catchment, for different years between 1991 and 1996. To facilitate the analysis and because of complementarity in location and similarity of years, we merged the maps for 1975, 1977, and 1978 (Gozalo et al., 1977; Landa et al., 1978; Landa and Johansen, 1978) to form what we will refer to as the “1975/78 map”. We merged three maps for 1991 (zone A, 19,748 ha (UNC, 1991a, 1991b, 1991c)) and two maps for 1992 and 1993 (zone B, 6,916 ha (Chilón, 1993; Saldaña, 1994)). Zone C is based on one map for 1996 (18,732 ha (M. Jimenez, UNC, unpublished)) (Figure 1). We also made a single map for the “1990s,” combining zones A, B, and C, using the most recent data when there was an overlap between zones.

All the maps were made using the same methodology. With air photos (most at a scale of 1:20,000) and fieldwork, map units were delineated and the percentage of different land-use classes within each unit was estimated. Land-use classes include broad categories of vegetation as well as different crops. For example, one map unit could contain 30% maize, 20% wheat, 40% shrub land, and 10% natural pasture. We simplified the maps in some cases by merging classes: rye and oats; potatoes and other tubers; and pulses (beans, lupines, lentils, and green peas). Fieldwork was mostly carried out during the main growing season (November to April). The maps were digitized using ArcInfo (ERSI, Redlands, CA, USA) and analyzed with ArcView (ESRI) and Microsoft Excel.

Land-use change

To study changes in land use, the 1975/78 data were compared with 1991, 1992/93, and 1996. All comparisons were made on the areas in common to the two maps. For a small area of 4,369 ha (zone D in Figure 1), we had an overlap of three studies (1975/78, 1991, and 1996). For all zones, we calculated the fallow ratio as the area of land in fallow divided by the total cultivated area (crops and fallow land).

Tabulating areas for one zone for two different dates allowed overall change to be assessed. As one land unit on a map can contain many land-use classes, we applied the following two rules to estimate which land-use classes changed into which other classes. For all land units, the following applies:

• If a land-use class is present in both time periods, we assume that the minimum of the two areas occupied the same location within that land unit in both periods (i.e., no change).
• The differences in area of one land-use class are proportionally subtracted from (in the case of an increase) or added to (if there was a decrease) the areas of all new land-use classes. The proportion is based on the change in area.

These rules are likely to result in conservative estimates, meaning that some changes may be underestimated, because they do not take into account changes in location of land-use classes within map units.

Results

Land use in 1975/78

In 1975/78, the largest land-use class in the Cajamarca catchment was natural pastures (40%); 38% of the land was cultivated (30% annual crops, 5% fallow,
and 3% cultivated pastures) (Table 1). The most important annual crops were barley and wheat. Annual crops and fallow land were relatively over-represented in the three study zones in 1975/78, in comparison with land use in the catchment as a whole (Table 1).

**Land-use change**

In all study areas, there was an increase in the area with shrubs (+10% for the 1990s), forest (+3%), wheat (+3%), and fallow (+0.6%), whereas there was a decrease in the areas with barley (-7%), pulses (-1%), and natural pasture (-14%) (Figure 2).

Changes in the other land-use classes were generally smaller and inconsistent: in some zones there was an increase and in other zones there was a decrease.

Most of the individual land-use classes in 1975/78 had, for the most part, the same land use as in 1990 (Table 2). This was especially true for land with shrubs, forests, cultivated pasture, and crops (around 70%). On average, over all zones, new forests have been planted on former natural pasture (38% of the new forest), cropland (21%), and on bare soil and shrub land (19%). In the 1990s, 15% of the former area of bare soil was cultivated

### Table 1. Land use in Cajamarca by different areas and years (%).

<table>
<thead>
<tr>
<th>Area</th>
<th>Year</th>
<th>Natural pasture</th>
<th>Shrubs</th>
<th>Forest</th>
<th>Cultivated pasture</th>
<th>Crops</th>
<th>Fallow</th>
<th>Bare soil &amp; rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment</td>
<td>1975/78</td>
<td>40</td>
<td>13</td>
<td>0</td>
<td>3</td>
<td>30</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Zone A</td>
<td>1975/78</td>
<td>27</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>45</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>5</td>
<td>26</td>
<td>3</td>
<td>1</td>
<td>37</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Zone B</td>
<td>1975/78</td>
<td>30</td>
<td>15</td>
<td>1</td>
<td>1</td>
<td>35</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>1992/93</td>
<td>20</td>
<td>23</td>
<td>3</td>
<td>1</td>
<td>34</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Zone C</td>
<td>1975/78</td>
<td>32</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>37</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1996</td>
<td>23</td>
<td>7</td>
<td>6</td>
<td>10</td>
<td>33</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Zone A+B+C</td>
<td>1975/78</td>
<td>30</td>
<td>8</td>
<td>1</td>
<td>4</td>
<td>39</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>1990s</td>
<td>16</td>
<td>19</td>
<td>5</td>
<td>5</td>
<td>35</td>
<td>9</td>
<td>12</td>
</tr>
</tbody>
</table>

![Figure 2](image-url)  
*Figure 2. Change in land use for three zones with different time series (1975/78–1991, 1975/78–1992/93, and 1975/78–1996).*
with crops again, 5% was fallow, and 1% was covered with cultivated pastures. New areas with bare soils or with shrubs were mostly in areas that had natural pastures or crops in 1978.

