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FINAL REPORT

ON A RESEARCH ON

SOIL FERTILITY MANAGEMENT IN CAJAMARCA, PERU

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INDEX

INTRODUCTION

Maintenance of the fertility of the soil is an important component of sustainable land use. In La Encañada, Cajamarca, one of the research sites of CIP´s Project 14 "Sustainable Land use in the Andes", it is believed that soil fertility levels are declining. However, research data are lacking to support this thesis. During 1998 a study on farmers´ soil fertility management was conducted. The results are presented in this report.

The objectives of the research were:

- To assess the effect of farmers' soil fertility management on the maintenance of soil fertility levels
- To analyze how available soil nutrient sources are utilized by farmers
- To select proposals for soil fertility management improvement

The following hypotheses were investigated:

- Current soil fertility management of cultivated fields on the mountain slopes of the La Encañada micro-watershed leads to a net removal of macro nutrients (N, P, K) and a decrease in soil organic matter content
- Alternative soil nutrient sources are available at the farm, but sub-utilized

RESEARCH AREA

The research is part of the “Integrated Fertility Management” component of the Project “Sustainable Land Use in the Andes” of the International Potato Center (CIP) and a contribution to the research program of CONDESAN (Consorcio para el Desarrollo Sostenible de la Ecorregión Andina). It was carried out in its benchmark site La Encañada micro-watershed in the Province of Cajamarca, Peru.

Within the same CIP project a comprehensive agro-economic survey was carried out in the *Ladera Alta* (high mountain slope) agroecological zone of the La Encañada micro-watershed. This area is located between 3200 m. and 3700 m. above sea level and has an extension of 6274 ha.. To be able to share data, and hence reduce data collecting costs, it was decided to work with a subset of farmers, which are participating in this agro-economic survey.

For the agro-economic survey 36 farmers of six hamlets were randomly selected from the census list of the municipality. The subset for this study initially comprised the farmers of the hamlets Usnio and La Victoria. Initially these were 11 farmers. During the research this number was reduced to seven as two farmers were not very interested in collaborating, one was not traceable and another one moved outside the research area. The hamlets Usnio and La Victoria were chosen because farmers live at a "walkable" (1 to 1 ½ hours) distance of the village of La Encañada"

METHODOLOGY

Farmers´ soil management and its effect on soil fertility levels can best be analyzed through a study of the flow nutrients (N, P, K) through the system. These flows are made visible by mapping exercises with the farmers. The magnitude of the flows are determined by farmers´ estimates and field samples. Once the direction and size of the flows are determined nutrient balances of farmers´ fields can be calculated. These balances will show if soil depletion takes place or not.

The research was divided in the following components:

Interviews on the cropping calendar. This information was essential for the planning of the collection of plant samples later on during the research. Farmers were asked to fill in sowing and harvesting and other cropping activities (land preparation, fertilizer application, weeding) on a pre-printed blank calendar.

Interviews on crop rotations. The rotation of crops, especially the incorporation of legumes in the rotation, influences the maintenance of soil fertility. Maps of the farmers parcels, sketched by the colleagues of the agro-economic survey were showed to the farmer and for each actual crop the previous crops were asked together with the history of fertilizer use for each crop, as far back as the farmer could remember. If maps of the survey were not available, these were sketched on the spot. Interviews took place at the actual parcels or after a reconnaissance visit to the parcel.

Mapping the farm and resource flows. Farmers were asked to draw their entire farm. For this exercise the sketches used in the previous interviews were redrawn on a bigger sheet of paper and completed with their house, waste pit and other infrastructure, crops, trees and farm animals. Through interviews the movement of separate plant (edible part, stover, etc) and animal parts, fertilizer, manure and other organic waste was made visible. For each crop an estimate of the yield was asked.

Interviews on the animal production component (fluctuation of the population, nutrition and location of farm animals during the year). In the studied farming system animals are essential agents in the transfer of soil nutrients. Soil nutrients enter the animals through feeding and leave the animal in the form of manure. The movement of these nutrients were made visible by interviews on the nutrition and origin of these inputs. To be able calculate the amount of manure produced during the year the number of animals and its fluctuation during the year was established. The location of the animals shows where the manure is deposited. Information was gathered through a mixture of interviews structured by different techniques such as following a calendar (to determine nutrition and number of animals during the year) and mimicking the movement of the animals with plastic animals over the map drawn by the farmer in the previous exercise.

Quantifying resource flows. The results of the interviews show how nutrients flow through the system. To quantify these flows it was necessary to gather additional data to calculate the nutrient content and quantity of the different sources (crops, manures, ashes, commercial fertilizers). A complete list of the data gathered and the origen of the information can be found in Table 1.

TABLE 1: Data gathered to quantify resource flows and nutrient balances.

	DATA GATHERED	SOURCE OF DATA
CROPS	Total yields of each crops	- interviews described above - data agro-economic survey
	Area of each crop	- data agro-economic survey
	Harvest Index and dry matter content of	
	- barley, wheat, faba bean, pea and lupin	- field samples and analysis in laboratory
	- potato, *oca, olluco, mashua, quinoa,* rye, oats, lentil	- based on literature review
	Nutrient (NPK) content of the crops	- based on literature review
MANURES	Amount of manure produced by cattle, sheep, donkey, pig, chicken and guinea pig	- field samples
	Dry matter content of these manures	- analysis of field samples in laboratory
	Nutrient (NPK) content of these manures	- based on literature review
ASHES	Amount of cooking ashes produced per family	- field samples
	Nutrient content ashes	- based on literature review
COMPOST	Dry matter content	- analysis of field samples in laboratory
	Nutrient(NPK) content	- based on literature review
ORGANIC FERTILIZERS	Dry matter content of *guano de isla* and *gallinaza*	- analysis of field samples in laboratory
	Nutrient(NPK) content	- based on literature review
LOCAL MEASURES	Conversion to metric system of *almud* and *puñada*	- field measurements
	Conversion to metric system of *brazada* and *carga*	- data agro-economic survey

Calculating Nutrient balance on farm level. A number of computer models are available to do this exercise, but these are very site specific. Given the uniqueness of Andean crops and climatic conditions and the few numbers of farmers, data was organized and calculations were made with spreadsheets of *Microsoft Excel.*

RESULTS

The Land

The farmers who participated in the research live on a mountain slope. On average they manage 5 parcels scattered over the slopes (Table 2**)**. The mean parcel size is 2 ha. Three of the farmers own all the land they cultivate. One farmer (the biggest one) has received a small parcel as a mortgage to a loan, but owns 99% of the land he works. The other three complete their cropping area with parcels which they sharecrop, usually owned by family or neighbors who have moved to the village of La Encañada or the city of Cajamarca.

TABLE 2: **Number of parcels cultivated and land area owned by each farmer and the range of altitudes of the farming operation (source: interviews and agro-economic survey)**

Farmer	Number of owned parcels	Number of other parcels	Total number of parcels	Total area of the owned	Altitude (msnm) range of the

	cultivated	cultivated	cultivated	parcels (ha.)	parcels
F1	3	0	3	3.6	3300-3330
F2	4	0	4	11.3	3300-3380
F3	2	2	4	6.2	3400-3600
F4	1	3	4	0.4	3250-3420
F5	6	0	6	7.7	3180-3320
F6	1	5	6	1.1	3180-3500
F7	7	1	8	14.2	3300-3700
Mean	3.4	1.6	5.0	6.4	

They mainly divide their parcels in two classes: the ones with clay soil (*suelo mitoso)* and the ones with loam soils (*suelo polviso).* The clay soils are used for cereals and the loam soils for a potato/Andean tuber (*oca, olluco)* driven crop rotation. Sowing potatoes in clay soils is evaded, because of a higher risk of Late Blight (*Phytophtora infestans*) infestation.

Soils also are distinguished by water retention capacity, normally in a negative manner, i.e referring to parcels as drying up rapidly (*secaron*). This is associated with texture, as these soils also are referred to as crumbly (*granulado).*

Another classification is based on soil color (dark/black or yellowish). These differences are attributed to organic matter content.

Although these differences can be found between parcels, variation within parcels is high also. It is not uncommon to find different soil classes within one parcel.

