CONDESAN

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Enhancing Livestock Productivity while Protecting Mountain Ecosystems

Concept Note submitted to the
Systemwide Livestock Programme, SLP
By

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&
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Introduction

Mountain ecosystems are a major source of the world's biological diversity, water, energy, and forest products. About 80% of the planet's fresh water supplies originate in mountain areas. Many of the world's most important food crops evolved in the unique micro-ecologies found in mountain valleys. Mountains account for 20% of the world's landscape and are home to at least 10% of the earth's people. However, management of their natural resources affects over 40% of the world population that live in adjacent ecosystems (chapter 13, Agenda 21). Mountains are also frequently associated with grinding poverty. Some of the poorest people in Latin America live in the southern Andes of Peru and Bolivia. Most of China's absolute poor are ethnic minorities living in remote mountains, mainly in the Hindu Kush-Himalayas.

Densely populated areas with relatively high agricultural production potential characterize the cool mountains and highlands of Latin America, Africa, and Asia. These areas are particularly suitable for livestock production due to their ecology, climate, and the relative absence of diseases. Livestock play critical role for the poor including being one of the main mechanism for asset building and the sustainability of farming systems. Mixed crop-livestock are the most common farming systems. One can also find large areas in the Andes and in the Hindu Kush-Himalayas especially on high altitude that are sparsely populated with relatively poor natural resource endowments and limited market access. Production in these areas is largely for subsistence. Because risk of frost and drought are very high, extensive grazing systems dominate the landscape.

Nearly all of the existing technologies have been generated with the single objective of increasing crop or livestock productivity. Nonetheless, with a careful analysis of the farming systems and the natural resource base some of them can be tested for both increasing the production efficiency and enhancing the natural resources. A more in-depth understanding of the crop-livestock and livestock based systems in mountain areas and their interaction with the environment is required. This interaction must be scrutinized not only at the farm level – the scale often used to generate and validate technology for livestock production – but at larger scales, if the impact on the environment is to be adequately assessed. Performance of production systems and ecosystems need to be documented with emphasis on determining vulnerable areas and potential negative and positive contributions of livestock production.

The focus of this study will be mainly the mixed crop-livestock systems in the highlands (Seré and Steinfeld, 1996). Main issues to be addressed are: the transition from mixed to specialized dairy systems due to market development, the tradeoffs between production and the environment resulting from the use of existing technologies, and the analysis of experiences and methods of transregional relevance.

CIP and ILRI will execute the project as a joint activity of the Global Mountain Program (**GMP**) and the System-wide Livestock Program (**SLP**). It complements ongoing research conducted by the **GMP** and **SLP** members in the research sites. Those were selected based on a history of research on livestock or NRM issues where farmers or groups of farmers are directly involved in the research process. This project adds new dimensions: the analysis of livestock-environment interactions, the search for win-win situations where the sustainable management of the natural resource base is assured by the enhancement of animal productivity, and the extrapolation of methods across highland/mountain ecoregions.

Sound research is a key element for shortening the process of achieving sustainable management of mountain natural resources. Modelling will be used as a tool to integrate information, select technological alternatives for testing or validation, and predict potential impacts from existing technologies or alternative policy scenarios. The project is designed in such a way that the SLP, the GMP, and the institutions involved in its implementation will generate short-term outputs to keep the confidence of farmers, donors, and others partners.

Project outputs will allow policy-makers and scientists to define more appropriate livestock and environmental policies and technologies based on a better understanding of mountain ecosystems and their dynamics. The project will also allow a quantitative assessment of the expected environmental damage caused by agricultural technologies presently in use if any. In addition, trade-offs between the production value of a set of technologies and the environmental damage – of crucial importance to poor farmers – will be assessed for the most important farming systems at different scales. Farmers groups will be empowered through their direct participation in the project and through a better understanding of trade-offs between livestock production and the environment.

To deliver these outputs participating researchers bring to the project:

- A good knowledge of the research sites, on-going participatory research aimed at improving crop-livestock systems in the Andes.
- An informal network of researchers, development agents and local decision-makers which are members of the CONDESAN consortium led by CIP, ICIMOD led initiatives in the Indu Kush-Himalayas, and the African highlands initiative, in which ILRI is also a member.
- Validated crop, livestock, and risk assessment simulation models,
- A software to analyze livestock and NRM interactions (based on process-based models, remote sensing, and GIS) from field to regional scales. This software is also useful to define the scale at which the two interacting elements share the same operational level thus providing the most appropriate level of aggregation where the joint distribution (livestock, environmental indicators) should be analyzed,
- Satellite imageries
- A model to assess tradeoffs between production and environment at different scales,

Through this project two CGIAR system-wide programs (**SLP** & **GMP**) join efforts to respond directly to the needs expressed in Chapter 13 of Agenda 21, regarding sustainable mountain development, focusing on the interaction livestock – environment in tropical highlands, a long-overdue issue.

