IRRIGATION AND EROSION/FLOOD CONTROL AT HIGH ALTITUDES IN THE ANDES

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Published in ILRI Annual Report 1989, p. 8 – 24
International Institute for Land Reclamation and Improvement (ILRI)
Wageningen, The Netherlands

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1. Introduction

Interesting developments in irrigation and the control of floods and erosion are taking place in the Andean mountain range of Peru. They are increasingly being based on the authority of the communities to determine their own agricultural production system. The developments are expected to result in the diversification of agriculture, the stabilization of animal husbandry, and more balanced living conditions for the mountain people. In the long run, this may lead to a gradual increase in production and a marketable surplus. The fragile socio-economic and environmental conditions, however, demand a cautious and concerted effort by development agencies and beneficiaries alike.

After having explained the land-use potential without irrigation, we shall discuss the possibilities, problems and limitations of irrigated agriculture in the Andean valleys, flood-plains and lacustrine plains. We shall then discuss the potential for small-scale flood-control projects and the scope of erosion-control measures.

2. Land Use without Irrigation

The basic land-use in the Andes is pastoral (Photo 1). The natural pastures are dominated by *Kikuyu* grass, which was once imported from Africa. The grass is a much appreciated grazing resource, but is at the same time a notorious weed in agricultural lands. The other grasses, *Festuca* and *Stipa*, are of local origin, The herds consist of cattle, sheep, lama's, and alpaca's. Cattle are found at altitudes up to 4000 m, and alpaca's above 4000 m.

Figure 1.

Livestock is important to the rural economy in the Andean highlands.

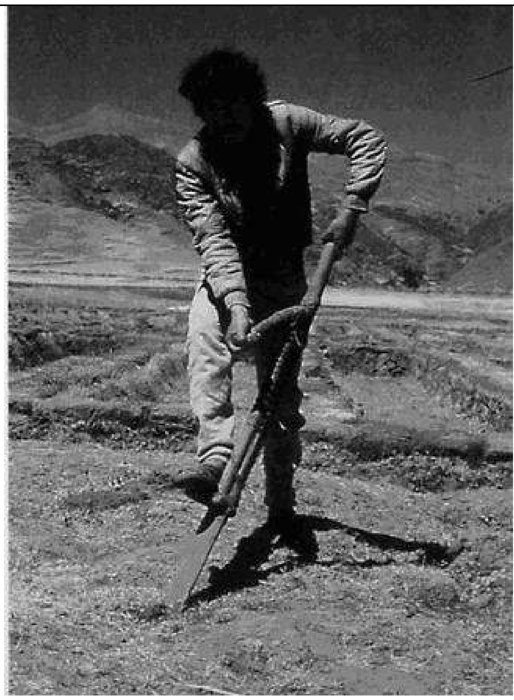
Here, a woman is carrying her sheep to have them treated for parasites.

Photo: Carlos Nishiyana

The cultivable soils in the rangelands are subject to the *layme* regime. This means that they can be cultivated under rain-fed conditions (i.e. during the wet summer season) only after a period of 3 to 5 years of rest as a pasture. When the pasture land becomes eligible for plowing (which is done by foot-plow, Photo 2), it is usually cultivated with potatoes in the first year, followed by broad beans, barley or wheat. The *layme lands* are cultivated for three to four consecutive years.

Photo 2.

The foot plow (*chaquitaquilla*)
Is used to convert the grassland into cultivable land



The *layme* cropping pattern and calendar is presented in Figure 1. The cropping system cannot be very diverse, because of ecological limitations, and I leads to a rather one-sided menu. As the harvest is limited to the period of May and June, the crops have to be stored for a ling period, and it is difficult to maintain the quality of the main crop: the potato.

Without irrigation the use of the cultivable soils in the Andean mountains is strongly determined by the climatic conditions, with the yearly distribution of he monthly rainfall and temperature, including the night frosts, playing a predominant role (Table 1). Seedbed preparation cannot start before the second half of November, but if the summer rains are delayed, the seedbeds are not prepared until December. The pace of vegetative growth is relatively slow because of the low temperatures at high altitudes, leaving a relatively short growing season before the start of the night frosts.