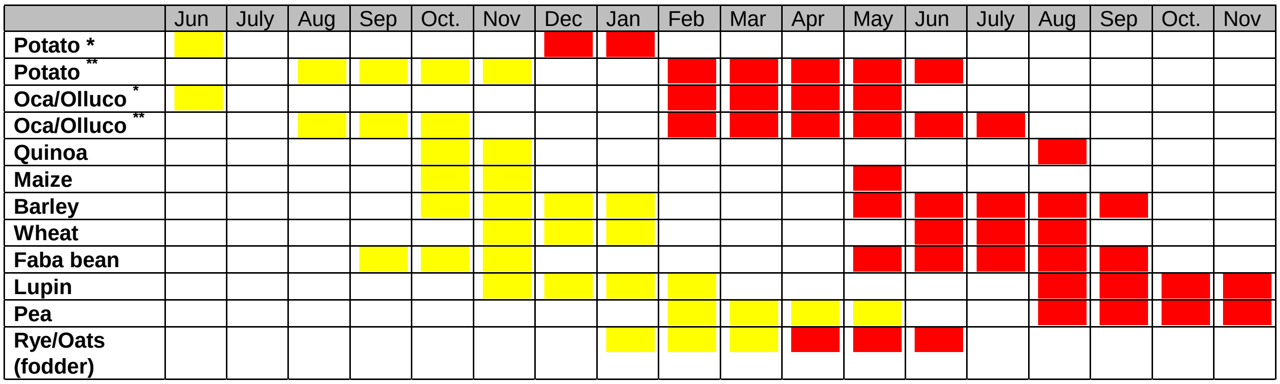
The Cropping System

As agriculture in the area is almost entirely rainfed, the cropping system is organized according to the rainfall. The rainy season usually starts in October- November and lasts until April. Of the 600 mm of annual rain, less than 10 % falls in the dry months June until September. The main cropping season is during the rainy months, while a small amount of tuber crops (potato, *oca* and *olluco*) are sown in the dry season. This so called small campaign (campaña chica) officially starts on 24 June (San Juan).

The other characteristic of the cropping system is the diversity of crops: each farmer grows between 10 to 12 field crops. Each crop has a specific sowing and harvesting period. The cropping calendar (Table 3**)** shows almost continuous sowing from August through April, while harvesting of the different crops starts at the end of December and goes on until November. As a consequence almost the whole year farmers are busy working in their fields; periods of relative idleness are end of September/October when they are waiting for the rains to start land preparation and end of January/February before the beginning of the potato harvest.

Sowing time for each crop is rather flexible. Farmers may sow the same crop at three different dates, with a month between each time. This is to evade the loss of complete harvests, due to climatic hazards, like frosts, drought or excess rainfall. They claim that the will get at least one good harvest with this strategy.

TABLE 3: **The main crops and the cropping calendar in Usnio and La Victoria, La Encañada, Cajamarca (source: interviews)**



NOTES: Yellow: Sowing Period and Red: Harvesting Period
* dry season (campaña chica) sowing
** rainy season sowing

This cropping system also secures freshly harvested food during 10 to 11 months of the year. While doing research in the area, farmers often offer breakfast or lunch. The menu follows the cropping calendar and one notices scarcity in November/December.

With 10 to 12 crops a lot of different rotations are possible. Table 4 shows the sequences registered by asking farmers about the crops sown before the crop found in the field. The majority of the rotations start with potato, most frequently followed in the second year by *oca* and/or *olluco* (these Andean tubers are usually planted in intercrops or in different blocks in the same field). Another popular rotation is potato followed by pea or faba bean. Two consecutive years of potato is rarely found. In the parcels dedicated to cereals, rotations are less diverse with sometimes the same cereal for two to three years or barley alternating with wheat, occasionally breaking this cycle with pea.

TABLE 4: Most frequent crop rotations found in the research area (in order of importance) (source: interviews)

TYPE OF ROTATION	FIRST YEAR	SECOND YEAR	THIRD YEAR
Tuber-tuber	Potato	Oca and/or olluco	Legume
	Potato	Oca and/or olluco	Cereal
Tuber-Legume	Potato - Pea	Fodder rye or oats	Oca
	Potato - Pea	Fodder rye or oats	Lupin
	Potato - Pea	Oca and/or olluco	Lupin
	Potato	Faba bean	(Barley or wheat)
	Oca/olluco	Faba bean	(Barley or wheat)
	Potato (-Fodder)	Lupin	Oca and/or olluco
Tuber-Cereal	Potato	Barley or wheat	Barley or wheat
	Oca/olluco	Barley or wheat	Pea
Cereal-cereal	Barley	Wheat	Barley
Cereal-legume	Barley or wheat	Pea	Barley or wheat
	Wheat/lentil	Wheat/lentil	Wheat/lentil
Cereal-tuber	Barley or wheat	Potato	
	Barley or wheat	Oca and/or olluco	
Legume-potato	Lupin (fodder)	Potato (fodder)	Lupin
	Lupin	Potato	Oca and/or olluco
	Faba bean	Potato	(Faba bean)
Pea-cereal	Pea	Barley or wheat	Barley or wheat

NOTE: between (brackets) = optional

Like *oca* and *olluco*, *quinoa* and faba bean are crops that often are sown in intercrops or mixture of crops. Lentils are usually grown together with wheat.

In the majority of the cases only one crop or intercrop a year is grown. However, pea is almost always sown directly after the potato harvest, without any previous soil preparation. This also may be the case with lupins. Also the fodder crops rye and oats, which are cut green after two to three months, are sown immediately after an early potato crop or are sown as a relay or intercrop.

After 3 to 4 years of cropping the parcel is left fallow for a period of 1 to 3 years. According to the data in Table 5, the area is left fallow amounts 23.8%. This implies 1 year of fallow after three years of cropping. However, Table 5 also shows that the % of area under fallow varies between farmers. That is because it depends on the specific situation of each farmer. For instance F1 and F6 bought part of the land which they are cultivating less than three years ago and hence recently started the rotation cycle (often land recently bought has remained fallow for several years). F4 has recently returned from Lima to start his farming operation. So the percentages of fallow land for these farmers, and the overall mean, will rise in the future.

TABLE 5: Percentage of the total owned area left under fallow for the seven farmers studied (source: agro-economic survey)

Farmer	Number of Parcels	Total Area (ha.)	Fallow Area (ha)	% of the area fallow
F1	3	3.6	0.7	19.8
F2	4	11.3	3.4	30.5
F3	2	6.2	2.4	38.5
F4	1	0.4	0.08	21.0
F5	6	7.7	1.3	17.1
F6	1	1.1	0.2	14.0
F7	7	14.2	3.7	26.2
Mean				23.8

There are a number of factors influencing the number of years of cropping and number of years of fallow, such as the natural fertility of the field, type of crops and farmers fertility management. Usually the cropping sequence is interrupted when yields of the crops decline (lower than the farmer expects to harvest).

During the fallow period the fields are grazed by the farmers´ animals (sheep, cattle, donkeys). An important criterion for taking fallow land into cultivation again is when the land does not yield pasture for the animals anymore (this pasture is not sown, but appears naturally). This shows that the cropping system can not been seen separately from the animal system. Both are highly interrelated. In the following section the animal production system will be described.

The Animal Production System

Diversity is not only a characteristic for the cropping system, but applies to the animal production system as well. The most important species are listed in Table 6. Due to consumption, selling, diseases, food availability and births the population fluctuates over the year. The numbers in Table 6 are the averages over the year.

TABLE 6: The farm animal population of the seven farmers studied (average number of animals over the year) (source: interviews)

ANIMAL	F1	F2	F3	F4	F5	F6	F7	MEAN
Sheep	5	6	17	-	8	27	12	10.7
Cattle	2	2	4	-	1	3	2	2
Donkey	-	2	1	-	1	1	2	1
Horse	1	-	1	-	-	-	-	0.3
Pig	2	1	2	1	2	-	1	1.3
Chicken	6	18	6	11	4	6	4	7.9
Guinea Pig	12	19	22	19	9	6	30	16.7

NOTES: * Number refers to animals owned by the farmer; F1 and F4 share animals with their parents. * The size of the guinea pig population is difficult to determine as these are kept loose in the kitchen and are difficult to count; the number of guinea pigs is probably higher * The chicken population was wiped out by a disease (*la peste*, the last three months of 1998

Donkeys are kept as pack animals. Usually one is sufficient for this purpose. Horses are used for transport and for threshing grains. These need more and higher quality feed than donkeys. Therefore most farmers opt for renting a horse, for threshing purposes. Number of both species does not fluctuate during the year.