ENVIRONMENTAL CHALLENGES IN TROPICAL HIGHLANDS

The following paragraphs summarize the impact that livestock production may have on the environment in tropical highlands. This summary is based on the publications on livestock and the environment by de Haan, Steinfeld, and Blackburn, 1997, and an ILRI working document (1999).

Overgrazing

Heavy grazing in the semi-arid highlands cause soil compaction, loss of the most palatable plant species, decreased water infiltration and storage and contributes to soil erosion. The increased proportion of very low quality plants induces the need of burning grasslands to get high quality new grass shoots. Niches for wildlife are seriously affected by fire. The problem is exacerbated when combined with firewood extraction.

Soil erosion

Soil erosion is pervasive in the tropical highlands particularly on sloping lands under mismanaged crops and degraded rangelands.

Soil fertility

Livestock play a key role in maintaining soil fertility. The problem arises when manure is not adequately managed, the amount of animals is reduced because of systems intensification, or cow's dung is used as fuel, among other reasons.

Biodiversity

The ecological systems are very dynamic in nature. Well-managed grazing or mixed crop livestock systems are also in harmony with conservation of the biodiversity of flora and fauna and the other way around.

Greenhouse gases

In grazing systems in semi-arid highlands such as the Andean Altiplano, seasonal burning of very low quality grasslands is a source of carbon dioxide emission. The low re-growth rate of the grasslands due to the cold weather might produce a negative balance between emission and re-absorption (when one growing season is considered). We hypothesize that this negative effect can be reversed with adequate management of grasslands.

Small ruminants (sheep and Andean camelidae) grazing in the semi-arid Altiplano are fed with very low quality forages with low levels of digestibility; therefore, it is expected that they have high methane emission per unit of feed intake. Preliminary observations indicate that when animals are supplemented with small amounts of better quality locally produced forage productivity is substantially enhanced and thus the methane emitted is also reduced.

OBJECTIVES

General objective

To improve smallholder crop-livestock systems in the highlands through appropriate management of natural resources

Specific objectives

Specific objectives of this research are:

1. To validate with farmers groups selected technologies that would enhance livestock productivity and benefit the environment.

2. To evaluate trade offs between livestock productivity and the environment for each case studied. Existing technologies and policies constitute the base for scenarios directly related to each case. Alternative scenarios will be constructed based on available technologies and policies.

3. To draw lessons of trans-regional analysis of case studies of the impact of livestock on the environment at different spatial scales, in the Andes, SSA, and HKH. The emphasis is given to

    - The quantification of the magnitude of overgrazing and its impact on land degradation in grazing systems;

    - How population pressure is inducing the involution (risk of collapse) of mixed farming systems; and,

    - Estimate the expected effects (risk of specializing) of a transition from mixed to specialized livestock systems on livestock production and the environment.

4. To train researchers and development agents on technological options and methods to sustainably improve crop-livestock systems in the highlands

RESEARCH UPDATE

The International Potato Center, CONDESAN and its associates working in the Andes, particularly ILRI and IFDC, are focusing on issues directly related to the objectives of this project. Similarly, ILRI and its collaborators in the East African highlands and ICIMOD in the HKH have on-going studies that will also complement activities proposed in this project. Most relevant findings, to be applied in this project, are listed in the following paragraphs.

CIP-ILRI/CONDESAN have identified technological alternatives for the improvement of crop-livestock systems. They include improved forages and feed supplementation based on non-traditional sources, use of shelters to protect calves against cold weather and others. Dry matter availability is increased by 45-50 % through the use of oats, ryegrass-white clover, barley and winter wheat. Milk production is being increased from 3-4 lt per cow per day to 7. Calves weight gain has increased by 53 % with the use of rustic shelters. A revolving credit scheme has been implemented in three sites in Peru and Ecuador. Ninety-two percent of loans have been recovered in the first year (Tables 1 and 2 show a result summary of on going research). An informal network has been established under the CONDESAN umbrella. It involves more than 45 scientists and development agents, representing seven institutions in 4 countries of the Andean region (Table 3, includes institutions and site description)

CIP and IFDC are conducting research on integrated nutrient management in the Andes. The goal is to adequately manage manure either alone or in combination with strategic use of fertilizers to enhance soil fertility in mixed crop-livestock systems.