Without irrigation, winter cropping is not possible because of the absence of rainfall from May to October. The months of January and February, when the last year's crop produce has been exhausted and the new crops are not yet yielding, are therefore characterized by a general food shortage. Also, by the end of the winter, the natural pastures are scarcely productive and the oxen needed for seedbed preparation at the start of the rainy season are weakened. Further, the livestock (used as an insurance against hard times) is lean and does not fetch a high price.

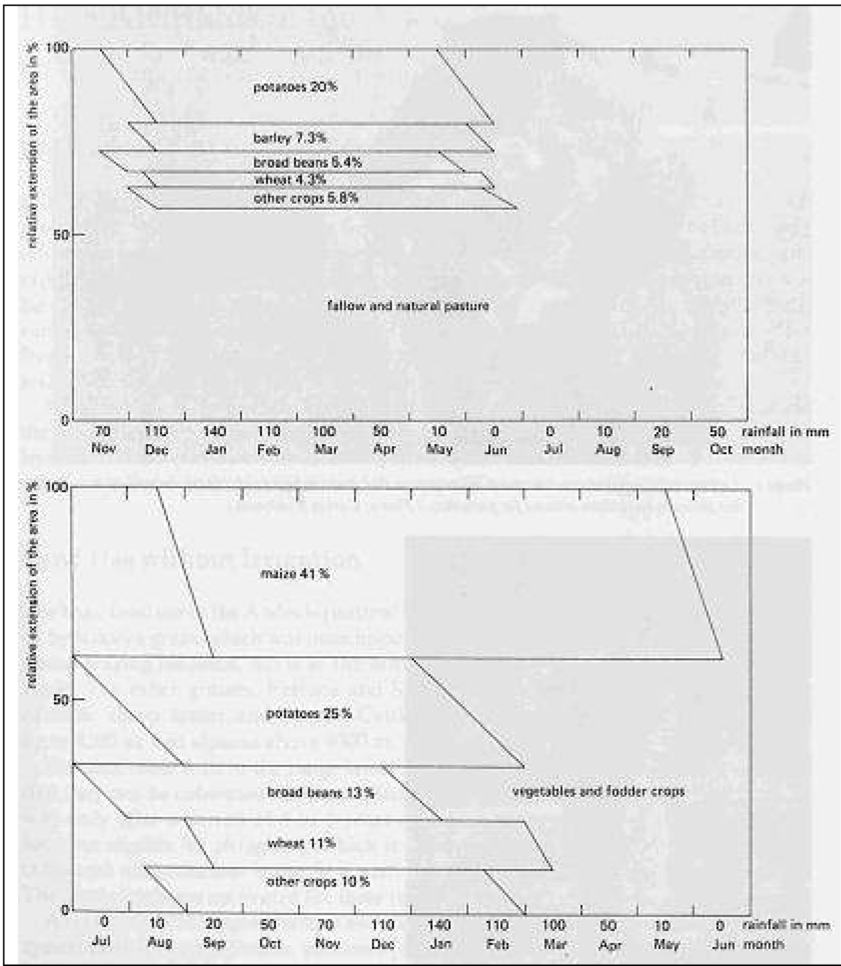


Figure 1.

Typical cropping calendars of rain-fed cops under the *layme* regime (above) and a possible cropping calendar under irrigation (below).

Table 1. An overview of some important climatic factors in the Peruvian Department of Cuzco

Period	Rainfall		Frequency of night frosts *)	
	Total (mm)	Average (mm/day)	Q ‘)	R “)
Apr 15 to Sep 15 (5 months)	50	0.3	f	p
Sep 15 to Nov 15 (2 months)	90	1.5	o	f
Nov 15 to Apr 15 (5 months)	525	3.5	s	o

*) p = predominant, f = frequent, o = occasional, s = seldom
‘) Q = zone from 3000 m to 3600 m altitude
“) R = zone from 3600 m to 4200 m altitude
(agriculture is found up to 3900 m, coinciding more or less with the tree limit)

In view of the restricted *layme* cropping calendar, it is obvious that there must be a peak labor requirement in November/December for field preparation and sowing, and in May/June for harvesting, whereas the other periods are slack. This irregular labor film is not conducive to a prosperous rural economy. Neither is the sudden increase in available food in May/June, which poses the problem of storage. If sold, the produce does not bring in much money, because of its seasonal abundance. The usually fast devaluation of the currency worsens the problem, because the money received for the products loses its value quickly.