Land preparation is done by a pair of cattle, so most farmers maintain two during the year. Some farmers sell their cattle after land preparation to buy pesticides for the potato crop or when there are possibilities to buy more land. With the cash of the potato harvest a new pair is bought. Also selling cattle, when these are not needed, eliminates the burden of supplying these with feed. Cattle manure is an important fertilizer.

Like cattle, sheep also function as the farmers saving account: being bought with surplus cash of the harvest and sold when inputs (fertilizers, pesticides) need to be bought. Besides that, these supply wool, meat and manure.

Pigs are raised on kitchen wastes and what these can find in the harvested fields around the house, where they roam around freely or tied to a peg, during day time. The night is spent in a shelter close to the house. Also, pigs are taken to harvested *oca* fields to get rid of diseased and not harvested tubers. When fattened these are sold.

Chicken are kept for egg production and fed with wheat and barley grains. They usually do not reproduce, which is attributed to the altitude.

The other important manure source are the guinea pigs. These rodents are kept free in the kitchen or in a cage. The manure is collected every 1 to 3 days. These animals fetch a good price on the market. But more importantly, guinea pigs are obligatory food for important occasions such as feasts, conclusion of construction works and the potato harvest. These happenings reduce the population. Further their propagation rate highly depends on the availability of quality feed.

The determining factor in animal production is the availability of feed. As in all rainfed farming systems scarcity occurs during the dry season. This can be illustrated through the nutrition calendars of guinea pig, cattle and sheep (Tables 7 to 9). Horses follow a pattern similar to cattle, while the nutrition of donkeys is more similar to sheep. Guinea pigs are fed with weeds freshly cut from the field close to the house or the field where the sheep are herded during day time. Together with cattle these also receive fodder rye and oats. These crops are periodically sown from the onset of the rains until the end of the rainy season and cut green two months after sowing. Sowing in intervals during this period secures availability of high quality feed during the first four to five months of the year. When this feed is getting scarce, cattle is fed with stover of tuber crops (potato, *oca*, *olluco)* and peas (harvested green). But from July onwards the feeding situation is getting worse and the diet mainly consist of cereal straw which is of low quality. From October to December feed is scarce and better endowed farmers resort to buying hay in the village of La Encañada.

TABLE 7: **Nutrition sources for Guinea Pigs during the year and number of farmers (each "+" represents a farmer) applying the source (source: interviews)**

Month	**Fodder Rye and Oats**	**Weeds cut in fields**	**Cereal and Pea Straw**	**Hay bought in La Encañada**
January	++++	++++		
February	++++	+++++		
March	+++++	+++++		
April	++++++	+++++		
May	++++++	+++++		
June	++	+++++	+	
July	+	++++	++	
August		+++	++++	+
September		+++	++++	+
October		+++	++++	++
November	+	+++	+++	++
December	+	+++	++	++

TABLE 8: **Nutrition Sources for cattle during the year and number of farmers (each "+" represents a farmer) applying the source (source: interviews)**

Month	**Fodder Rye and Oats**	**Crop Residues**	**Hay bought in La Encañada**	**Free Grazing in Crop Stubbles**	**Free Grazing on Fallow Land**
January	++++	+	+		++++++
February	++++	+			++++++
March	+++++	++			+++++
April	+++++	+++		++	+++
May	+++	++++	+	+++	++
June	++	+++++	+	+++	++
July		++++	+	+++	++
August		++++++	+	+++++	
September		++++++	+	+++++	
October	+	++++++	++	++++	++
November	+	+++++	++	++	++++
December	++	+++++	++	++	++++

Cattle are fed by the farmer early in the morning and at the end of the day. During daytime these are herded in fallow fields, where they graze on natural (not sown) vegetation. From April until the end of the year these also graze in the stubble of harvested fields. Cattle usually enter the harvested fields first to graze the bigger weeds and some of the leaves of the cereal straw. Sheep follow to graze what the cattle has left. To the fallow fields sheep, cattle and donkey are taken together.

TABLE 9: **Nutrition Sources for sheep during the year and number of farmers (each "+" represents a farmer) applying the source (source: interviews)**

Month	**Free Grazing in**	**Free Grazing on**

	Crop Stubbles	Fallow Land
January	+	+++++
February	+	+++++
March	+	+++++
April	+++	+++
May	++++	++
June	++++	++
July	+++	+++
August	++++	++
September	+++++	+
October	++++	++
November	+++	+++
December	+++	+++

Table 9 shows that sheep only live on what can be found in fallow and stubble fields. The herd usually rotates between different fields, staying one week in each field (depending on the size of the field and herd) and returning to the same fallow field every 40 days. With this system one needs to maintain five to six areas fallow. Two farmers deliberately maintain certain fields fallow to herd their stock. Others have to rent areas for herding. Farmers clearly express that the animals only can and are being herded in fields they own or sharecrop. In the dry season vegetation on the fallow fields also gets scarce. This is temporarily solved as in the same period crops are harvested and so more land becomes available for the animals. But the situation becomes problematic from October to December when the first crops are sown.

From the perspective of fertility management it is important to notice that animals are almost entirely fed with sources from the proper farm and sharecropped areas. Only in exceptional cases nutrients are brought in from outside. So, animals are only responsible for the recycling of nutrients within the farming system and the movement of these between different fields. How the nutrients move within the system will be described in the following sections.

Farmers' soil fertility management

Farmers` apply the following practices to manage the fertility of their soils:

- Fallow
- Application of animal manures
- Recycling of household wastes
- Recycling of crop residues
- Incorporation of leguminous crops in the rotation
- Application of commercial fertilizers

Below each of these practices will be described.

Most fertility practices are primarily directed to benefit potato, the first crop in the rotation, while crops that follow benefit from possible residuals. Table 10 shows that in the season 1997/1998 the seven studied farmers planted 21 fields with potato. In 16 cases (76%) the field had been left fallow before the potato crop. In four of the other five cases potato was the second crop in the rotation, two times following a first potato crop. Furthermore, an intercrop with a legume (lentil, faba bean) in the mixture preceded potato in four of the five cases.

TABLE 10: Land use before the potato crop and fertility management of the fields of the seven studied farmers in the cropping season 1997/1998 (source: interviews; agroeconomic survey).

Farmer	Land use before potato	Majadeo[1] before potato	Commercial Fertilizer applied[2]	Equivalent in kg/ha of N	P	K	Area (ha)	Yield[3] (kg/ha)
F1	Fallow	-	100 kg AmP; 50 kg PCl; 200 kg guano de isla	63	66	49	0.21	11.5
F1	Potato	-	150 kg AmP; 50 kg PCl; 200 kg guano de isla	67	72	46	0.58	10.1
F1	Fallow	+	50 kg AmP; 25 kg PCl; 200 kg guano de isla	65	65	51	0.28	5.8
F1	Fallow	+					0.04	2.7
F2	Fallow	-	1200 kg AmP; 450 kg Urea; 450 kg PCl	272	0	135	1.67	17.1
F2	Fallow	-	600 kg AmP; 200 kg Urea; 200kg PCl	336	216	155	0.64	13.7
F2	Fallow	-	100 kg 12-12-12	56	24	46	0.22	12.4
F2	Fallow	-	600 kg AmS; 200 kg Urea; 200kg PCl	120	0	56	1.80	11.8
F2	Fallow	-	150 kg AmP; 50 kg Urea; 100 kg PCl	72	47	67	0.75	4.7
F3	Triticale/Lentil	-	100 kg gallinaza	7	23	4	0.23	0.9
F3	Fallow	+					0.18	0.2
F4	Fallow	+					0.07	8.6
F5	Lupin	-	50 kg 12-12-12	30	13	25	0.20	5.1
F6	Fallow	+	50 kg 12-12-12	27	12	23	0.22 [4]	1.7 [4]
F6	Fallow	-	50 kg 12-12-12	20	9	17	0.30	0.7
F7	Wheat/Lentil	-	150 kg 12-12-12	69	30	57	0.26	7.1
F7	Fallow	+					0.04	5.2
F7	Potato/Faba b.	+	150 kg 12-12-12	60	26	50	0.30	2.9
F7	Fallow	+	100 kg 12-12-12	52	23	43	0.23	2.1
F7	Fallow	-					0.33	1.7
F7	Fallow	-					0.34	0.6
	76% Fallow	38% maj.	71% of the fields receives com. Fertilizer					