ICIMOD and ILRI have undertaken two collaborative studies in the HKH: the characterization of crop-livestock systems in Nepal, and the characterization of the dairy sector in Nepal, Bhutan and two districts of India. Constraints and opportunities for improving these systems, particularly the dairy systems are also being studied. Studies on the ground are being conducted by NARS in the respective countries. Results so far indicate changes in species composition (cattle to buffalo /small ruminants, local to improved breeds, etc.) in all systems, land allocation to different systems and farmer responses to markets. Similar studies are envisaged in other ICIMOD mandate countries in the region.

Long-term experiments involving different levels of grazing pressures are being conducted under on-station and on-farm conditions by ILRI and its partners in the African Highlands to study biomass production, bio-diversity changes, water infiltration and run-off, soil erosion, soil compaction etc. Results are providing vital information on vegetative thresholds for supporting seasonal grazing pressures and protecting the soil at different land gradients. Impact of grazing and manure cycling on the above/below surface biodiversity and nutrient pools are being assessed involving farmers, and these are providing management options for optimizing biomass productivity and soil protection that are compatible with other land-uses.

Strategic supplementation for grazing small ruminants has also been tested. Preliminary data (Coca and Quiroz, unpublished) showed that sheep greatly improved average daily gain when supplemented with around 10% alfalfa hay in the diet. This small amount was sufficient to provide animals with enough protein for rumen microorganisms to make a better use of low quality forages. The advantage of strategic supplementation is not only the increased production value, but also the decreased production of methane. We are looking for alternative local crops that could provide similar responses e.g. *Chenopodium sp.* (Quinoa and Cañihua), *Suaeda fructicosa*, and protein banks for grazing animals as shown by a previous project in the Altiplano (PISA, 1992).

Increased livestock production efficiency has been attained when *Elodea potamogeton* and *Schaenoplectus totora* are adequately used as feed resources in highly intensive mixed crop-livestock systems in the Lake Titicaca basin (PISA 1992; Quiroz et al., 1999). The technology was developed with the sole objective of increasing productivity. Therefore, complementary options should be designed to avoid conflicts with the environment. Both hydrophyte plants are needed to maintain the biodiversity of fish and birds. The extraction of these feed resources must be rational and seasonal. Alternative feeding systems are required.

Process-based models suited to adequately simulate crop and livestock in tropical highlands have been successfully tested in the Andes (Arce et al., 1994, Quiroz et al., 1999). These models would be adapted relying on existing experimental data, prior to their use in those areas. Process-based models to assess soil erosion by water, under different management options are being tested in the Andes (Bowen et al., 1999).

León-Velarde and Quiroz (1999) described an experimental approach for the application of simulation tools to search for sustainable management options when several quantitative factors are prioritized. The authors used response surface designs; a method that would be further expanded in this project to evaluate livestock-environment interactions.

Two complementary software are being developed at CIP to conduct analysis at different scales. SIMSRIG, an integrated system for multiscale modeling based on remote sensing and GIS (CIP, 1999), and the Trade-off Decision Support System (DSS), a software designed to support policy decision making by a variety of stakeholders, including policy-makers, agricultural and environmental research planners, and development specialists (Crissman, Antle, and Capalbo, 1998).

SIMSRIG - a user-friendly integrated multiscale-assessment system software package - was developed with the financial support of the Ecoregional Fund managed by ISNAR. The system is composed of four subsystems: 1) Image input and processing, 2) Specialized functions for multiscale analyses, 3) Interface with GIS, and 4) Interface with process-based models. The four subsystems and their respective components work interactively and dynamically with an integrated database. The System incorporates digital processing of remotely sensed (RS) data, process-based models, and GIS in a user-friendly software package. The remote sensing / geographical information subsystem combines existing capabilities of commercial software with new tools to perform quantitative multiscale analyses, as part of the subsystem 2. By combining remote sensing with process-based models the system is capable of simulating both crop and livestock production at different spatial scales and to generate data needed to analyze scaling functional relationships, if existent. For example, if livestock production over a large area and under grazing conditions is to be assessed with this system, several steps are followed. Low cost low resolution AVHRR imagery and a digital elevation model are processed to define “pseudo-homogeneous zones”. Topography, variables estimated from RS data such as vegetation index and quality, evapotranspiration, and temperature are used to define these zones. High resolution images are then processed (10 – 30 m) to estimate pasture availability and quality as input for the livestock simulation model. Given a herd structure, the model simulates animal behavior, production, and reproduction for every pixel. Production over a pre-defined area is estimated as the summation of the results of all pixels contained within. In mixed crop-livestock systems, where stovers are important feed sources, a crop growth model is linked to the RS system to estimate the amount and quality of fibrous residues for each pixel.