The problem of potato storage is somewhat reduced by the conversion of potato into *chuño*, which is done by subjecting it alternately to night frost and sunshine. Although the *chuño* can be stored well, it has less nutritive value than the original potato.

With the low prices for the lean livestock and for the abundant foodstuffs, the months of May and June are characterized by an intensive exchange of these commodities, in which the monetary transactions have only a short term significance so that there is practically a barter trade.

3. Irrigation Prospects

With irrigation, a much more diversified cropping calendar is possible than without (Figure 1). Not only can the summer crops be sown earlier (which relaxes the peak labor requirement, ensures the yield, and allows an earlier yield to be produced precisely in the period of food shortage), but also a winter crop is made feasible.

As irrigation makes early sowing possible, maize can be grown at higher altitudes, up to 3800 m. The indigenous people consider maize a vey important crop for its nutritive value, its ease of storage, and the value of the straw as fodder. On irrigated land, therefore, it is the predominant crop. It is often cultivated with an alfalfa or clover variety as undergrowth for fodder.

The winter crops may consist of night-frost resistant vegetables, like onons and carrots (Photo 3), but may also be fodder crops (Photo 4). Particularly promosing would appear to be the mixed cultivation of barley and vetch (a legume that fixes nitrogen in the soil, thereby raising the soil fertility). The harvest of the winter fodder crops occurs at a time when natural pastures are scarcely productive because of the lack of rainfall. This crop thus reduces the drop in animal production during a critical period.

To illustrate the importance of irrigation in the Andes in general, we shall compare the conditions in Cuzco with those of Cochabamba in Bolivia. The average annual rainfall in Cochabamba is 450 mm (400 of which occurs in the months of December to March), which is less than in Cuzco. Irrigation in Cochabamba therefore offers even greater prospects than in Cuzco, but the potential benefits are the same: diversification of crops, flexibility in planting time, and the introduction of a second crop. Because of these potential benefits, one finds that the native communities in the Cochabamba region have made strenuous efforts to construct storage resrvoirs and irrigation canals in the rugged mountain area (Sevenhuysen et al. 1988. ILRI Annual Report 1987, p. 54).

As a second crop, the farmers around Cochabamba grow the same bulb and tuber vegetables as their fellow-farmers in Cuzco, but in addition they grow green vegetables and flowers. In general the second (irrigated) crop in Cochabamba is more common than in Cuzco.

Photo 3.

Irrigation facilitates the cultivation of vegetables during the dry winter season.

Women display a great interest in this activity. Here we see a women's associaton (*Club de Madres*) selling part of their first-ever vegetable harvest.

Photo 4.

Cattle are grazing on irrigated fodder.

The farmer was the first in his community to introduce the winter crop.

There are perhaps three reasons why winter irrigation is less common in Cuzco compared to Cochabamba:
1. – Traditionally Mother Earth (*Paccha Mama*) is supposed to sleep during winter; therefore no crop should be grown in that period;
2. – The irrigation techniques are not strongly developed (which is perhaps due to the strong social oppression suffered by the Andean people for many centuries), and

irrigating too late, too lightly, or too heavily may damage the crop and cause soil erosion.
3. – The mountain roads are very poor and transport facilities are scarce. Close to important markets, winter crops are grown, but further away they are almost absent. For example, more than 50 km from the city of Cuzco hardly any winter crop is grown. Instead, most of the vegetables consumed in Cuzco are brought in from Arequipa, some 700 km away.

The benefits of irrigation are to be found in the first place in improved possibilities for the farming communities to diversify their agriculture, to prolog the cultivable period, to ensure the crop yields, to improve their diets, and to produce additional fodder – all of which will help them attain a better level of self-sufficiency.

