Evolving from farming systems research into a more holistic rural development approach: Experiences in the Andean region

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Acknowledgements

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Preface

This document describes the evolution of the Farming Systems Research (FSR) approach into an expanded development framework that takes into account the chain of activities from the farm level to the processing of products and access to markets. The development framework includes the identification of commodities with a comparative advantage in effectively contributing to poverty reduction.

The evolution of the original FSR methodology into a more holistic rural development approach proceeded during a long process of research for development carried out in the Peruvian Altiplano, where CIP and its partners have conducted a string of projects. The evolution described in this document is a significant contribution to the robustness and scope of FSR; it is not one of those slight changes of denomination that are frequently presented as new or alternative approaches (but that are, in essence, the same FSR with the convenient addition of new methodologies and tools). It is important to recognize the difference between a new approach and the enrichment of an old one by the addition of tools and methodologies. The evolution here is the result of incorporating the analysis of the continuum from farm to markets and identifying agricultural products with comparative advantage as contributors to poverty reduction.

The authors, based on their experience in conducting several agricultural projects in the Andean Altiplano and other regions, hope that this document will help clarify the conceptual framework of the systems approach and integrate it into multidisciplinary efforts to generate, through research, adequate technological alternatives for rural development and so contribute to poverty reduction.
Evolving from farming systems research into a more holistic rural development approach: Experiences in the Andean region

INTRODUCTION
The Andean region is a mountainous area of around 1.5 million km² and is well endowed with natural resources. Its population is estimated at more than 115 million, most of whom depend on agriculture for their livelihood. Over 60% of the population lives in rural areas, although this is changing as urbanization increases, with related increases in unemployment and the demand for services. In rural areas the main agricultural systems are mixed crop–livestock farming; extensive livestock grazing predominates in drier areas. Subsistence farming, where animals play complementary roles as a source of food, traction, asset building, insurance against climate shocks and food security, is a trademark of those systems.

Due to limited market access, lack of appropriate technologies, and increased population growth, the deterioration of natural resources – mainly soil and water – and the loss of fauna and palatable native grass species of the high Andes are evident. This degradation threatens the capacity of the land to provide environmental services and sustain the growing human population. It also fuels rural poverty and migration to urban areas, which exacerbates urban unemployment and poverty.

In the search for technological options for small farmers of the Andean region, many projects were implemented to enhance crop and livestock production at the farm level. However, some projects also focused on consolidating participatory research methodology for rural development.

These projects originally took a collaborative approach, focused on fieldwork with farmers to solve identified agricultural problems. They promoted adoption of new technologies generated at experimental stations, with the assumption that they would produce almost immediate results. Technology adoption by users was promoted by support in terms of inputs and infrastructure.

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Document prepared on the basis of information from different projects carried out in Puno, Peru by the CIP, in close collaboration with CIRNMA and other partners and collaborators.
The first steps in the work were the analysis and characterization of the farming systems and households.

However, project progress showed that problems were very complex, and required further analysis and synthesis. Therefore, both biophysical and socioeconomic studies were emphasized to produce a synergism between both fields. These conjoined studies improved understanding of the problems limiting farm production and technology adoption by the farmers, and helped formulate mathematical models to simulate and test scenarios and hypotheses regarding the operation of production systems.

The use of participatory methods fosters producer-oriented research that solves problems prioritized by the farmers themselves, as opposed to a top-down approach that imposes technologies based on results from experimental stations. Contests among farmers such as those promoted in "seed fairs" generate a more fluid dialogue between farmers and scientists, and contribute to exchange and mutual assessment of experiences in seeking joint solutions. However, since this approach limits the extrapolation and adaptability of results, and may influence the objectivity of the explanation for particular phenomena, the extensive use of simulation models was progressively introduced into our research activities. This allowed treatments or technological alternatives to be simulated before implementing them on farms; it also allowed for ex-ante and ex-post analyses of systems (Dent, 1993; and León-Velarde and Quiroz, 1994). Models were valuable tools for professionals who were inclined to assign special importance to traditional practices of production management. Also, the capacity of the models to handle variables which are difficult to measure but amenable to be simulated (e.g. potato tuber development), helped explain the rationale of farmers. The results of the evaluations were positive, indicating that both approaches (on-farm trials and simulation models) could be used to validate technology options that had broad acceptance.

Nevertheless, surplus production without the market capacity to absorb it is a problem that should be addressed. Likewise, problems of land tenure, equity, property rights and product transformation should be addressed to understand the dynamics of evolving agricultural production systems. Consequently, the technologies and strategies used, as well as the policies and capacity building that link research and development, must be based on the following: (1) adequate use and conservation of natural resources, (2) market-oriented agricultural production systems, and (3) improved post-production processes. Also needed are policies that promote trade and regional integration.
This paper describes experiences in the Andean region, from the perspective of some members of a group that initiated the work as a Farming Systems Research (FSR) team. Highlights of the evolution during the last fifteen years are presented.

The paper is divided into three parts. In the first is an overview of systems and the FSR approach and its evolution. It was important to present some details since the methods and experiences from this phase were the basis for and the theoretical framework behind the move to a different paradigm.

The second part is related to the implementation and evolution of the farming systems approach within some Altiplano projects, where members of the original FSR team developed "more holistic approaches" towards the Systems Analysis Research and Rural Development (SAR&RD) approach.