NOTES:
[1] *Majadeo* is a system in which sheep or cattle are confined in a field during the night in order to fertilize the parcel with their droppings (see below).
[2] Abbreviations synthetic fertilizers: AmP = Ammonium Phosphate (*Fosfatodiamonico*)
AmS = Ammonium Sulphate (*Sulfatodiamonico*)
PCl = Potassium Chloride (*Cloruro de Potasio*)
[3] Yields are year specific: the 1997/1998 season started with drought and ended with excess rainfall, due to "*El Niño*", which caused a high incidence of Late Blight (*Phytophthora infestans*)
[4] Yield/ha is underestimated as about 1/3 of the field was planted with *oca* and *olluco*

During the fallow years at daytime the fields are grazed by sheep and cattle, which are depositing manure and urine while grazing. However, this is an extensive system of recycling nutrients. It is not managed, so the nutrients are deposited where these drop, in an irregular way. Also the animal feces are not worked into the soil and hence are prone to losses due to volatilization and run off with rainwater.

A better managed system is the *majadeo* system. When the animals return from grazing in the fallow these are kept confined in a field until the next morning. Sheep are kept in a mobile corral of 20 m^2. These are moved to an adjacent block of 20 m^2 every two weeks. At the same time the field is tilled to incorporate the manure in the soil. In one year about 500 m^2 can be covered with an average herd of 10 sheep. Cattle are tied to peg with a rope of about 1.5 m. So a pair can cover another 400 m^2 a year. This is clearly not sufficient: the size of most potato fields sown in the season 1997/1998 was between 2000 m^2 and 7500 m^2 (Table 10)

The lack of animals is not the only reason why only 38% of the fields (Table 10) in the season 1997/1998 were treated with the *majadeo* system. Farmers do not apply this system to fields which are far away from the house, as at night animal robberies are quite common. One farmer solves this problem by saving the manure and transporting it to more remote fields. Several farmers have two fields with a house, which permits them to move with the animals during the season (during their live farmers acquire new fields and may decide to move to bigger/more fertile fields, leaving their old house behind, or sometimes buy a field with the house of the former owner). The *majadeo* system also is applied to fields which are sown with crops like *oca* and *olluco.*

At night pigs and chicken stay in a shelter close to the house. The manure which these leave may be collected. All farmers collect guinea pig manure. As these stay in the kitchen, some farmers collect the manure with the ashes of the cooking fire, while others collect the ashes separately. Farmers take these manures and ashes every three to seven days to fertilize yellowish spots in fallow fields These paler areas in the field are believed to be less fertile. So these farmers are practicing "Precision Agriculture", which is a new trend among soil scientists in Western countries. Usually the manure is applied to areas which are not treated with the *majadeo* system and for practical reasons again more remote fields receive no or less of these fertilizers.

A recent change for La Encañada farmers is composting. This technique was introduced two to three years ago, by the NGO CARE with the installation of a drinking water system. Household wastes and animal manures are composted in a pit, dug next to the house. All farmers dug the pit and most farmers say they do make compost, as they committed themselves to the *ingenieros.* Only two of the seven take it more seriously, though. It seems that initially only household wastes were composted. Now one farmer claims to compost all chicken and guinea pig manure, while the other throws these manures in the pit in a less regular way. The first one applies compost to potato, while the latter farmer uses it to fertilize faba bean and quinoa.

This ultimate farmer also exercises another unusual practice. Despite causing the laughter of his neighbors, he collects eucaliptus leaves, "officially" only of his own woodlot. The leaves are burned in fields, which do not receive *majadeo* and the ash is incorporated in the soil. He applies as much as he can during the dry months. He started with this practice five years ago, because he lacked sufficient amounts of kitchen ashes. He says he obtains good potato yields. Besides that, potatoes are free of *gusanos*, probably larvae of the potato tuber moth.

Crop residues are mainly recycled through animal fodder. This is the case for the straw of wheat and barley and the stover of potato, *oca*, *olluco*, and pea. The only plant parts, which are not eaten by the animals are the stalks and empty pods of lupins and faba beans. The stalks of lupins are an important source of fire wood and hence return to the field as ash. Faba bean stalks only are used for this purpose, when fire wood is scarce. Usually these are burned together with the empty pods in the field. Pods of lupin also are burned at the threshing side. Ashes are applied to the same field or left at the side. In the case of burning only phosphorus and potassium are recycled.

Leguminous crops are harvested completely. Crop residues may be burned and the ashes returned to the field, losing its nitrogen. This means that bulk of the possible nitrogen fixed by these crops is removed with the harvest, leaving only the part in found in the roots to the soil. The farming system as a whole may benefit of some of the nitrogen fixed by peas and lentil and excreted in the manure of cattle fed on stover.

As shown above not enough animals are available to fertilize potato fields only with the *majadeo* system. Most farmers buy commercial fertilizer but the amount and type they use varies between farmers and between fields of the same farmer. Only one of the seven studied farmers uses high amounts of synthetic fertilizer in most of his fields: between 56 and 336 kg of nitrogen/ha, between 0 and 120 kg of phosphorus/ha and between 46 and 155 kg of potassium/ha (Table 10). Two farmers apply intermediate amounts (about 60 kg of nitrogen/ha); another two add low amounts of fertilizers to their fields (between 20 and 30 kg of nitrogen/ha). Of the remaining two farmers one applied a low amount of organic fertilizer (*gallinaza*), while the farmer with the smallest field only relied on three years of fallow and *majadeo*.

The composite fertilizer 12-12-12 is popular among the farmers of the hamlet La Victoria, which is situated further away from the main road. These argue that by using a composite they only have to buy and carry one type. The two farmers that use higher amounts of different kinds of fertilizers live close to the main road. Both farmers also are or have been involved in seed potato production programs of the Ministry of Agriculture and produce on a more commercial scale. Their wives are sisters. Together with other relatives they bought the synthetic fertilizers in bulk in the city of Cajamarca. The farmer with the biggest farm owns a truck, which they used to transport the sacks of fertilizer home. The transportation business seems his primary enterprise. During the season 1998/1999 he brought a large amount of *gallinaza* returning from a trip to the coast.

For the other farmers transportation is a problem. They buy the fertilizers in the city of Cajamarca, ship the bags with public transport to the village of La Encañada and than use a donkey to bring the bags home. Transport costs are considerable: Farmers say that they pay a passenger fare for each bag of fertilizer they take on the minibus. The donkey usually is paid in kind.

In open questions many farmers say they use *guano de isla* or *gallinaza*. However, when asked what they applied specificly in the season 1998/1999 only two farmers actually used these organic fertilizers. One bought *guano de isla* in the office of the Ministry of Agriculture in the village of

La Encañada and added this to his mixture of synthetic fertilizers. The other farmer bought two bags of *gallinaza* in La Encañada as it is the cheapest fertilizer. Remarkably the farmer who applied the largest amount of chemical fertilizer, claimed in other occasions that he preferred *gallinaza* over synthetic fertilizers and that he always applied 25 tons/ha of this organic fertilizer to his potatoes. Apparently he did not like his chemical experience of the season 1997/1998, because the next season he ordered several trucks of *gallinaza* from the coast (in potato sowing season huge trailers, each carrying 35 tons of *gallinaza*, are driven from the coast up into the mountains).

Farmers say they do not apply *guano de isla* or *gallinaza* to the early potato sowings, because the weather is still dry. Without sufficient rain these fertilizers are said to burn the crop. The season 1997/1998 started with drought and this may be a reason why most farmers did not use these fertilizers.