The Peruvian Government, and to some extent also the Bolivian, is aiming at a greater autonomy for the rural communities and a greater degree of determining their own development policies. If external economic and marketing conditions improve, political stability will then also return. If the communities become sufficiently confident of their legal position, it is to be expected that in the long run they will use the above-mentioned possibilities to obtain a marketable production increase amd thus achieve an economic benefit at regional level.

4. Field Irrigation Concepts and Practices

At present there are two major irrigation projects in the Peruvian Department of Cuzco: PlanMeris and ProDerm. The first is sponsored by West Germany, the second by The Netherlands and the European Economic Community. During the last few years, both projects have been attaching more and more significance to the irrigation practices at field level, acting in close cooperation with the members of the communities, rather than merely constructing canal systems with only passive indulgence of the communities. ProDerm is taking the viewpoint that, if farmers are convinced of the benefits of irrigation and have accepted the inclusion of field irrigation in their farming activities, they will make greater efforts in constructing, operating, and maintaining the irrigation systems.

It has frequently been observed that the traditional irrigation around Cuzco is based on very small irrigation flows of 1 l/sec or less. These flows originate from the smaller streams, which, in the months of early sowing, (i.e. October/Noveber after a long spell of drought), carry only little discharge. As a result it takes a long time to irrigate a field, and much of the irrigation water disappears as deep percolation. Because of the long irrigation time, the irrigator does not remain in the field during the wetting, and much of the water runs down uncontrolled. This field irrigation method is not much more than wild flooding (Photo 5).

ProDerm is therefore advocating the use of larger irrigation flows per irrigated field (the unit stream size): at least 5 l/sec and preferably 10 to 15 l/sec. This, of course, is only possible by tapping larger streams and by constructing relatively large canals. Most of the newer irrigation projects have canal capacities of 20 to 50 l/sec, and though these still represent comparatively small discharges, they need a correct distribution system to bring the unit stream size to the different fields in a proper manner and at the right time. In addition, the field irrigation methods will have to be adjusted to the larger stream size, otherwise there is a danger of soil erosion in the steeply sloping fields. In a few instances, such erosion already occurred.

Photo 5. Example of an unattended irrigation application with a small and inefficient stream size.

The traditional practice of small irrigation flows in Cuzco stands in contrast to the large flows used in Cochabamba. The irrigation systems in Cochabamba are designed to make as much use as possible of the flash floods in the rivers and brooks. This demands large canals and a fast watering of the fields (*riego por golpe).* The unit stream sizes may go up to 50 l/sec per field and sometimes to the point that they become erosive. In general, however, erosion does not take place. On the contrary, the silt load of the water is often deposited on the land, enriching and fertilizing the soil (the *lameo*).

During periods of low river flows, the Cochabamba farmers enter into a method of rotating the available flow of water over the farms that have acquired users' rights to this water (the *mita*). As the canals have a relatively large dimension, as the *mita* rights are expressed in terms of duration of water use at certain intervals, and as the fields have been prepared for large stream sizes, also the mita water is applied to the fields in *golpe*.

When the river flows are so low that they hardly allow irrigation, as happens during the winter period and during the months in which early sowing of the summer crop is desired, use is made of the water stored in reservoirs that have been arduously constructed in the mountains. These reservoirs are sometimes 50 km or more away from the irrigated land and they often tap water from other, more rainy, catchment areas than those in which the irrigated lands are situated. This means that long link-canals are required. The dam site and canals need frequent supervision and maintenance, e.g. in view of landslides and against theft of water.

The irrigation water can only be used by the entitled persons. They have acquired their rights by contributing to the construction of the system, or by heritage, and they keep the rights by contributing to the supervision and maintenance. For the same reasons as explained for the *mita* water, the reservoir irrigation water is also applied in *golpe*. An additional reason is that he water must be released in great quantities, otherwise the infiltration losses occurring in the canal system between the reservoir and the agricultural land become disproportionally high. Further, there is the matter of time available: the irrigable land must be served within a reasonably short time span if one does not want to lose the advantage of early cropping or of drought relief.