Recently, a preliminary version of the DSS was developed with financial support from the USAID Soil Management Collaborative Research Support Program (SM-CRSP) and The Ecoregional Fund managed by ISNAR. The Trade-off DSS also provides a framework for guiding disciplinary integration and its contribution to policy analysis. This can be used to quantify trade-offs between production and the environment in livestock and mixed crop-livestock systems.

The Trade-off DSS integrates geo-referenced soil and climate data with the DSSAT suite of crop growth simulation models, econometric-based simulation models of land use and management decisions, and environmental process models (e.g., pesticide leaching and soil erosion models). With the software, one can draw a statistically representative sample of fields in a region such as a watershed, conduct integrated analysis, and statistically aggregate the results to a scale relevant to policy decision making. The software then allows the display of trade-offs between competing or complementary policy objectives in simple two-dimensional graphs, showing how these trade-offs might change under alternative policy and technology scenarios.

The Trade-off DSS provides a framework in which constraints to sustainable agriculture are being assessed in the Andes, emphasizing crop production. For example, tradeoff indicators presently being analyzed include value of crop production, soil productivity and water quality, and human health. Constraints being addressed include reductions in soil productivity associated with soil erosion and soil compaction, losses in nutrients, impacts of management practices on water quality, and impacts of pesticide use on human health. Scenarios for enhancing the long-term sustainability of Andean production systems include improved soil management and conservation practices, pest management practices and IPM, improved crop varieties, and farmer training to improve the safety of pesticide use and farm machinery practices.

The project proposes to integrate the livestock component into this model to have a tool that would evaluate crop and livestock options and the trade-offs with the environment.