Table 10 shows variation in amount of fertilizers between fields of the same farmer. Farmers say they do not use fertilizers or use less fertilizers for fields which receive *majadeo*. However, the table does not show this pattern. Also, more fertilizer is used for fields, which they consider less fertile.

The potato yields (Table 10) reached in the season 1997/1998 varied from 17 ton/ha to less than 1 ton/ha. Farmers which applied considerable amounts of external fertilizers obtained higher yields. Although yields were influenced by drought, pests and diseases (especially Late Blight and Andean Potato Weevil), these figures also indicate that fertility management may be a problem in this system. In the next sections we will study this issue more in depth by analyzing the flow of nutrients at farm level and the nutrient balance at parcel level.

Nutrient Flows and Balances

The farming system can be divided in three components: the crop production system, the animal production system and the household. A simplified model of the system and its nutrient flows are depicted in Figure 1. This model is based on the NUTMON model developed for Kenyan farming systems (van den Bosch et al, 1998) and adapted to the situation in the research area. In this study the focus is on the nutrient balance of the crop production system, which is the nutrient balance of the soil. Hence for the other two systems, only the flows that influence the crop production system are considered

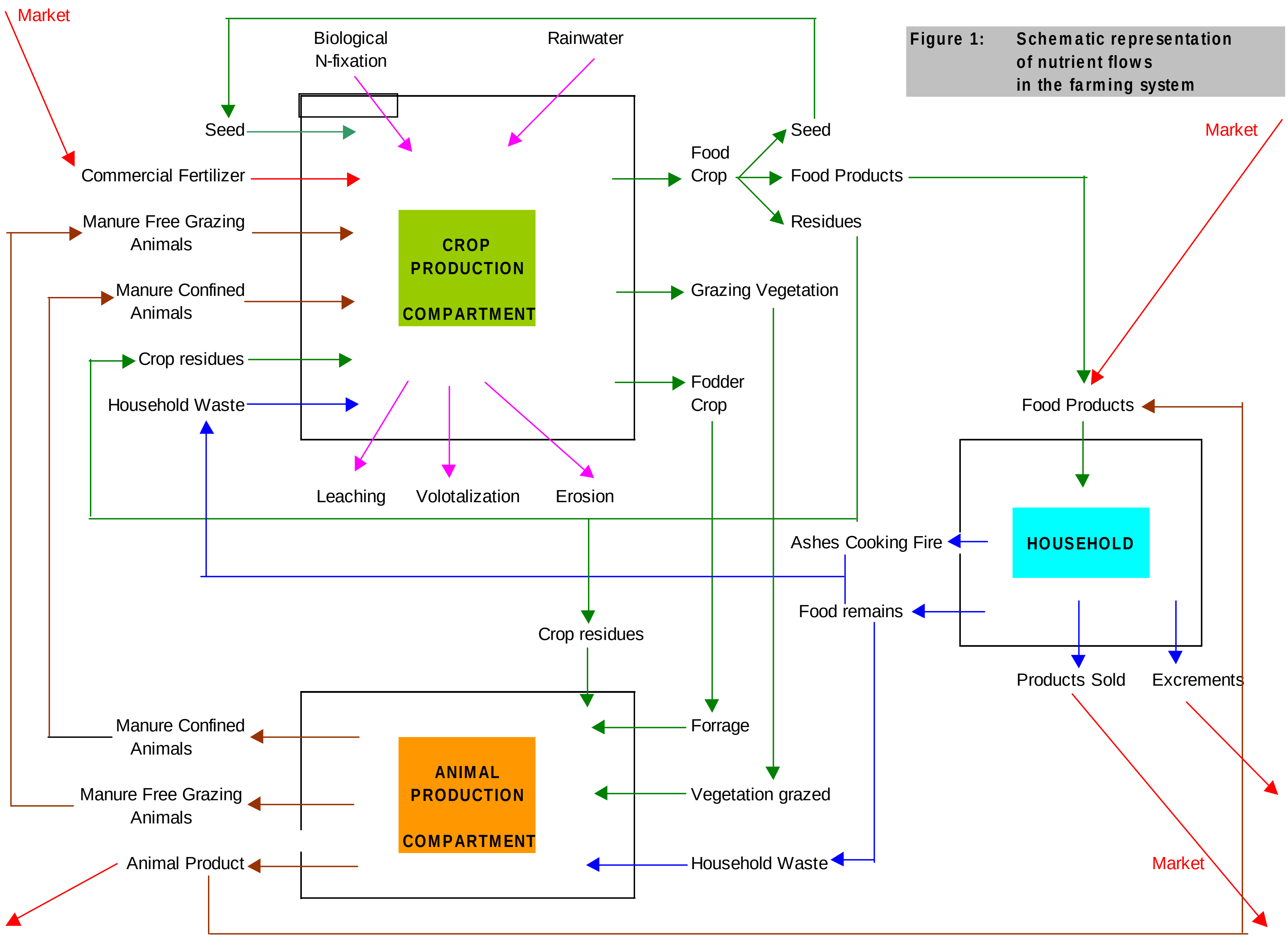


Figure 1: Schematic representation of nutrient flows in the farming system
Market
Biological N-fixation
Rainwater
Seed
Commercial Fertilizer
Manure Free Grazing Animals
Manure Confined Animals
Crop residues
Household Waste
CROP PRODUCTION COMPARTMENT
Leaching
Volotalization
Erosion
Food Crop
Seed
Food Products
Residues
Grazing Vegetation
Fodder Crop
Market
Food Products
HOUSEHOLD
Ashes Cooking Fire
Food remains
Products Sold
Excrements
Crop residues
Manure Confined Animals
Manure Free Grazing Animals
Animal Product
ANIMAL PRODUCTION COMPARTMENT
Forrage
Vegetation grazed
Household Waste
Market

The flows are:

		Input	Output
A1	Seeds	x	x
A2	Commercial Fertilizer	x	
A3	Manure of confined animals	x	
A4	Manure of free grazing animals	x	
A5	Household Waste	x	
A6	Food Products		x
A7	Crop Residues	x	x
A8	Fodder		x
A9	Vegetation Grazed		x
A10	Rainwater	x	
A11	Biological N-fixation	x	
A12	Leaching		x
A13	Gaseous Losses		x
A14	Erosion	x	x

The nature and direction of flows A1 to A9 were determined through interviews using mapping and calendar techniques. Below each flow will be discussed separately.

A1: Seeds. Farmers save seeds of the previous harvest for the next sowing. Occasionally seeds are acquired to replace lost seeds or to obtain new varieties. The data of the agroeconomic survey confirm that the latter does not occur very frequent. Therefore this flow is considered neutral (input=output)

A2: Commercial fertilizers. The types and quantities of these fertilizers used during the season 1997/1998 are discussed on pages 12-13. Data of samples, which were brought by farmers and institutes to the soil analysis laboratory of the INIA research station in Baños del Inca, Cajamarca show that the quality of the organic fertilizers *gallinaza* and *guano de isla* is highly variable. Nitrogen content in *gallinaza* ranged from 1.1% to 2.2% while in *guano de isla* values between 0.5% and 10.5% were found (Annex 1). It is said that providers mix their product with sand. For further calculations the mean values of these samples were used.

A3: Animal Manure of confined animals. This refers to dung deposited at night by cattle and sheep in the *majadeo* system and to the excrements which are collected by the farmers from the night stays (chicken and pig) or their permanent stay (guinea pig). To calculate the amount of manure which these "confined" animals leave, the deposits were gathered and weighed. Table 11 shows that the amount of manure produced by each farmer varies from 888 kg/year to 3341 kg/year, with an average of 2049 kg/ha. Most manure is produced by sheep and cattle. These manures are recycled to the fields. During collection and transport a part is lost, though. Also nutrients disappear due to leaching and volatilization.