The last, but not the least, reason for irrigation by *golpe* is that, because the soil has dried out considerably during the previous rainless winter period, it needs a large irrigation application (the *machaco*) for seedbed preparation. Since the amount of water applied per irrigation is fairly high, since the operational problems of the long canal system are great, and since the total amount of water available from the reservoirs is limited, the intervals between irrigations are rather log: up to two months.

The major irrigation project in Cocahbamba (the PRAV), which is sponsored by West Germany, is expanding its irrigation and, at the same time, is regulating the irrigation flows to obtain a less violent and more steady irrigation regime. The design irrigation supply is about 0.5 l/sec/ha, or 4,3 mm/day. Further, the design unit stream flow is 15 to 20 l/sec, so that it can cover an area of 30 to 40 ha. The irrigation interval is reduced to about two weeks, instead of two months in the traditional situation.

The above design values imply that each day about 2 ha can be irrigated and that the soil stores about 60 mm of water with each irrigation turn, a realistic value. If a farmer needs more water for seedbed preparation after the dry winter season, he may prepare half his area, using 120 mm (the *machaco*) instead of 60 mm, and ait for two weeks to prepare the other half. In this way he spreads his work of preparing the land over a longer period and avoids the congestion of labor input.

The ProDerm project in Cuzco is applying more or less the same concepts. Hence it is interesting to note that, whereas the PRAV is trying to reduce the traditional stream size, ProDerm is increasing it, but the target values are similar. In addition, both projects are considering the idea of dividing the areas that are irrigated from one source of water into irrigation sectors (also called tertiary units). During peak irrigation periods, these sectors will receive a constant irrigation flow, whilst within thw sector the flow will be rotated over the various fields, farms, and water users, in accordance with a pre-defined schedule (in India this is called the *warabandi* system).

In one important respect, however, the projects in Cochabamba and Cuzco differ greatly. This is due to their hydrological and geographic situation. The project in Cochabamba used seasonal storage reservoirs, which are meant to serve both mountainous regions and a large part of the flat *pampas*, which are plains formed by the sedimentary filling of former lakes. In Cuzco, on the other hand, the project concerns mainly mountainous regions, and there are no seasonal storage reservoirs because the water can be directly diverted from the small rivers that continue to transport water during the dry winter. However, in Cuzco, the smaller overnight storages are used to avoid irrigation at night. These overnight storages are not feasible in the flat *pampa* of Cochabamba. Together with the ability of the Cochabambinos to handle large irrigation flows, this explains why the tertiary units in Cochabamba are large, encompassing at least one full community, compared with those in Cuzco, where there are two or more units per community.

The profound changes proposed in the traditional irrigation regimes require the full cooperation of the communities – and of the individual irrigators – to operate the new systems as designed. Otherwise, the new projects will fail. Vital components for success are therefore close communication with, and participative action by, the communities. Any lack of agreement with the communities or any objections raised by them should be carefully analyzed, and the projects adjusted accordingly.

5. Participative Action by the Communities

If an irrigation project is to be effective, the proposed modifications to the traditional methods must be discussed with the beneficiaries. These discussions might cover the following points:
1. – Do the beneficiaries (men and women alike) recognize the value of the proposed concepts: the agricultural prospects, the field irrigation practices, and the water distribution methods? Are they willing to accept these concepts either in amended form or as the area?
2. –Do the farmers lack experience that would enable them to judge the proposed concepts? If so, would they be willing to follow a training program to gain this experience?
3. – Are the communities able to organize themselves into new, democratic, water users organizations that can contribute to the construction works (e.g. by supplying a rotating labor force, the *faena*), manage an equitable and effective distribution of the water, perform the maintenance tasks collectively, and handle conflicts justly?
4. – do the communities lack experience that would enable them to judge the feasibility of a proper water users organization? If so, would they be willing to follow a training program on the subject?

Initially, the projects in Cuzco and Cochabamba lacked the participative approach. This had lead to the disuse of costly irrigation structures. There were also instances of absentee landowners, who suddenly returned, making fierce claims to the land that was going to be irrigated, thus upsetting the communal development and causing a communal lack of interest in continuing with the project. Fortunately, in recent years, these matters have been given closer attention. ProDerm, for example, maintains many multidisciplinary teams who live in the villages and work in daily consultation with the inhabitants, and the government is granting increasing authority to the communities to decide how and by whom their lands are to be used.