The third part presents case studies focused on sustainable natural resource management (NRM) based on innovative methods of empowering farmers/resource-users and communities. Emphasis is given to efficient learning, monitoring and evaluation of the learning process, and the effect that learning has on decision-making and the impact of that decision-making. The cases examined deal with our experiences on how to involve the producers and bring them and the private sector together in order to increase investment in the agricultural sector.

Finally, a short concluding section shares some of the lessons learned with the reader.

**The Systems Approach**

The systems approach is critical to our modern views on agriculture and rural development. Particularly as researchers and developers currently seek to intervene in agriculture via technology, policy instruments, education and market support programs, and to improve the welfare of disadvantaged rural people by increasing income, improving health and nutrition, providing education and facilitating fair access to markets (Bertalanffy, 1968). Thus, in work oriented to improving agriculture using the systems approach, the classic way of conducting analyses and interventions is by focusing on farms as the unit of analysis. In other words, the systems approach attempts to study total-system performance rather than its components. Understanding the performance and rationale of farms and farmers can provide a means of gauging their reaction to different conditions and, hence, of predicting the consequences of policy interventions (McGregor et al., 2001). This systems concept is used by many disciplines, as it contributes to organizing and understanding a complex situation (Shannon, 1975). In
agricultural production research, the systems thinking helps incorporate the farm components into a conceptual framework defining the FSR approach. Its use began in Latin America in the early 1970s and since then its adoption, adaptation and evolution have been highly variable across the continent (Hart, 2000). In some cases the development of a new approach that rendered the systems approach “obsolete” was claimed. However, in many cases, this simply involved creating a new name after researchers had integrated some tools and methods (such as modeling or stakeholders’ participation) into the basic conceptual framework of FSR. Consequently, there are different research groups that are implementing the original approach used by some of the pioneers in the 1970s, while other groups are moving into allegedly "more holistic" approaches, which at their core are methodologically and conceptually the same as the “Systems Approach”.

Nevertheless, to apply the original FSR approach or any variant (Hart, 1982), it is necessary to start by defining a “System” and the hierarchal level in which the system stands (Fresco and Westphal, 1988). A system is an arrangement, set or collection of physical things connected such that they form an entirety or act as an integral unit (Hart, 1982; Conway, 1985). Therefore it is possible to define its structure, function and objective. Basically each system has a limit, components, inputs, outputs and relationships among components, commonly denominated interactions.

Figure 1A shows, schematically, a system and its components that can be easily related to a particular commodity like potato; thus, the system becomes a “Potato Production System”. Figure 1B shows a general crop–livestock production system, a common production system in the Altiplano, which is more complex due to an increased number of components. This complexity helps to define certain characteristics of a system related to the environment, organization, change, interdependency, counterintuitive behavior and drift to low performance (Shannon, 1975).
Since the system approach can be applied to different situations it is necessary and fundamental to define the operational level. Thus, it is necessary to define the level of work by defining the hierarchal level.

Figure 2 shows the hierarchal levels related to agricultural systems. Once the level is defined it is not possible to describe other systems within the system. However, it is possible to define a subsystem, which becomes a system if we separate it for a specific analysis. However, this subsystem should be always located within the system to which it belongs.
Once the hierarchical level of work is defined, it is necessary to characterize the studied system by describing its components and their relationships. Figure 3 summarizes, graphically, the subsystems and their components of the agricultural production systems in the Altiplano. This is done through the characterization phase, which implies the use of several techniques and adequate procedures to collect relevant information to diagrammatically represent and analyze each component.

The analysis of subsystems and their components is based on the definition of both their static and dynamic representations. The first representation is a graphic model of an actual system (Figure 3), and the second involves a computer program that deals with dynamic changes. This is
one existing option that can be used to formalize the knowledge generated by research in a manner useful for designing, testing, and implementing technology innovations and knowledge.

In their scientific endeavors, agricultural researchers applied the scientific method to search for answers to factors limiting agricultural production. The scientific method is a valuable process that utilizes knowledge to generate new knowledge (Cañas and Lavados, 1989); however, its application in isolation is not enough to solve technological problems (Figure 4).

![Figure 4. Schematic representation linking a problem with knowledge generation by scientific method and its application in Systems Analysis Research and Rural Development (SAR&RD) methodology, considering the main limitations and constraints (adapted from Cañas and Lavados, 1989).](image)

Problem solving requires adaptation of knowledge to overcome limiting factors. The successful use of technology to solve major limitations to agricultural production relies upon an adequate acquaintance with the problems within a specified context (i.e. environment) and a good application of available knowledge. When this interface is used to solve agricultural problems of small farmers with their active participation, we say that we are applying a holistic methodology to SAR&RD.

In the Altiplano the application of the FSR approach was initially oriented to solve the food security problem and producing, whenever possible, a surplus for the market. The details are presented elsewhere (INIA-PISA, 1992 and 1993; Quiroz et al., 1994; León-Velarde et al., 2000). Dent (1993) and Thornton (1991) discuss general problems in the implementation of the approach.
Figure 5 shows the original approach with its methodological steps: characterization, research, validation, and the production programs. These are oriented by the analysis of the target area and opportunities related to surplus production for the market, to increase income.