Table 11: **Manure produced (kg/year) by the animals of each farmer participating in the research (source: field samples; interviews)**

	Manure produced in kg dry matter/year							
ANIMAL	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**MEAN**
Sheep	201	347	744	179	615	1688	657	633
Cattle	376	614	1387	336	548	1248	1005	788
Donkey	12	365	183	46	183	208	488	212
Chicken	88	258	84	162	55	87	58	113
Guinea Pig	211	353	393	347	157	110	548	303
TOTAL	888	1937	2791	1070	1558	3341	2756	2049

A4: Animal manure of free grazing animals. This is the dung left by sheep, cattle and donkeys while herded in fallow land and crop residues. It is estimated that the animals stay 1/3 of the day in the fallow fields and 2/3 of the day confined. So the amount of manure left in the fallow fields is half of the manure left while confined.

A5: Household waste. The main part consists of ashes of the kitchen fire. These are saved by farmers and applied to the fields. Samples of the daily production were weighed. An average family produces 430 kg of ashes a year. Lupin stalks and eucalyptus are the most important source of fire wood. Two farmers compost kitchen waste but claim to only produce 100 kg of compost a year. Also a part of the food remains are fed to pigs and the nutrients end up in the fields through the manure

A6: Food Products. These are taken to the household. A part is consumed by the family, while the rest is sold. In both cases the nutrients are lost for the system (except for a small part that ends up as kitchen waste or is fed to the animals).

A7: Crop Residues. Through the mapping exercise the destination of crop residues was determined. Most are fed to the animals (Table 12) and return to the fields as manure. Quinoa, lupin and faba bean stems are used for the cooking fire and eventually return to the field in the form of ash. Pods of the latter legumes are burned directly in the field. To estimate the amount of residues, crop samples were taken and harvest index was determined (Annex 2).

Table 12: Destination of crop residues (each "x" represents one farmer) (source: interviews).

CROP	**RESIDUE**	**DESTINATION:**		
		Animals	**Fire Wood**	**Field**
Potato	Stover	xxxxxx		x
Oca/*Olluco*	Stover	xxxx		xxx
Quinoa	Stems		xxx	
Barley/Wheat	Straw	xxxxxxx		
Pea	Stover	xxxxxxx		
Lentil		xxxxx		
Faba bean	Stems		xxx	xxx
	Empty pods			xxxxxx
Lupin	Stems		xxxxxxx	
	Empty pods			xxxxxxx

A8: Fodder. These are the cereals rye and *Avena strigosa* which are cut green and mainly fed to cattle and guinea pig. The nutrients are recycled to the fields through the manure of these animals

A9: Vegetation grazed. The vegetation grazed by animals of fallow land. No estimates of this flow were made.

A10: Rainwater. Samples were not analyzed because of lack of funds

A11: Biological N-fixation. The amount of nitrogen fixed by legumes depends on soil fertility and climatic conditions (e.g. drought stress diminishes the amount of N fixed). No reliable information was available to estimate the amount fixed by the farmers´ crops. For further analysis of nutrient balances it was decided to attribute 50% of the nitrogen removed by leguminous crops to biological fixation. This probably is a conservative estimate.

A12-A14: Leaching, gaseous losses and erosion. These flows are difficult to measure. The underlying processes depend on the characteristics of soil and climate and hence estimates found in literature are site specific. It was decided not to incorporate these flows in the analysis.

To quantify these flows farmers were asked to give estimates of crop yields and inputs (seed, fertilizer). Further plant, manure, ash, compost and organic fertilizer samples were taken to determine harvest index and dry matter content. The amount of manure produced per animal and other local inputs, such as kitchen ashes was measured. As no funds were available to analyze plant and manure samples for nutrient (N, P, K) content, this information was derived from literature (Annex 3 and Annex 4). For some crops no data could be found in literature. Estimates for these were based on data of similar species (Annex 5)

The following steps were calculating the magnitude of these flows and the nutrient balances on parcel level. Major uncertainties in these calculations are the amount of nutrients lost due to inefficient handling of manure, leaching and volatilization. It was decided not to incorporate these losses in the calculations as doubtful estimates only would confound the outcome and take this into account with the analysis of the results. Also biological nitrogen fixation is unknown. It was decided to: attribute 50% of the nitrogen removed with the harvest to biologically fixed nitrogen; this probably a very conservative estimate. Further the amount of vegetation grazed by animals was not taken into account.

Table 13 gives a summary of the flows between the different sub-systems and the amount of nutrients which enter the crop production system with commercial fertilizers. Obviously nutrients leave the system through the household (home consumption and sales). These are balanced by external fertilizers in the case of the two farmers who use more of these inputs (F1 and F2). In the other cases the animal production system helps to reduce the nutrient deficit. Almost no feed is brought in from outside, so these nutrients come from the vegetation grazed, while herded and weeds cut of the fields by the farmers. However, as explained above, not all the nutrients of manure becomes available for crop production. If, for instance, one would estimate that only 25%

of the nutrients potentially recycled through manure become available, overall nitrogen balances for all six farmers who use animal manure become negative. Mining of phosphorous and potassium is not a problem for the majority. Only F5 shows considerable deficits of potassium. He mainly removes this element with the stalks of lupins and faba beans.

F5 manages an intensive cropping system and leaves relatively little space for animal production . However, a considerable amount of his area is sown with leguminous crops (faba bean, lupin). Part of his nitrogen deficit may be caused by an underestimation of the nitrogen fixation by these crops.

TABLE 13: The flow of nutrients (N, P, K) in Kg between the Crop Production System and the Animal Production System, Household, direct recycling (to the crop production system) and External Inputs (Fertilizers) for the seven farms.

Crop Production System		Animal System			Household			Crop Production			External inputs			Total		
		N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
F1	Sum In	23	8	14	0	2	0				97	103	70	120	113	84
	Sum Out	16	3	27	99	19	27	3	0	5				119	22	59
	Balance	**7**	**5**	**-14**	**-99**	**-17**	**-27**	**-3**	**0**	**-5**	**97**	**103**	**70**	**2**	**90**	**25**
F2	Sum In										563	174	475	563	174	475
	Sum Out	74	14	95	402	75	143	6	1	10				482	90	248
	Balance	**-74**	**-14**	**-95**	**-402**	**-75**	**-143**	**-6**	**-1**	**-10**	**563**	**174**	**475**	**80**	**84**	**227**
F3	Sum In	79	29	59	0	2	0				1	5	1	81	36	60
	Sum Out	4	1	4	17	2	9	1	0	2				22	4	15
	Balance	**75**	**28**	**54**	**-17**	**-1**	**-9**	**-1**	**0**	**-2**	**1**	**5**	**1**	**58**	**32**	**44**
F4	Sum In	29	11	18	0	2	0							29	12	18
	Sum Out	10	2	12	26	4	8	1	0	1				37	6	21
	Balance	**19**	**9**	**6**	**-26**	**-3**	**-8**	**-1**	**0**	**-1**	**0**	**0**	**0**	**-8**	**6**	**-3**
F5	Sum In	41	15	30	1	7	4				8	5	5	49	26	39
	Sum Out	44	11	27	140	19	58	13	2	22				198	32	108
	Balance	**-3**	**4**	**3**	**-140**	**-13**	**-54**	**-13**	**-2**	**-22**	**8**	**5**	**5**	**-148**	**-6**	**-69**
F6	Sum In	74	26	52	0	2	0				42	18	35	116	46	87
	Sum Out	29	7	21	68	9	21	5	1	8				102	17	50
	Balance	**46**	**19**	**31**	**-68**	**-8**	**-21**	**-5**	**-1**	**-8**	**42**	**18**	**35**	**15**	**29**	**36**
F7	Sum In	71	27	53	0	2	0				66	29	55	137	57	108
	Sum Out	61	14	43	93	14	35	4	1	6				158	29	84
	Balance	**10**	**12**	**10**	**-93**	**-12**	**-35**	**-4**	**-1**	**-6**	**66**	**29**	**55**	**-21**	**28**	**24**

Table 13 also shows that the internal recycling of the crop production system - residues that directly return to the fields- is negligible.

The nitrogen, phosphorous and potassium balances on parcel level are presented in Table 14 to Table 16. For nitrogen half of the parcels show a positive balance; however if we reduce the contribution of animal manure to 25% only one quarter of the parcels show a positive balance.