There was an average decrease of 4% of the total arable land area (Table 1), which includes crops and fallow land, roughly irrespective of altitude (Figure 3). The relative proportion of fallow land over crop land increased. In 1978, there was one ha of fallow for every 5.6 ha of cultivated land (including fallow), while in the nineties there was one ha of fallow for every 4.8 ha of cultivated land.

Land-use change in zone D, for which we had data for three years (1975/1978, 1991, and 1996) confirms the major trends: there is an increase in the areas of bare soil, shrubs, forests, fallow, and wheat, and an important decrease in the areas with barley and natural pastures. Although for most classes the changes between 1975/78 and 1991 and 1975/78 and 1996 point in the same direction, the size of change can be quite different (Figure 4).

Conclusions and Discussion

We have not found any evidence for intensification of land use in the Cajamarca catchment between 1975 and 1996. The total area under cultivation had decreased slightly, and the fallow ratio had increased. Neither did we find evidence for an extension of the agricultural frontier into higher areas; this is often suggested to be happening.

Our results are in line with the observations of Frias (1995) that, despite population growth, the importance of agriculture for employment is decreasing in both absolute and relative terms. However, the results seem to contradict Seifert (1990), who found that fallowing had disappeared on farms of less than 5 ha. This could be because these small farms, although they are the most common

Table 2. Change in land use from one class to another between 1975/1978 and the 1990s (expressed in percent of area of each land-use class in 1975/78).

<table>
<thead>
<tr>
<th>1975/78</th>
<th>Natural pasture</th>
<th>Shrubs</th>
<th>Forest</th>
<th>Cultivated pasture</th>
<th>Crops</th>
<th>Fallow</th>
<th>Bare soil / rocks</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural pasture</td>
<td>39</td>
<td>20</td>
<td>6</td>
<td>3</td>
<td>15</td>
<td>5</td>
<td>11</td>
<td>100</td>
</tr>
<tr>
<td>Shrubs</td>
<td>3</td>
<td>69</td>
<td>5</td>
<td>1</td>
<td>12</td>
<td>4</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>Forest</td>
<td>3</td>
<td>9</td>
<td>69</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>Cultivated pasture</td>
<td>10</td>
<td>3</td>
<td>2</td>
<td>73</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Crops</td>
<td>6</td>
<td>11</td>
<td>2</td>
<td>2</td>
<td>66</td>
<td>8</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Fallow</td>
<td>10</td>
<td>15</td>
<td>3</td>
<td>3</td>
<td>19</td>
<td>43</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>Bare soil / rocks</td>
<td>5</td>
<td>12</td>
<td>5</td>
<td>1</td>
<td>15</td>
<td>5</td>
<td>57</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 3. Agricultural area (crops and fallow) by altitude class for 1975/78 and the 1990s.
farm size, only cover 10% of the cultivated area (Seifert, 1990). The decrease of area planted to tubers and the increase of area under cultivated pasture coincides with Frias’s (1995) study for the whole Cajamarca Department. However, instead of the decrease in wheat described by Frias (1995), we found an increase.

The largest change is an increase in shrub land and bare soil, mainly at the expense of natural pasture. Overgrazing may have led to soil erosion and loss of soil fertility, which in turn, may have led to an increase in unpalatable shrubs. Alternatively, it might be a sign of vegetation recuperating because of a decrease in grazing pressure. The increase in forested areas matches the pattern of agricultural dis-intensification and retraction. Also, over the past few decades, there has been considerable public investment in forestation in Cajamarca, particularly through a local non-governmental organization.

One complication with our data is that we compared not only across different years but also across different zones. The only zone for which we had data for three periods was zone D. However, it appears that for some land-use classes, the effect of classification error overrides the effect of years. In zone A, the areas with shrubs, fallow land, and bare soil were probably overestimated at the expense of natural pasture, because it is quite unlikely that much of the soil that was bare in 1975/78 would be cultivated again 20 years later, as our data suggest. Rigorous definitions of these land-use classes are necessary to improve this type of study. Crops are easier to classify, and the results for zone D indicate that there is considerable variation between years in areas with specific crops.

For estimates of crop area, the timing of the survey is very important. In the off-season, there would be much more fallow and the natural vegetation would be more likely to be classified as bare soil. The spatial effect of rotation on land-use patterns should not be of much importance for this study because it should average out within and between land units.

This study is descriptive in nature and does not offer insights into the factors that drive the changes we observed nor in other important aspects of land use, such as productivity. Further research, including detailed fieldwork, would be needed for
this. At the other end of the spectrum lies the question about the representativeness of our results for a larger area such as the northern Peruvian Andes, which, for example, could be studied with satellite images. Representativeness is an important issue because the Cajamarca catchment may not be typical. Because the catchment is located near an important departmental capital, land use may have been relatively intensive for a long time; then, over the past few decades, there may have been more intensification in other areas. Whereas in our study area, the area of exotic forest (eucalyptus, pine) increased, natural forests in nearby areas are believed to have decreased dramatically over the last 30 years (H. Willet, personal communication; ONERN, 1975). The time period we studied is obviously arbitrary and completely driven by the presence of land-use maps. The results could be put into a wider context using census and household data in which an important milestone would be land reform of the early 1970s.

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References