Thus, farm income is one of the main factors analyzed and evaluated in agricultural systems. Considering the factors involved in income generation, it is then possible to determine the points of interventions to enhance it. Figure 6 shows farm income determinants and constraints, the research issues addressed by most rural development efforts. Due to the complexity of agricultural systems, the majority of agricultural projects aimed to increase production per unit of land area (t/ha). The other two factors, “total area” and “price” were not considered since the area is fixed, as determined by the system limits, and price is highly variable depending on the demand and supply. However, the income generated by any agricultural production system, particularly those managed by small producers, requires a more comprehensive analysis because it is also considered a poverty indicator. Figure 6 relates farm income to some production system components and shows that any increase in income depends on increases in production by unit area as well as on the cost of production and the market price of the product. Since market price could be fixed it is also necessary, in any kind of intervention, to reduce the production costs. Thus, increasing the productivity and increasing the difference between sale price and production cost will result in a better gross margin, benefits and total income. However, when market competition increases, the price of the commodity could be reduced, bringing down farm income. This effect can be minimized when the products with comparative advantage in the market are well defined.
The definition of products with comparative advantage is related to the market opportunities. Analyses of production cost, sale prices and time series of total production and internal gross product in relation to market demand help identify those products. Likewise, optimization methods can allow the generating of bio-economic scenarios to determine future interventions with adequate technology to improve technical and economic efficiency (León-Velarde and Quiroz, 1994).

Table 1, which is related to Figures 5 and 6, shows the different techniques and procedures utilized in the SAR&RD. They all require an adequate group of human resources within a particular institution. Nevertheless, continuous training and integration of new knowledge (Figure 4) contributes to technological change.

To initiate a technological change, adequate technological alternatives must be implemented for each production system identified, including the market opportunities. Preferentially, the alternatives should have low input requirements for an increased production at a lower unit cost. Figure 7 shows an integration of the phases and possible results in each phase.
To implement the different phases of the farming SAR&RD, both financial and skilled human resources are required. In many projects the work has focused on the system's characterization phase, which includes defining the target area and identification of the needs and opportunities through system analysis. Nevertheless, many projects have excessive work in characterization and definition of a baseline but define neither the products with comparative advantage nor the technological alternatives, which could benefit the target households. Likewise, the adoption phase usually has insufficient funding or the technology dissemination process is inadequate. Consequently most of the work remains in pilot sites, which are described as case studies in final reports.

Table 1.
Main methods and procedures utilized in participatory agricultural system analysis research by a partnership of different institutions.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Methods and procedures</th>
<th>Observations/procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characterization, defining: Target and baseline Needs and opportunities</td>
<td>Secondary information Static and dynamic surveys Rapid rural appraisal GIS &amp; remote sensing</td>
<td>Statistics/compilations, charts, figures Farmer participation; depending on the dynamic of the variables Farmer participation Satellite images; ground truthing; maps</td>
</tr>
<tr>
<td>Analysis, defining: Products with comparative advantage</td>
<td>Principal components &amp; cluster analysis Linear and non linear mathematical models Econometric models and simulation models Cost–benefit analysis</td>
<td>Definition of farmer strata and target population Trends; sustainability (logistic, linear and non-linear models) Comparison of scenarios (current and potential production); risk analysis Economic response; profitability; risk analysis. Linear and multiple goal programming</td>
</tr>
<tr>
<td>Research, defining: Technological alternatives or innovations, on farm/on station Experimentation and validation</td>
<td>Experimental designs (classic) Central composite design Trials farmers vs alternatives</td>
<td>Cause–effect response Response surface; bio-economic scenarios; cost–benefit analysis Validation on farms/linking adoption</td>
</tr>
<tr>
<td>Diffusion, promoting capacity building; Farmers, researchers and extension agents</td>
<td>Fields days; short courses Seminars; workshops; technology contests Publications; manuals Communication media</td>
<td>Farmers’ participation/linking adoption Description of technological alternatives or innovations Researchers and extension agents Radio, television (documentaries and case studies), Internet</td>
</tr>
</tbody>
</table>
To avoid concentration on one particular phase of the approach or a bias for a particular discipline it is necessary to identify the phases and their objectives. Thus characterization includes defining a target area and a clear set of needs and opportunities for a particular product with comparative advantage related to market demands. This phase also includes a complete analysis of perceptions and aspirations of farmers, who need to recognize that some interventions or modifications to improve the production system are required. In a similar way, the research phase includes model simulations to evaluate the integration of technological options or alternatives of low production cost into well-defined production programs. This includes linkages for dissemination as well as a good evaluation program to assess the impact of the interventions in the targeted production system. Figure 8 summarizes the relation between phases and objectives. This scheme has been modified and is described in summarized form by the International Potato Center (CIP) as the pro-poor cycle for rural development.
Nevertheless, one of the lessons of the application of FSR in Latin America in the 1970s is that farmers do not adopt complete technological packages, but components of them (León-Velarde and Quiroz, 1994; PRODASA/CIP, 1996; Collinson, 2001; Tinsley, 2004). Unfortunately, this message has not reached key research and development decision-makers, since most of the limited agricultural extension and development projects in the region tend to promote technological packages to small farmers. Changes in productivity of a small farm from a low level to its potential level might be pictured as an ascending spiral (DASA-CIP, 1997; Quiroz et al., 2000) with actual production level at the lower end and potential at the upper end (Figure 9).
The number of turns required to go from the actual to the potential level differs among agricultural production systems. Results are not expected in the short term. Technological alternatives will be incorporated on each turn depending on their profitability (increased cash flow). It can be envisioned that a complete turn of a cycle requires the application of several methodological steps (Figure 9) and the participation of several agents. At the level of the agricultural scientist a high level of precision is demanded, which apparently decreases in each turn, but the demand for better policies to obtain equity and natural resource conservation increases. The role of institutions and policy makers increases with each turn. A balance of integrated planning and responsible decision-making in each turn is necessary considering a bottom-top and vice versa planning of activities (adapted from Quiroz et al., 2000).