For phosphorous and potassium the majority of the parcels, more than 70% show a positive balance (this does not change dramatically discounting the contribution of animal manure).

TABLE 14: Nitrogen balance in Kg per parcel, Kg/ha and the amount of Nitrogen that entered the parcel through animal manure and external fertilizers

NITROGEN in Kg							
		P1	P2	P3	P4	P5	P6
F1	Balance	-3	-3	26	-7		
	Balance/ha	-2	-5	26	-15		
	Animal Manure	11	8	3	1		
	External Fertilizers	17	0	80	0		
F2	Balance	-14	-44	317	261		
	Balance/ha	-24	-11	190	52		
	Animal Manure						
	External Fertilizers	0	54	434	444		
F3	Balance	48	18				
	Balance/ha	15	6				
	Animal Manure	56	23				
	External Fertilizers	1	0				
F4	Balance	11	-14	1			
	Balance/ha	29					
	Animal Manure	22	3	4			
	External Fertilizers	0	0	0			
F5	Balance	-13	-13	-21	-22	-23	-10
	Balance/ha		-39	-7	-96	-10	-6
	Animal Manure	0	3	27	2	2	7
	External Fertilizers	0	0	8	0	0	0
F6	Balance	50	3	-22	3	9	-4
	Balance/ha	46	1				
	Animal Manure	59	7	2	0	0	7
	External Fertilizers	6	12	0	6	18	0
F7	Balance	4	1	12	-4	5	-3
	Balance/ha	1	1	2	-9	3	-5
	Animal Manure	47	4	13	3	2	1
	External Fertilizers	30	0	18	0	18	0

TABLE 15: Phosphorus balance in Kg per parcel, Kg/ha and the amount of Phosphorus that entered the parcel through animal manure and external fertilizers

	PHOSPORUS in Kg						
		P1	P2	P3	P4	P5	P6
F1	Balance	16	3	73	-1		
	Balance/ha	12	5	75	-3		
	Animal Manure	4	3	1	0		
	External Fertilizers	18	0	85	0		
F2	Balance	-3	15	-26	105		
	Balance/ha	-6	4	-16	21		
	Animal Manure						
	External Fertilizers	0	35	0	144		
F3	Balance	25	8				
	Balance/ha	8	3				
	Animal Manure	21	9				
	External Fertilizers	5	0				
F4	Balance	7	-2	1			
	Balance/ha	19					
	Animal Manure	8	1	2			
	External Fertilizers	0	0	0			
F5	Balance	-2	-3	3	-5	-4	5
	Balance/ha		-8	1	-20	-2	3
	Animal Manure	0	1	10	1	1	3
	External Fertilizers	0	0	5	0	0	0
F6	Balance	21	4	-5	2	6	1
	Balance/ha	19	1				
	Animal Manure	20	2	1	0	0	2
	External Fertilizers	3	5	0	3	8	0
F7	Balance	15	1	9	0	6	0
	Balance/ha	5	1	1	-1	4	-1
	Animal Manure	18	2	5	1	1	0
	External Fertilizers	13	0	8	0	8	0

TABLE 16: Potassium balance in Kg per parcel, Kg/ha and the amount of Potassium that entered the parcel through animal manure and external fertilizers

POTASSIUM in Kg							
		P1	P2	P3	P4	P5	P6
F1	Balance	5	-1	29	-9		
	Balance/ha	4	-2	30	-19		
	Animal Manure	7	4	2	1		
	External Fertilizers	14	0	56	0		
F2	Balance	-7	-25	168	103		
	Balance/ha	-13	-6	100	20		
	Animal Manure						
	External Fertilizers	0	50	225	210		
F3	Balance	32	14				
	Balance/ha	10	5				
	Animal Manure	41	17				
	External Fertilizers	1	0				
F4	Balance	3	-7	1			
	Balance/ha	8					
	Animal Manure	13	2	3			
	External Fertilizers	0	0	0			
F5	Balance	-14	-13	-10	-24	-9	1
	Balance/ha		-39	-3	-101	-4	1
	Animal Manure	0	3	20	1	1	5
	External Fertilizers	0	0	5	0	0	0
F6	Balance	35	0	-14	3	10	0
	Balance/ha	32	0				
	Animal Manure	41	5	0	0	0	5
	External Fertilizers	5	10	0	5	15	0
F7	Balance	4	2	16	-3	9	-1
	Balance/ha	1	1	2	-5	6	-2
	Animal Manure	34	3	11	3	2	1
	External Fertilizers	25	0	15	0	15	0

Parcels which reach positive or less negative balances are those which receive external fertilizers or a more intensive fertilization with animal manure. In the majority these are sown with potato. So, the balances for each field may vary from year to year, depending on which crop(s) of the rotation are grown that specific year. This indicates that available nutrient sources in the system are concentrated on the potato fields. These nutrients may come from external fertilizers or transported from fallow and other fields through animal manure. The latter case applies specially to fields close to the home of the farmer, which are treated with the *majadeo* system.

DISCUSSION AND CONCLUSIONS

Methodology

The bulk of the information was gathered through interviews on the farming system. A sequence was used which started with “easy to get” information like the cropping calendar and rotations and ending with more complicated information such as the movement of animals and manure with mapping exercises. The advantage of the sequence was that the author, who did not know the farming system, got to understand the system in the process and was more prepared to guide the more complicated interviews as he would have been with little knowledge of the system. Also it enabled to build up confidence between researcher and farmer family. Disadvantage of the sequence was that about eight interviews per family were necessary to complete all the information required. Part of the information gathered in the early stages also pop up during the more complicated exercise. So, less sessions might have been necessary when one would have started with the mapping exercises and resource flows, completing the missing bits of the easy to get information at the end.

Reducing the amount of interviews also is essential because farmers are very occupied during almost the whole year and only can be contacted during a short period of the day. As the researcher used a slow mode of transportation, on average one farmer a day could be contacted.

Data may be biased by gender. Men are the family heads and obvious persons to be interviewed. Women are reluctant to speak when their husbands are not at home, especially if it is about production details of the economic enterprise of their husband. When husbands are present they move to a save distance of the site of the interview. In the ultimate phase of the study this barrier was disappearing, though.

The research had to be carried out with a limited amount of means and resources. This implied that certain data could not be gathered. The animal production system is crucial for the fertility management and the calculation of nutrient balances. For a more complete calculation detailed information on animal nutrition (amounts fed and grazed) would have been necessary. This would require monthly monitoring of animal nutrition and manure production. Also calculations are based on farmers’ estimates for yield. It is not known how reliable this information is. It would have been better to combine these estimates with real field measurements. Another uncertainty is the use of estimates for nutrient content of crops and manure from literature. It is not known how close these resemble the real nutrient contents under the specific conditions of the local farming system. Samples were gathered, but not analyzed due to lack of resources.

Results

The research was started with two hypotheses:

- Current soil fertility management of cultivated fields on the mountain slopes of the La Encañada micro-watershed leads to a net removal of macro nutrients (N, P, K) and a decrease in soil organic matter content
- Alternative soil nutrient sources are available at the farm, but sub-utilized

Only one farmer uses high doses of external fertilizers, while two others use moderate amounts. However, the current soil fertility management system does not cause considerable deficiencies in phosphorous and potassium (only one farmer is removing higher amounts of potassium from his soil). The nitrogen balances depend on the estimates for the efficiency of manure management and losses due to leaching and volatilization. If no losses are taken into account the balance is positive for 50% of the fields. However, if we assume that only 25% of the nutrients become available for crop production, 75% of the fields become deficit in nitrogen.

A closer look to the management of manure shows that losses are likely to occur. This is certainly through for the manure deposited by herding animals. This is left in the field without any protection from the sun and the rain. In the *majadeo* system manure is better managed. However, it still only is worked into the soil every two weeks. The other important manure sources are guinea pigs and manure of animals (cattle, donkeys) left at night close to the house. In the majority of the cases these animals are not confined to a certain place. So losses occur with the collection of the manure and also when these are applied to the fields without tillage. This shows that a scenario with high losses due to inefficient nitrogen management is not unrealistic and nitrogen mining is likely to occur.