In new irrigation projects, the ownership of the land parcels should be carefully defined and registered, as should the water rights attached to them. This applies particularly when the land is communal grazing and *layme* land that will be brought under irrigation and parceled per family. (Irrigated parcels are usually cultivated better by a family than by a community.) In Cuzco, there are firm indications that those lands are being assigned to young people who would otherwise have to leave the area because of the lack of resources, and who would migrate to the larger cities for employment.

Any strong dispute that arises from inadequately defined land and water rights, or from the feeling that the benefits of the project are unevenly or unjustly distributed, paralyzes the whole undertaking. This not only signifies a waste of labor and resources, but also involves negative side effects, both environmental (through spillage of water) and social (unrest and distrust). In several instances, these negative effects have manifested themselves in both Cuzco and Cochabamba.

One of the most successful endeavors of ProDerm to acquire participative action by the villagers around Cuzco has been the introduction of field irrigation contests, the *unu kamachiq*. The contest is organized by a community, which makes the land and the water available. Irrigation teams are invited from the surrounding villages. The teams consist of five persons, and there is a maximum of twenty participating teams. The communities usually enter separate teams of men and woman. All teams receive preparatory training by memebers of the organizing community, who have been trained by ProDerm. The contest itself lasts one week, during which the teams prepare the land for seedbed and irrigation (Photo 6). Furrow and border-strip irrigation are applied (Photo 7). The quality of the land preparation and the irrigation application are evaluated by a jury. Also the quality of selection and preparation of the seeds, the quality of the agricultural implements used, and some other aspects are judged. The winners receive prizes and all participants receive agricultural implements. It is not unusual for the female teams to score very highly, or even to win the contest (Photo 7). The winning team organizes the contest in its own village the next year. The gathering of the various teams in one place for a whole week makes the contest a real festival: the *unu kamachiq raymi*.

Photo 6.

Contrary to tradition, the women prepare the land for seedbed and irrigation with oxen-driven plows.

This used to be a man’s job.

Photo 7.

A female team contesting in the *unu kamachiq* is preparing the field for seedbed and irrigation, using the furrow system.

Despite the success of the *unu kamachiq*, the new irrigation methods are only very slowly adopted by the communities. It is thought that perhaps the existence of the *ayne* groups offers an explanation for this. An *ayne* group consists of a number of farmers, who combine their workforce to prepare one anothers' land. The *ayne*, therefore, is a neighbor-help group. If a farmer who participated in the *unu kamachiq* wishes to introduce new irrigation techniques, he must first convince the members of his *ayne* to accept them. This is no easy undertaking. The *unu kamachiq* is therefore now followed up by identifying and including the whole *ayne*. The contests are now taking place on the lands of the whole *ayne*, and last a whole season, from seedbed preparation to harvest. The *ayne* leader will be a person who participated previously in the *unu kamachiq*. It is hoped that, in this way, the new irrigation techniques will be more readily accepted and adopted.

Photo 8. Last year's winning team is staging an allegorical performance around the Inca*, dedicating their trophy to the present contestants*

Not only does irrigation at field level need attention, also the operation of the irrigation system at communal and inter-communal level must be addressed. To this end, the communities nominate an irrigation officer (the *tomero*) for a certain period. It is his duty to distribute the water to the water users in accordance with a predetermined set of rules. Instead of employing a rigid rotation method, the communities normally opt for an on-command method. That method has the great advantage of flexibility, but it is less efficient from the point of view of water management. For example, if two users along the same canal have applied for irrigations on different days, the water in the canal will have to be set up two separate times, which constitutes an extra complication. Also, when the water is in high demand, the possibility of corruption arises. Anyway, the method of water distribution of communal and inter-communal level in the new projects are in the experimental stage and need continuous monitoring and evaluation jointly by project team and community.