In some cases, institutions applying the system approach or any modification of it tend to organize networks or other types of partnerships. This approach is correct and valid when there is no bias in the objective of the targeted system. However, some research institutions that retain a disciplinary or commodity orientation for their work are convinced they are using the system approach for conducting applied research, but by considering the mode of production of the isolated commodity as a production system, the analysis of the whole farming system is incomplete or missing altogether (McGregor et al., 2001). Consequently, there is not the required emphasis on the farm as the unit of analysis and intervention, which hampers the generation of relevant research outputs and the improvement of the livelihoods of smallholders with complex agricultural systems. Thus, in any intervention it is necessary to recognize and identify the actions that could maintain the “status quo” of the system, enhance one or more of its components or change the system altogether - which is the most difficult action (León-Velarde and Quiroz, 1998).

Therefore, in any case it is necessary to clearly identify the research needs and opportunities to apply the adequate knowledge generated for a particular situation. When an institution implements the approach described above, there is a need to recognize that the work is dynamic and continuous; since in some cases the activities apparently do not have a beginning or an ending, thus distorting the approach. For each activity it is necessary to recognize the phase and the level of work that is being executed within the SAR&RD approach.
Implementing the farming system analysis research approach oriented to rural development in the Altiplano

The Altiplano is a special ecoregion in South America, covering approximately 180,000 km$^2$ between Peru and Bolivia at an altitude of 3,800 masl. Some of the area is well endowed with natural resources. However, it is also a region with high climatic and economic risks. In addition, due to historical, cultural and political reasons its population has a quality of life well below its potential. Poverty, a very slow rate of development, an increasingly high population growth rate, unequal distribution of wealth, and natural resource degradation characterize the region. In recent years, government policies have promoted the development of large urban centers and, as a result, most of the population is now found in major cities. It is estimated that by the year 2025 over 75% of the population will be urban (IICA, 1994; Winograd, 1995). Although extreme poverty is common in city outskirts, the majority of the poor are in rural areas, and most are small farmers.

Most farmers are smallholders and they comprise over 70% of the Altiplano farm population practicing a highly diversified agriculture to cope with both climatic and economic risk. Within these diversified farming systems, crop–livestock production systems are critical, as they provide valuable products to contribute to a sustainable agricultural system, but are well within agricultural subsistence farming. Therefore, these farmers demand options derived from a clear problem solving focus to improve livelihoods, while preventing natural resource deterioration. For decades the usual approach has been to improve the system by increasing productivity. However, such an approach did not necessarily improve the overall system. Figure 10 shows a simplification of the poverty cycle in relation to the natural resources in the region. The scheme indicates that poverty is not related to only one factor or indicator. Therefore a clear intervention on exogenous factors to reduce the effects of migration, malnutrition, poor education and poor health is needed (IICA-RISPAL, 1996). It is also necessary to recognize the comparative advantage of other institutions, thus a clear and strong horizontal collaboration should be organized. Likewise, a holistic approach integrating other disciplines, various sectors of the economy and policy studies must be organized and oriented towards rural development.
Figures 8 and 9 jointly describe the integrating methodology used at different hierarchical levels, as well as the institutions necessary to complete each turn of the pro-poor research and development cycle. The classical scheme of FSR includes diagnosis, experimentation, validation and diffusion (Zandstra et al., 1981, Hart, 1982; Conway, 1985; INIA-PISA, 1992; León-Velarde and Quiroz, 1998). These research phases, have been commonly applied by most research teams following FSR methodology or its modifications during the last decade. However, in many cases the diffusion phase is the most difficult step. Usually, constraints by land tenure, size of operation, access to credit, market opportunities, education and health prevent adoption of technological alternatives or innovations.

A brief description of each research phase in the generation of technological alternatives or innovations for a specific agricultural product with comparative advantage in a specific market was provided in the previous section. Thus, several technological alternatives were developed for each product and integrated so that each farmer could use a combination of them according to their resources (capital and land) to improve the productivity of the commodity with more comparative advantage and so enhancing their income (see Figure 11). The agricultural system includes crops and livestock and not all farmers have the same ability or adequate resources for both activities. Consequently, in the analysis of the agricultural system it is necessary to consider the skills and aspirations of the farmers.
Therefore, it is necessary to identify the crop and livestock products with comparative advantage from the point of view of the farmer and the region. Thus the productivity of those products can be improved to enhance their access to markets and income generation. In this scheme the organization of producers is important, because most production is collected by aggregation. There is a need to create solid farmers’ organizations linked to the market, to obtain better commodity prices and farm income.