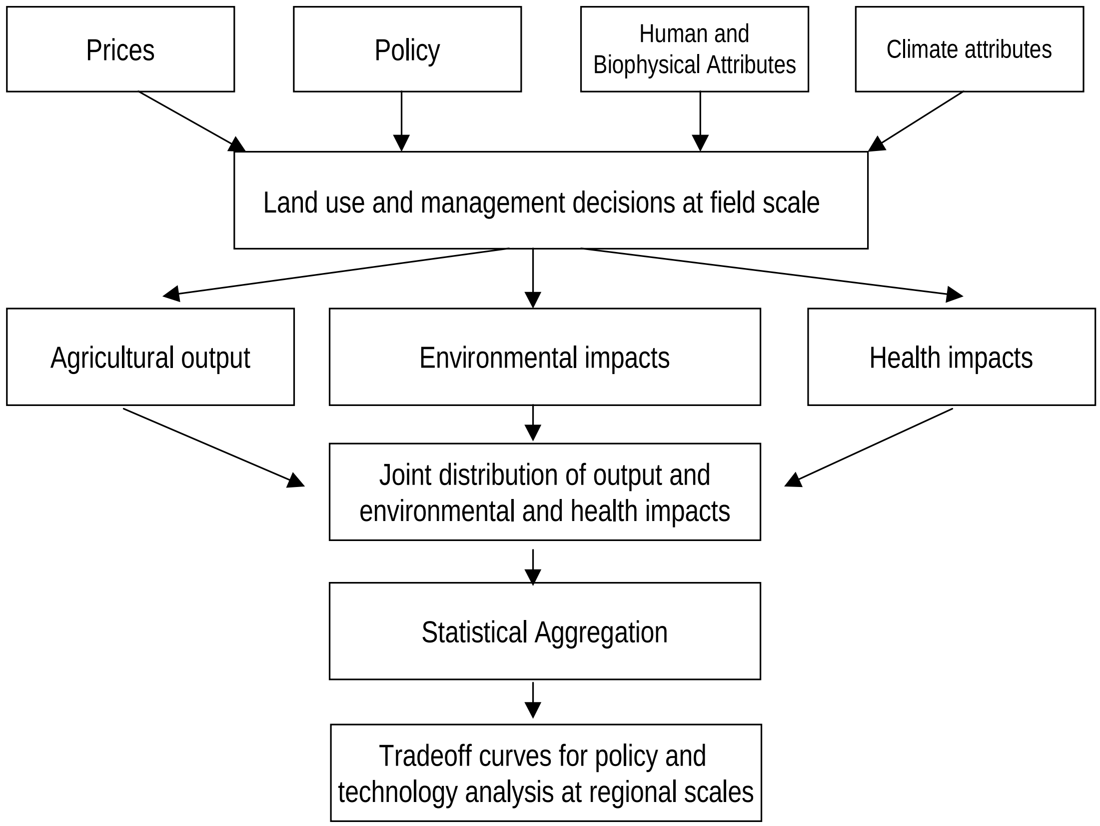

Figure 1. Conceptual framework for disciplinary integration and policy analysis.

RESEARCH PLAN

Objective 1

1. To validate with farmers groups selected technologies that would enhance livestock productivity and benefit the environment.

The following activities will be conducted (details in Table 4).

- On-going trials on the use of improved forages will continue in 5 sites in the Andean ecoregion (Complementary information in Table 2).

- Nutrient cycling trials to determine livestock-environment interactions will be started in Ecuador (Riobamba), Peru (Manazo), and Bolivia (Aroma). Design is based on farmers expressed needs, and the use of simulation models to determine best bets. Farmers' preferences will be considered to decide on validation trials.

- Supplementation of calves and heifers based on protein banks in La Miel, Colombia.

- Recovery of saline soils based on the use of planted forages (*Suaeda fructicosa*) in Aroma, Bolivia.

- Non traditional feed resources for milk production and fattening in Viscachani (Puno, Peru)

Objective 2

2. To evaluate trade-offs between livestock productivity and the environment for each case studied. Existing technologies and policies constitute the base for scenarios directly related to each of the cases. Alternative scenarios will be constructed based on available technologies and policies. Specific activities are related to:

    - Definition of scenarios
    - Collect economic, agricultural, and environmental data
    - Conduct trade-offs analysis
    - Feedback to farmers and policy-makers

The trade-off DSS, previously described will guide disciplinary integration and its contribution to policy analysis in the project (Figure 1). Developed from earlier research (Crissman, Antle, and Capalbo, 1998), this framework is designed to address the methodological issues raised by disciplinary integration and aggregation from the scale of a farm field to a level appropriate for policy analysis, e.g., the watershed or regional scale. Moving from top to bottom, the framework captures the logical sequence of how climate, the biophysical setting, human aspects and macro-level prices and policies affect farming decisions that result in micro-level impacts. The model then shows how those impacts should be aggregated back up to units useful for macro-level policy analysis and impact assessment. The framework shows how disciplinary research can be coordinated to produce linked results that can then be combined for illustrating trade-off between pairs of policy variables.

Objective 3.

3. To draw lessons of trans-regional analysis of case studies of impacts of livestock on the environment at different spatial scales, in the Andes, SSA, and HKH.

The following activities will be conducted

- Quantification of overgrazing and its impact on land degradation in grazing systems;

- How population pressure is inducing involution (risk of collapse) of mixed farming systems; and,

- Estimate the expected effect of a transition from mixed to specialized livestock systems (risk of specializing) would have on the production and environment.

Objective 4

4. To train researchers and development agents on technological options and methods to sustainably improve crop-livestock systems in the highlands

- Short courses and in service training will be carry out on policies and technology to enhance the positive effects of the interactions of humans' needs, livestock and the environment.

References

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Table 1. Main results in crop-livestock production system in the Andean ecoregion

Component	Alternative technologic/research	Results/observations
Soil and land use	Studies; nutrient cycling	Combination of forage fertilized with manure showed increases of production and forage availability with an indirect improvement of milk production between 12 a 16 %
Forage availability • Risk minimization • Annuals and y perennials species	 Forage based/ shelter-calves Combination of barley-oats and winter wheat with alfalfa	 53% of weight gain in improved calves. Improvement of 38 to 76% in dry matter availability.
Herd management	Alpaca genetic herd simulation model Herd cow management	Improvement between 16-22 % of the bio-economic characteristics of alpaca fiber through a selection index. Use of simple records by colors of main activities of reproduction and herd management.
Credit studies	Revolving fund/credit	Improvements of forage DM, milk production and herd management.
Family income	Integration of technological alternatives	US$ 1,980; 55-104% Potato, 2.8 kg/m^2; commercial greenhouses; horticultural production at commercial level. Development of milk process (fresh cheese)

Table 2. On going results in use of non-traditional resources for animal feeding in the Antiplano.