6. Flood Control

Flood-control measures have been tried, both in the *pampas* and in the valley bottoms of the larger rivers (the river flood-plains). In general, it can be said that flood-control works have better in the *pampas* than in the river valleys. The main reason is that the large river valleys need major engineering works, which are costly and often damaging to the environment, whereas the *pampas* have small, easily controllable brooks, and relatively extensive lands that will benefit. Second reason is that river valleys are more liable to soil salinization than the *pampas*, especially after the introduction of irrigation. This can be explained by the difference in geo-hydrological conditions (the *pampas* have better natural drainage) and by the fact that the introduction of irrigation in river valleys is a large-scale affair compared with that in the *pampas*.

Without flood-control, the *pampas* are marshy because of inundations, and offer few natural resources. They are used for extensive grazing, but the quality of the pastures is poor, and various diseases originate there, one of which is liver fluke. However, the environmental value of the wetlands is only partly known and needs more study.

With flood-control the *pampa* becomes much drier, which promotes its use as improved rangeland or as cropland under the *layme* regime (i.e. without irrigation). Some of the flood-protected *pampas* around Cuzco have therefore witnessed the growth of new settlements (Photo 9).

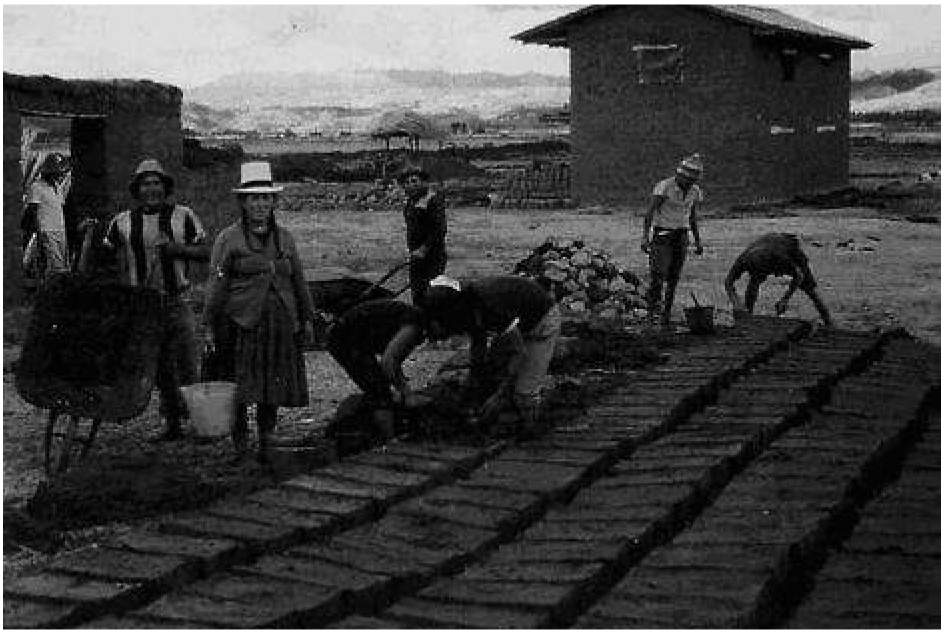


Photo 9. Showing settlements of youths from the surrounding communities in flood-protected land. The youngsters had returned from the cities where they had been trying to find a livelihood because of the scarcity of resources in their birthplace.

The flood-control measures consist mainly of bunds, built along the brooks traversing the *pampa*. Sometimes, the lower parts of the brook, where its gradient becomes small, are excavated. This, however, has the disadvantage of recurring sedimentation, so that the excavations need regular maintenance, especially if no erosion-control measures are taken in the higher parts of the watersheds, to diminish the inundation an siltation problems.

Often, the flood-control bunds are ingeniously made of *champas* (Photo 10), which are sods cut from the nearby natural pasture. The bunds, therefore, remain vegetated and are very stable. They have also proved their usefulness in the bank protection of irrigation canals. Even the larger bunds along major rivers have successfully been constructed of *champas*. Further, it appears that the borrow areas of the sods restore their vegetation quickly, and thus do not lose much of their pastoral value.