The level of farm income is usually a criterion to group producers for research purposes. However, in many cases it is necessary to include other factors related (or in addition) to income. These include land size, number of children, level of education and assets; they can be integrated using cluster and principal components techniques. Figure 12 shows a summary of a cluster analysis of communities in the Altiplano and Ecuador. The Altiplano community is grouped by area and assets (animals: alpacas, llamas and sheep) and the Ecuadorian community is stratified by family components (children) and assets (land area and animals: cattle and swine).
The categorization of farms allows a clear intervention on the way of producing the commodities with main comparative advantages. The result is reflected in income, one of the main poverty indicators. Table 2 shows the income range in the Altiplano (Ilave and Mañazo zones), from an analysis of five components: crops, livestock, processing, labor off the farm, and external support. The average daily gross income range is US$1.46–2.81 per day and, when expenses are deducted, the annual gross margin is $US70–97, which puts these farmers within the category of ‘poor’ (World Bank, 2004). Consequently they have a very low or no level of investment.
Therefore, the approach was oriented to identify products with comparative advantage to enhance farm income by improving crop and animal productivity and access to markets whilst improving household health and nutrition. Figure 13 shows the biophysical components for which research has generated technological alternatives adequate to farmers' resources. Some of the appropriate technological alternatives generated for the Altiplano are summarized in Table 3. These technologies cause no deterioration of natural resources. There was a study on farmers' assessments of these technologies (INIA-PISA, 1993) and the evaluation of the interventions was reported by De Los Rios and Diaz (2003).

Methodologically, the application of the farming SAR&RD approach to generate technological alternatives, besides a clear participatory process with partners, allows the introduction of process-based simulation models and decision support systems. A step-wise description of the Andean experience in systems analysis is presented in Quiroz et al. (2000). Simulation models were used to select treatments for on-farm experiments, perform ex-ante evaluations of technology options, conduct simulated experiments whenever biophysical or economic limitations existed, understand the farmers' rationale on specific production decisions, and assess the sustainability of practices and options. The process, including farm interventions, is conducted with full participation of farmers. Several examples are given elsewhere (Arce et al.,

<table>
<thead>
<tr>
<th>Sources</th>
<th>Range</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crops (potatoes, quinoa, oca, barley, others)</td>
<td>109 - 240</td>
<td>22.36</td>
</tr>
<tr>
<td>Livestock production</td>
<td>378 - 458</td>
<td>53.56</td>
</tr>
<tr>
<td>Processing (handicrafts, animal products, jerky, meat)</td>
<td>10 - 107</td>
<td>7.50</td>
</tr>
<tr>
<td>Migration and trading</td>
<td>0 - 60</td>
<td>3.84</td>
</tr>
<tr>
<td>External support (food aid, others) and credit - loan</td>
<td>37 - 162</td>
<td>12.75</td>
</tr>
<tr>
<td><strong>Total gross income</strong></td>
<td>534 - 1027</td>
<td></td>
</tr>
<tr>
<td>Expenses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own consumption of products</td>
<td>240 - 393</td>
<td>45.41</td>
</tr>
<tr>
<td>Food and supplies</td>
<td>140 - 340</td>
<td>34.43</td>
</tr>
<tr>
<td>External support (food aid and others)</td>
<td>19 - 62</td>
<td>5.81</td>
</tr>
<tr>
<td>Other cash expenses</td>
<td>20 - 32</td>
<td>3.73</td>
</tr>
<tr>
<td>Credit -Loan</td>
<td>18 - 130</td>
<td>10.62</td>
</tr>
<tr>
<td><strong>Total gross expenses</strong></td>
<td>437 - 957</td>
<td></td>
</tr>
<tr>
<td><strong>Gross margin</strong></td>
<td>97 - 70</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Sources of income and expenses in typical small farms in the Altiplano.