Crop	Place	Characteristics; main use
Quinua (*Quenopodium quinoa*)	Altiplano,Puno, Peru	Use of dual-purpose varieties based on grain-forage G/F. Commercial varieties for human consumption produce 1500 kg/ha of grain with a biomass of 2.2 t/ha of dry matter. Dual-purpose varieties produce grain in a range of 900-1200 kg/ha with a biomass of 2.6 to 3.1 t/ha. Improving its use as complementary forage implied a possibility of rumen defaunation allowing better use of bacterial protein, as well as improved milk production
kañihua (*Chenopodium pallidicaule Allen*)	Altiplano,Puno, Peru	Use of dual-purpose varieties based on grain-forage. Production from 800 a 1200 kg of grain and a biomass of 1.2-1.8 t/ha allows incorporation of protein as complementary forage
Cauchi (*Suaeda fructicosa*)	Altiplano;Aroma Bolivia	Improvement of saline soils (desalinization). Grazing use; Digestibility varies from 69 to 74.2 %; crude protein 12-16%; Biomass production from 2.8 to 3.3 t/ha
Water lentil (*Lemna sp*)	Altiplano,Puno, Peru	Water decontamination; case of Puno bay. 37.5 % of water lentil in combination with oat hay (37.5%) and barley grain (25%) increase weight gain by 72% compared with only crop residues (oat straw or barley)

Table 3. Main participating institutions.

Institution	Type	Agroecological zone	Site	Action
Centro de Investigación del Medio Ambiente y Recursos Naturales, CIRNMA. Puno, Peru	NGO	Steep hills (Suni); Puna	Mañazo, Peru; Aroma, Bolivia	Credit, technical assistance
Universidad Nacional Agraria; La Molina	Teaching Research	Inter-Andean valley	Junin, Peru	Research Education
Universidad Nacional de Cajamarca, Peru*	Teaching Research	Inter-Andean valley	Cajamarca Valley	Research Education
Universidad Nacional Alcides Carrion; Facultad de Zootecnia, Oxapampa	Teaching Research	Marginal hills (forest margin)	Oxapampa valley	Research Education
Universidad Nacional de Caldas, Colombia*	Teaching Research	Sub-humid and dry hillside	La Miel	Research Education
Instituto Nacional de Investigaciones Agropecuarias, Ecuador, INIAP	National research	Inter-Andean valley –hillsides	Riobamba zone, and Carchi.	Technical assistance, Research Education

Institutions are members of CONDESAN.
*Include the IGALA foundation and the SAIS Tupac Amaru, respectively.
Communities and individual farmers will collaborate in the project

Time table

Table 4. Schedule of activities within objectives.

Activities / objectives	Year 1	Year 2
Objective 1: To validate with farmers groups selected technologies that would enhance livestock productivity and benefit the environment.		
• Set up trials to improve forage base use in 5 sites in the Andean ecoregion.	XX	X
• Trials on nutrient cycling trials to determine livestock-environment interactions; Ecuador (Riobamba), Peru (Mañazo), and Bolivia (Aroma). Design includes farmers' participation.	XX	X
• Use of simulation models to determine best bets; interaction with development agents and farmers.	X	XX
• Supplementation of calves and heifers based on protein banks in La Miel, Colombia.	X	X
• Recovery of saline soils based on the use of planted forages (*Suaeda fructicosa*) in Aroma, Bolivia.	X	X
• Non traditional feed resources for milk production and fattening in Viscachani (Puno, Peru)	X	X
Objective 2: To evaluate trade-offs between livestock productivity and the environment for each case studied. Existing technologies and policies constitute the base for scenarios directly related to each of the cases. Alternative scenarios will be constructed based on available technologies and policies. Specific activities are related to:		
• Definition of the scenarios	XX	
• Collect economic, agricultural, and environmental data	XX	
• Conduct the tradeoff analysis		X
Objective 3 To draw lessons of trans-regional analysis of case studies of impacts of livestock on the environment at different spatial scales, in the Andes, SSA, and HKH. .		
• Overgrazing quantification; studies on impact on land in grazing systems.	XX	X
• Studies on population pressure and mixed farming systems	X	
• Estimate transition from mixed to specialized livestock systems on the production and environment.	X	X
Objective 4 To train researchers and development agents on technological options and methods to sustainable improve crop-livestock systems in the highlands		
• Short courses and in service training; policies and technological alternatives; use of model simulation		XX