Animal manure is not the only available nutrient source, which is sub-utilized. Leguminous crops, such as pea, faba bean and lupin are another source of nitrogen. While pea stover is recycled as animal feed, the nitrogen in stems of faba bean and lupin is lost when these are burned. However, recycling these products to the fields would conflict with the need for fire wood.

The organic matter balance was not calculated due to lack of information.

Alternatives and further research

Most nutrient balances are positive or close to zero, if manure would be utilized optimally. There are several ways to achieve this. Collection can be improved by confining animals at night in simple stables or keeping guinea pigs in cages. Farmers in another region of Cajamarca were taught to do this by a development organization and acknowledged its effects. Losses due to volatilization and leaching can be reduced by storing manure in areas, which are protected from sun and rain, and by working these materials into the soil, directly after its application.

Yields are low, which implies that only balancing the nutrient input and output is not enough. More nutrients should enter the cycle. This can be done by buying commercial fertilizers. Price and transportation seems to be a limitation for farmers, who live far from the village of La Encañada and do not have their proper means of transport.

Another entry, not explored yet, is the replacement of part of the fodder crops (rye oats) with leguminous fodder crops. Nitrogen fixed by these crops would be recycled through manure. A research should be started to select possible leguminous species for this purpose.

The overall biomas production of the system is low. This can be attributed to altitude and climate, which causes slow growth rates. However, a view on the landscape shows that large areas, such as the borders of the fields could be occupied to increase biomas production. Planting hedges with shrubs, which could be used as fodder would increase the amount of nutrients passing through the cycle. This also needs a research on potential species.

Availability of feed limits the size of the animal population. Sheep and cattle depend on fallow for their nutrition. Most land is left fallow to recuperate its fertility. This study gives the impression that nutrients are removed from fallow lands by grazing and are transported through manure to the cropping fields. This seems to be contradictory to the objective of fallow. Therefore a more detailed study on what exactly happens with the fertility of fallow land is recommended. Key questions are

- Does soil fertility improve during fallow and how fast?
- What are the processes, which cause this improvement?
- How much nutrients are removed by grazing animals?

These questions should give us clues about improving the animal carrying capacity of fallow. A better managed fallow would allow farmers to increase their herd, and hence increase manure production.

ANNEX 1: Nutrient content of different samples of *gallinaza* and *guano de isla*, bought from 1995 to 1997 by farmers and institutes in Cajamarca

Sample	N (%)	P (%)	K (%)	Organic Matter (%)	Sample	N (%)	P (%)	K (%)	Organic Matter (%)
Gallinaza	1.6	1.7	0.5	32	guano de isla	7.6	4.3	1.6	9.0
Gallinaza	1.4	4.1	0.3	18	guano de isla	6.3	10.5	1.7	7.0
Gallinaza	1.2	4.5	1.5	26	guano de isla	11.0	8.5	1.6	10.0
Gallinaza	1.3	2.4	1.5	29	guano de isla	2.0	10.0	1.6	9.2
Gallinaza	1.2	2.2	1.6	27	guano de isla	9.3	8.5	1.6	10.8
Gallinaza	1.2	6.6		18	guano de isla	4.2	9.1	1.3	4.6
Gallinaza	1.1	7.0		17	guano de isla	7.1			6.0
Gallinaza	1.1	6.7		18	guano de isla	6.6			6.0
Gallinaza	2.6	4.8	0.2	26	guano de isla	13.0	9.0	2.1	9.5
Gallinaza	2.2	12.5			guano de isla	13.0	10.0	1.8	9.2
					guano de isla	12.5	9.4	1.9	11.2
					guano de isla	12.2	3.3	1.8	9.2
					guano de isla	1.0	4.8	1.3	0.7
					guano de isla	0.5	1.1	1.0	1.0
Mean	1.5	5.3	0.9	23.4	Mean	7.6	7.4	1.6	7.4
Range	1.1-2.2	1.7-12.5	0.2-1.6	17-32	Range	0.5-13	1.1-10.5	1.0-2.1	0.7-10.8
Coef.of Var.	32.5	57.7	65.3	23.1		56.5	40.6	17.7	43.9

Source: elaboration of data provided by the soil laboratory of INIA - Baños del Inca

ANNEX 2: Harvest Index and % humidity of different crops

Crop	Variety	HI			% humidity			Farmer
		grain/total	straw/total	pods/total	grain	straw	husks	
Barley	Zapata	0.64			6.7	5.7	5.2	F2
Barley	81	0.68			6.2	6.0	20.7	F6
Faba bean	Mixture	0.21	0.72	0.07	3.5	6.5	8.4	F3
Lupin	"Común"	0.26	0.53	0.20	1.0	9.5	8.7	F7
Lupin	Blanco Local	0.20	0.65	0.14				F1
Lupin	Blanco Local	0.20	0.67	0.14				F5
Lupin	Blanco Local	0.19	0.62	0.18				F6
Pea	Arvejón Blanca	0.42	0.50	0.08	35.7	26.6	47.1	F3
Pea	Arvejón	0.36	0.54	0.10	7.0	5.7	10.4	F1
Pea	Arvejón Blanca	0.34	0.56	0.10	6.3	6.1	8.7	F2
Pea	Barbilla	0.43	0.47	0.10	6.6	7.9	10.4	F6
Wheat	Singer Colorado	0.64			6.5	5.8	7.7	F5
Wheat	Singer	0.47			6.1	7.1	21.7	F4
Wheat	Gavilán	0.55			6.7	5.4	6.9	F4

Source: Field samples

ANNEX 3: Estimates of Harvest Index (HI), Dry Matter content (dm) and Nutrient Content of different crops found in Literature

Crop	Plant part	HI	dm (%)	N (%)	P (%)	K(%)	Source
barley			87.1	1.7	0.3	0.4	farm
lupin	seed		90.2	6.9			Gross et al.
maize			85.0	1.6	0.3	0.4	farm
oats		0.24					Montenegro R.
oats			87.1	1.7	0.4	0.5	farm
oca	tuber	0.65	17.1				Hijmans et al.
oca	tuber	0.70	20.2				Hijmans et al.
oca	tuber		13.8	0.9			Gross et al.
oca	tuber			1.4	0.3	2.0	Kays et al.
oca	leaves				0.5	2.6	Kays et al.
olluco	tuber		12.4	1.4			Gross et al.
pea			85.4	4.2	0.4	0.5	farm
potato	tuber	0.70	31.9				Hijmans et al.
potato			23.0	1.7	0.3	2.1	farm
quinoa	seed		90.5	2.5			Gross et al.
standing hay			90.0	0.7	0.1	0.4	farm
straw			85.0	0.6	0.1	1.0	farm
wheat			85.6	2.2	0.4	0.4	farm

ANNEX 4: Estimates of Nutrient Content of Animal Manure and Wood Ash found in Literature

Type	N (%)	P (%)	K (%)	source
cattle	1.93	0.66	1.12	Augstburger
compost manure	1.52	0.54	0.85	Augstburger
compost vegetal	0.85	0.48	1.10	Augstburger
cuy	2.49	0.84	1.50	Augstburger
chicken	4.1	2.1	3.1	farm
donkey	1.33	0.87	2.16	Augstburger
horse	1.38	0.74	1.38	Augstburger
pig	1.79	0.95	1.74	Augstburger
sheep	1.73	0.54	1.26	Augstburger
wood ash	0	0.39	0.02	Augstburger

ANNEX 5: **Estimates of Harvest Index (HI), Dry Matter content (dm) and Nutrient Content of different crops which could not be found in literarture**

CROP	Plant Part	HI	dm %	N (%)	P (%)	K(%)
Olluco	tuber	0.70	0.20		0.3	2.0
Maize		0.40				
Rye	seed	0.30	0.87	1.7	0.4	0.5
Rye	fodder		0.20	1.5	0.4	0.5
Oats	seed		0.20	1.5	0.4	0.5
Quinoa	seed	0.30			0.4	0.5
Faba bean dry	seed	0.21	0.90	5.0	0.4	0.5
Faba bean fresh	seed		0.70	5.0	0.4	0.5
Pea fresh			0.70			
Lupin	seed				0.4	0.5
all crops	stover			0.60	0.1	1.0