Figure 13. Scheme of biophysical components for research interventions to generate technological alternatives adequate to farmers’ resources and production alternatives.
<table>
<thead>
<tr>
<th>Alternative of production</th>
<th>Technological alternative</th>
<th>Impact on traditional use</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>Use of manure: decomposition/mud Compost from crops residues</td>
<td>Increase water retention and nutrient availability</td>
<td>14% increase on potato and quinoa crop rotation production; reduce the use of fertilizer by 30%</td>
</tr>
<tr>
<td></td>
<td>Use of bitter potato varieties clean of virus</td>
<td>Availability of healthy product and better quality</td>
<td>Increase of 20% on bitter potato production</td>
</tr>
<tr>
<td>Quinoa</td>
<td>On conventional production the use of improved varieties, and fertilizer NPK 80-40-80 or 40-20-00 per hectare Organic fertilization and use of biocides</td>
<td>Increase quinoa production from 0.62 to 1.3 t/ha Improve production to 1.1 t/ha and quality grain increasing demand for organic product.</td>
<td>Increase production by 110% and family income by 82% Increase production by 77% and family income by 84% protecting the environment</td>
</tr>
<tr>
<td>Oca</td>
<td>Use of genetic variability and adequate storage (rustic shelter) of tubers combining with compost and organic fertilization</td>
<td>Increase quality product and production from 6.5 t/ha to 8.2 t/ha improving demand</td>
<td>Increase production by 34% and family income by 62%</td>
</tr>
<tr>
<td>Cattle</td>
<td>Use of improved forages and forage conservation (silage and hay)</td>
<td>Increase forage production and availability</td>
<td>Increase production by 35% Minimize climatic risk while maintaining production levels</td>
</tr>
<tr>
<td>Meat Milk</td>
<td>Forage budgeting; use of perennial and temporal forage base (improved pastures)</td>
<td>Increase forage availability and weight gain Reduce age at first mating Increase milk production</td>
<td>Forage increment 38-96% weight gain increase 53% 18-20 months 45-75%</td>
</tr>
<tr>
<td></td>
<td>Use of aquatic forage; llachu-totora</td>
<td>0.584 g/day</td>
<td>Increase income by 142%</td>
</tr>
<tr>
<td></td>
<td>Use of shelter</td>
<td>Climatic risk minimization; increase of milk and meat production</td>
<td>53% on weaning weight 25-35% milk increased</td>
</tr>
<tr>
<td>Crops/ Greenhouses</td>
<td>Use of vegetables/ horticulture</td>
<td>Potato 2.8 kg/m² minimizing climatic risk on seed production Increase mixture of vegetables</td>
<td>Availability of seed for conventional production Improved the family diet and increase family income by 58%</td>
</tr>
<tr>
<td>Alpaca fiber</td>
<td>Alpaca management production system; fiber-interchange of sires</td>
<td>Increase: Fiber production Birth weight Income (US$1980/year)</td>
<td>12-15% 18% 55–104%</td>
</tr>
<tr>
<td>Trout</td>
<td>Use of natural and artificial ponds on alpaca highlands farms</td>
<td>New alternative and source of protein and family income</td>
<td>Improve availability of family diet and income</td>
</tr>
<tr>
<td></td>
<td>Use of floating cages and adequate feeding strategy and management oriented to intensify trout production</td>
<td>New alternative oriented to national and international market</td>
<td>Improve the trout farm and family income up to more than 300% by market articulation.</td>
</tr>
</tbody>
</table>
It is clear that the implementation of technological alternatives requires a strong linkage between production and consumption, where markets are important as the driving force of the farming SAR&RD approach.

Figure 14 shows the components of this orientation aimed at improving production at low production cost to generate a surplus. This includes an adequate process of transformation to generate an added value product that responds to demand, which can be local, regional, national or international. The production to market chain should be analyzed with respect to costs of production and transport to the market. In some cases the processing should occur in other areas with the infrastructure and marketing connections.

To complete the cycle of the farming SAR&RD approach (Figure 5), production programs must be implemented. Without the implementation, the population benefiting from outputs of the SAR&RD approach is limited to a small number of farmers, mainly those participating in the process, as the dissemination reaches a very low percentage of the population. This is exemplified in Figure 14. Note that since a long time is required to reach the total population, so
immediate impact can be limited. The presented case on potato seed production in rustic greenhouses involved the use of fertilizer and plastic, materials that negatively affected the rate of dissemination of the technology after the project activities ended (SEIMPA, 1995). A similar experience was documented for the commercial greenhouses producing vegetables in the Altiplano (CIRNMA, 1999) and mixed forages in Carchi, Ecuador (León-Velarde and Barrera, 2003).

In the Andes, the possibility of initiating and maintaining effective production programs through conventional means is very low (Figure 15). Local and national governments have neither the level of financial support required nor the infrastructure to implement them. Innovative methods

Figure 15. Rate of technology dissemination. A) Shows the potential to increase the rate of adoption by using a participatory method among farmers; it is more important the rate of communication than the initial number of farmers adopting a particular technological alternative; the use of farmer collaborators and contests among farmers contributes to an increase in the adoption rate. B) Shows a particular case study on rustic greenhouses to produce seed potato; during the first three years an average of 88% of the objective (goal) was reached, which represents the 18% of the total population (target). The question remains on the continuity of actions to reach the total population; some cases do not consider linkages with other institutions and the diffusion rate decreased.
to attract producers and the private sector with cost-effective mechanisms to increase the adoption rate of good technological practices are required. In addition to solving the productivity problem other important issues must be included in the new paradigm: the protection of the natural resource base, market competitiveness and the generation of rural income and employment. Empowerment of farmers’ organization and participation of private enterprises under well-defined market rules consolidate the impact at the farm and regional levels.

In this way, the integration of the knowledge and experience within the SAR&RD approach is shown in Figure 16, which summarizes a representative scheme and results obtained in the Altiplano, where a sort of activities were concatenated to achieve an impact at the regional level. The defined objective to work from production to consumption, including products transformation, created the necessity to promote capacities in a step-by-step mode. During this time many projects with specific roles and locations were carried out, representing a continuous line of action with several partner institutions, which contributed to attaining the objectives and the goal of the research for rural development, creating producers’ capacity and linkages with the private sector.