Photo 10. A brook, traversing the pampa *(a former lake filled with sediments) has been bunded with sods (*champas*) from the surrounding natural pastures, an effective way of flood-control.*

The bunding of brooks is no guarantee against water-logging in the areas adjoining them, when the water-logging results from direct rainfall. So, after the construction of the flood-control works, some parts of the flood-protected land are still not fully cultivable. This problem could be solved by introducing a system of ditches to control the water-table. It is probably not a good idea, however, to eliminate all the wetlands in a *pampa*, because they have great environmental importance, being used for example by ducks and other waterfowl. Furthermore, it has been proved that the wet spots can yield productive grassland during the dry winter season. Also, in the wetlands, there are instances of permanent and very valuable fields of rye grass, clover and alfalfa, which need no irrigation.

7. Erosion Control

The measures for erosion control in the projects of ProDerm are mainly related to the protection of irrigation structures or flood-control works against the excessive surface run-off of soil and water from the eroding, sparsely vegetated, mountain slopes. The run-off causes damage to the structures and impairs the irrigation or flood-control system. If the farming communities have developed sufficient interest in the irrigation at field level, or in the use of flood-protected land as *layme*, they will perform regular maintenance on the structures in *faena.* Nevertheless, from the points of view of both labor efficiency and environmental stability, it would be a good investment to protect the structures against the erosive forces. It goes without saying that erosion control also has a great intrinsic value, independent of its role in protecting structures.

Different methods have been considered for the protection of mountain slopes. They are categorized as interception ditches (*zanjas de infiltración*), short, steep terraces (*terazas*) and the traditional long terraces (*andenes*).

The interception ditches are dug along the contours to intercept the run-off, store it, and let it slowly infiltrate into the soil., Often. The space between the ditches is barren and is therefore being planted with local shrub or cactus species. ProDerm has developed nurseries for this purpose. The disadvantages of interception ditches are that they require a very high labor input, that they may silt up, that serious damage occurs when the water overtops, and that they do not produce cultivable land.

The short terraces are made across erosion gullies, and have stonewall-protection. Their main purpose is not to protect irrigation canals, but rather to halt further gully formation and, at the same time, to form cultivable soils (e.g. for seed potatoes, Photo 11)

Photo 11. Short terraces with stonewall protection made in a steep gully to halt erosion and to produce seed potatoes.

Long terraces are built across the more or less regular mountain slopes. They consist of two types: constructed terraces and slowly forming terraces. The constructed long terraces, like the short terraces, are usually protected by stonewalls, and are fit for cultivation or forestation. Their construction demands so much labor, that there are not many new ones to be found: most of them stem from *Inca* and pre-*Inca* times. At present, therefore, more attention is being given to the slowly forming terraces.

In principle, the slowly forming terraces consist only of simple walls across the slopes, which will fill up to terraces by natural processes. In other words, the walls are meant to retain the eroded materials, so that in the long run a terraced landscape will develop, and the erosion will be halted. The walls can, again, consist of stones, but they can also be made of shrubs, cactus plants, or other vegetative material.

8. Conclusions

Irrigation and flood-control practices at high altitudes in the Andes have quite distinct agro-ecological and socio-economic requirements and characteristics compared with similar water management activities elsewhere. If one wishes to improve these practices, one must first have an intimate knowledge of the various human interests, the environmental conditions, and their interactions.

The potential for small-scale irrigation the Andes of Peru and Bolivia is great, but it is only being partly exploited. The reasons for the limited use of the water resources are probably found in the precarious socio-economic conditions of the mountain tribes (mainly the *Quechua* speaking Indians) and the turbulent history of national policies towards their social, cultural, and economic development. Irrigation development projects, therefore, need much care and attention.

The potential for small-scale flood control is not as great as for irrigation, because it is limited to he smaller *pampas*. Flood control, however, can be effective and inexpensive (with the use of the widely available *champas*), and can provide a quick improvement of the natural pastures. Yet, like irrigation, the practice of flood control has not been developed to its full potential probably owing to the same background conditions of the people.

There is a great need for erosion-control measures, because they will improve the fertility of the mountain slopes, will preserve water, and will mitigate downstream floodings. The present tendency to grant more authority to the Andean communities in determining their own land use is providing the necessary incentives for an increased and sustained agricultural production, especially if the development agencies involved gear their efforts to socially acceptable, environmentally sound, and locally manageable activities.