**Creating producers’ capacity and linkages with the private sector for rural development.**

![Figure 16. Schematic forms of association of the small producers of products that have a comparative advantage.](image)

The opportunity to expand the area of crop–livestock systems, thus increasing the size of operations, can only be realized if concrete measures are taken. Given the circumstances, a large challenge of the rural sector is the incorporation of underutilized land to increase the cultivation
area as well as to generate new jobs, protect natural resources and produce sufficient to guarantee food security. However, the incorporation of new land is constrained by topography, type of soils and water availability among other physical factors. Consequently, the discussion about the evolution of agriculture should be focused on the economic competitiveness of the crop–livestock production systems as compared with other ways of employment generation (rural tourism, agro-industry, construction of roads, etc.) and other uses of natural resources (protection of water sources, capture of CO₂, construction of terraces, etc.). Thus it is necessary to incorporate producers with the capacity to invest in efficient technological alternatives for producing commodities with comparative advantages. This implies assessing the potential for added value and generation of employment and income of different commodities. Figure 17 shows the relationship of production at different levels with the market demand (local, regional, national and international).

The dotted area represents the link with the demand of products. However, the economic control includes mechanisms of liberalization to support the primary sectors that are most affected. This dislocation was so significant that none of the Andean countries have been able to allocate enough resources to cope with those effects, leaving the mixed systems at a disadvantage compared to other production systems (i.e. intensive production systems). Contrary to expectations, the Andean countries increased their public expenditures creating fiscal deficits.
that were impossible to handle rationally in the following years (gross domestic product debt service increases from 1% to 6%). Consequently, limited resource availability makes the political cost of investing in poor areas very high, drastically limiting government willingness to invest directly to help small producers. Likewise, the pressures of the services and industry sectors maintained the exchange rates below equilibrium level, in favor of imports of crop–livestock products, showing a clear bias toward the consumers. With that exchange rate management, public debt increased disproportionately and there were no possibilities of exporting crop–livestock products. Other structures created by state modernization reforms were expected to contribute to developing the agricultural sector, but have had limited success. The semi-fiscal funds are interested in state-of-the-art technology and very few are willing to invest in infrastructure and/or support for small-scale production systems and much less in mixed systems (Estrada and Quiroz, 1999).

Nevertheless, through different projects the NRM Division of CIP is exploring the possibility of bringing together the small producers and the private sector to invest in rural areas. The strategy is based on the premise that there are low-cost, underutilized products with comparative advantages. This is particularly true in areas of Peru and Ecuador. The following paragraphs summarize what NRM/CIP is implementing in some areas. The main objective is to help the producers solve their problems through sound management of natural resources, and for them to achieve technical and economic efficiency and social equity.

There are producers, landowners and investors that want to enter in strategic alliances to ensure possession of land and/or production of raw materials. However, under the current situation:

- Few producers in different areas are keen to finance the establishment of a farming business of necessary scale to guarantee adequate market price for their products.
- The availability of land has been reduced, and the lack of income makes it impossible for producers to accumulate capital to purchase more land and thus expand operation size.
- With the current levels of unemployment the cost of capital has increased for the small producer.
- The government or private banks are neither willing nor have the available capital to finance the establishment of rural micro enterprises, even if it is demonstrated as one of the best investment alternatives.

With this scenario, one viable solution is to create groups of producers to promote commercial alliances between farmers, entrepreneurs and large producers. These alliances should promote the development of business capacity among the farmers.
There is a consensus on the need for making the change through strategic alliances. This consensus is based on the required better administration, vertical integration of the production chain, and agreements on prices in critical periods. An absolute necessity is to have objective criteria to prioritize investment, so that it fulfills partners’ expectations.

Each member of the alliance plays a complementary role. National research institutions and universities are important in technology generation. Non-governmental organizations, which are in contact with farmers, contribute to the implementation of activities. In the Altiplano, CIRNMA was responsible for creating the farmers’ associations and managing the credit fund. In this case, the project provides technical assistance to farmers in the different stages of the research and development process, including marketing of farm products. Farmers sign an agreement of co-responsibility to pay the loans provided by the project through a voluntary credit scheme based on revolving funds, oriented to facilitate access to markets.

**Challenges for the Natural Resources Management (NRM) Division of CIP to reduce poverty at farm level**

The NRM Division conducts several projects in the Altiplano, which have activities oriented to:

- Designing case studies within the project that would be attractive to farmers and other actors,
- Promoting the creation of farmers’ associations and a credit fund,
- Creating a strategic alliance among producers and the private sector based on actual revenues for all the partners,
- Helping negotiate the financial support and link with the market,
- Creating financial mechanisms that can stimulate participation.

To illustrate the work that NRM/CIP is doing we include a summary of the on-going program “Poverty reduction in the high Andean region through the production, transformation and marketing of agricultural products” (Figure 16). This program integrates several projects in a horizontal collaboration manner based on the comparative advantage of each project, all with a similar general objective. Thus, there is an integrated effort, pooling funds towards the same objective to minimize transaction costs and conduct more activities.
Activities are based on the SRA&RD approach, which facilitates different types of associations of small producers. Figure 18 summarizes three main types of association based on the population of producers. From this population, one individual producer can create a micro enterprise, such as the case of the dairy farmer who is now producing cheese. Also from the population, a group of farmers could constitute a micro enterprise, which is the case of oca farmers who now produce oca marmalade. Another type of association links a group of producers with the private sector. This is the case of trout production, textiles (sweaters) and other handicrafts. Table 4 describes the different stages of the production to consumption chain for three products with comparative advantage in the Altiplano, oriented to different markets. The table shows the gain that each segment obtains. The first step is to increase production with low-cost inputs, which increases the producer’s income. This is facilitated by technical assistance and supervised credit. The other stages add value through processing and facilitate access to markets.
A few lessons learned in the process

During many years of continuous implementation of different projects in the Andes some lessons were learned and applied in the new agricultural project. Among them we can summarize:

- The operational size of the participating farm is critical. The size should be as efficient as possible to minimize fixed costs.

- The geographical coverage should be selected to include as many small farmers as economically viable. It is required that the alliance be effective in a great scope of action without significantly reducing profitability. This is necessary so that the alliance can select areas with biological potential that guarantees productivity and in turn includes an adequate number of small farmers in areas where a large impact on environmental externalities is expected.

- It is of outmost importance to generate income in the shortest time possible. This is most attractive to the private sector and ensures future investment that benefits a larger rural population. Products with periods of less than 18 months of production have a clear advantage.

- Fast implementation should be a priority. To do this, the selected product should have a consumer demand and be linked with private sector partners. Partners from the private sector strongly linked to local, regional and international markets facilitate fast implementation of the project.
A very important part of the economic and social benefit is related to evolution of the existing alliances. It is expected that the alliances by product should increasingly evolve toward niches of poor population with environmental impact. Government is willing to invest to achieve this change, whenever ex-ante analyses show the alternatives produce a large total benefit (economic and social). Some products are more suitable than others, but in most cases the evolution depends on the convening capacity and leadership of the entrepreneurs and managing partners.

Timely investment is required. The long-term products that are those which currently have better profitability are subjected to cyclic price fluctuations in both the national and international markets. The profitability of the investment and the cash flows are closely related with the time the activity is initiated, and as a result it should be regarded as a key element to identify the niches of investment available in the Andean countries. Defining the optimal time of investment involves a complex analysis that requires long-term information and studies of cycles of production and prices. Entering in these businesses without knowing these fluctuations in depth might make the difference between project success and disaster.

Maintaining or creating rural employment, as investment necessary for generating permanent employment is a major issue. Unemployment is one of the main problems in rural areas and this indicator is valid for identifying niches where government investment is more effective. There are good opportunities to invest in smallholders’ farms that could increase profitability in response to minor management changes.

Equivalent income of the producers that enter in the alliance: the shadow prices for the farmers, adjusted for the costs of the basic services, would be an indicator of the regional niches to which investment should be oriented. The shadow price of the wage is one of the most decisive factors in the profitability of the alliances. The critical economic situation in the Andean countries is making farmers enter in alliances where they contribute labor for 12 months, without receiving a cash payment, expecting only the income at the harvest.

Strategic alliances with the private sector require government funds to cover a percent (around 30-40% of the total amount required). To achieve this, projects must include governmental priorities such as generation of rural employment or the protection of the environment.

The fund should be initially managed by the private sector and then transferred to farmers. The process should include the training of farmers in managerial skills.
Alternative financing sources for small producers. Large export companies have access to credits, provided the government policies are clear and stable; therefore, they will be able to attract new capitals.

CONCLUDING REMARKS

The challenge to rural agriculture in the Andes is no longer limited to productivity. Other elements such as global competitiveness, the conservation of the natural resource base, and the generation of rural employment, among others, are becoming more relevant. These changes imply that the scientific community must also evolve to provide the answers needed by the rural farmers.

Research based on farming systems analysis, oriented to rural development, is an approach that has contributed to overcoming limitations in the productivity of rural farms. Some of the tools introduced through this approach, such as systems analysis, have been instrumental not only in solving local problems but also as a repository of knowledge management systems. The information and knowledge generated in a specific environment can be encapsulated, transported and adapted to other situations thus minimizing the cost of searching for specific answers.

Due to the localized impact of the technology generated and validated following the farming SAR&RD approach, new complementary methods with more participation of other actors – policy-makers, NGOs, groups of farmers, private sector, etc. – have been tested. The paper focuses on examples where the so-called more holistic approaches are being tested. All cases are highly participatory without free-gifts to farmers. Farmers must pay their way to solve their problem. In both cases systems analysis tools have played an important role. In the first case, the models built were used to show to the national institutions and donors the expected feasibility of the project under the SAR&RD approach. In the case of scenario analyses, it had to be very convincing for the private entrepreneurs to buy-in. We strongly believe that more holistic approaches are viable with good scientific backstopping, and that those more holistic approaches, formerly known as production programs, are a necessary complement to SAR&RD.
REFERENCES


CIP’s Mission
The International Potato Center (CIP) seeks to reduce poverty and achieve food security on a sustained basis in developing countries through scientific research and related activities on potato, sweetpotato, and other root and tuber crops, and on the improved management of natural resources in potato and sweetpotato-based systems.

The CIP Vision
The International Potato Center (CIP) will contribute to reducing poverty and hunger; improving human health; developing resilient, sustainable rural and urban livelihood systems; and improving access to the benefits of new and appropriate knowledge and technologies. CIP will address these challenges by convening and conducting research and supporting partnerships on root and tuber crops and on natural resources management in mountain systems and other less-favored areas where CIP can contribute to the achievement of healthy and sustainable human development.

CIP is supported by a group of governments, private foundations, and international and regional organizations known as the Consultative Group on International Agricultural Research (CGIAR).

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