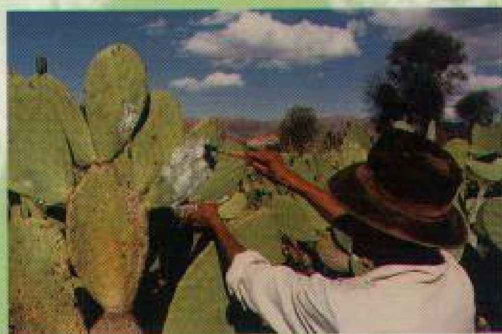
Cactus Pear and Cochineal in Cochabamba

The development of a cross-epistemological management toolkit for interactive design of farm innovation



A. Tekelenburg

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About the author

Tonnie Tekelenburg was born in Wilp, The Netherlands, on March 26th 1960. In November 1985 he obtained his MSc degree in Tropical Horticulture at the Wageningen Agricultural University. This study contained technical as well as socio-economic subjects: soil-cover techniques for fruit orchards, organic farming perspectives in Ghana, working conditions and position of (illegal) foreigners employed in Dutch greenhouses and an interdisciplinary analysis of the agrarian policy of the Sandinist (Nicaraguan) government from 1980 to 1984. Research was carried out in multidisciplinary teams of economists, sociologists and technical agronomists, except for the soil-cover study. The research on working conditions in the Dutch greenhouses was based on the action-research perspective. During his studies, he spent six months working on conventional and biological farms in The Netherlands as well as nine months in the Bolivian highland village of Tiraque.

After his study he was invited to do a desk study for the Dutch co-financing agency ICCO on five Bolivian agricultural projects, and went for three months to Bolivia in order to visit some of the local counterparts (NGOs) of ICCO. Returning form Bolivia in March 1986 he prepared, guided and evaluated the first course of Ecological Agriculture in Tropical Zones at the Warmonderhof school for agrarian education.

The Bolivian NGO FEPADE invited him to become an extensionist, researcher and project leader. In 1991-1992 he was team leader of the Cactus Pear and Cochineal Research Project (PITC) of the Bolivian Export Foundation. From October 1992, he was responsible for research and extension of the projects in the local NGO TUKUYPAJ. In July 1993, he started preparations for his PhD study. During the writing of the manuscript in Managua, Nicaragua, he carried out several short-term consultant contracts in Honduras and Nicaragua on environmental problems and sustainable agriculture (1996-1997). From 1998 to 2001 he was director of the Management Centre for family farming (Centro de Gestión) in Talca Chile, a pilot project for new extension strategies of the Agricultural department of the University of Talca.

Stellingen

1. Bij interactieve leerprocessen gaat het er niet alleen om hoe boeren bij wetenschappelijk landbouwkundig onderzoek worden betrokken, maar ook hoe wetenschappers effectief de door boeren (stakeholders) geïnitieerde en geleide ontwikkelingsprocessen kunnen ondersteunen. (dit proefschrift)

2. Nog meer dan tropische gronden is de onderzoekmethodologie (technieken, -methodes en -benaderingen) voor landbouwontwikkeling onderhevig aan erosie, maar beide kunnen gerehabiliteerd worden. (dit proefschrift)

3. Experimenteel onderzoek en scenario ontwerpen kunnen bijdragen aan verbeterde besluitvorming, maar kunnen de besluitvorming niet vervangen. (dit proefschrift)

4. De validatie van een productiescenario mag niet leiden tot een legitimatie achteraf, maar moet gebruikt worden als een techniek voor verhoogde beslissingskracht tijdens de besluitvorming. (Van Pelt, 1993)

5. Op basis van een specifieke praktijksituatie (learning in practice) en de participatieve reflectie op en systematisering van de ervaring (learning from practice) is het mogelijk nieuwe theoretische concepten en methodologie te ontwikkelen (learning for practice). (dit proefschrift)

6. Indien van een boer wordt verwacht, dat zij/hij voedselproducent is, bedrijfseconoom, milieu-specialist, natuurbeheerder, technisch vakman en een vooruitstrevend ondernemer, dan is dat op zijn minst tegenstrijdig met het feit dat deze veelzijdige mensen in hun zoektocht naar bedrijfsontwikkeling bijgestaan zouden moeten worden door een multi-disciplinair team van monogame vakspecialisten.

7. Tegen uitbuiting is verzet mogelijk, tegen solidariteit (het handelen met betrekking tot niet ter discussie staande rechtvaardigheid) valt niets te beginnen.

8. Indien interactief onderzoek (het produceren van operationele kennis met, door en voor boeren) een norm is aan de Universiteit Wageningen, dan hoort daar een eigen beoordelingssysteem bij voor promovendi middels een veel bredere opzet van de publieke verdediging (van proefschrift en stellingen) en beoordelingen van betrokken stakeholders uit het onderzoek en de case study area.

9. Indien de evolutietheorie wordt getoetst op de oorsprong en ontwikkeling van het insect cochenille (genus Dactylopius sp.), dan zou je waarlijk in een scheppingsverhaal gaan geloven.

10. In geëmancipeerde gezinnen kan de promovendus niet meer dankzij maar moet hij/zij ondanks partner en eventuele kinderen het proefschrift schrijven.

11. Indien we de voorwaarden voor duurzame ontwikkeling, die gesteld worden aan de financiering van kleinschalige landbouwprojecten in de Derde Wereld, in het verleden hadden toegepast op de ontwikkeling van de Nederlandse landbouw, dan zou deze er heel anders hebben uitgezien.

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Cactus Pear and Cochineal in Cochabamba;

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Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
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he de comer esta tuna
aunque me espina las manos

Dedicated to:

my grandparents
Tekelenburg and Vriezekolk,

Farmers, who practised small scale, mixed arable and livestock production in the IJsselvalley, Voorst, the Netherlands.

Preface

My grandparents and some uncles and aunts were small scale and mixed arable and livestock producers. They put the agrarian topics on the discussion table at family meetings. I remember so well the fierce discussions they held in the 1970ties about farm innovation, the national agrarian policy, 'modernisation' of agricultural production, and credit facilities of the bank. I discovered that farmers in the IJsselvalley worried about their future as farmers. My Uncle used to ask: "Shall I be one of the winners and what can I do to continue being the farmer that I have always wanted to be?" Policy-makers were clear: more than 50% of the farmers must stop their production activities in order to improve competitiveness and income for those who remain. The main stream of agricultural development was extending the area of production per family, intensification of production, mechanisation and specialisation. My uncles intended to follow the mainstream but remained small scale and mixed arable and livestock producers in comparison with the National situation.

These farmers also mentioned that there was no significant help for them, in their choice for developing other styles of farming than the main stream. They expressed their criticism to national policy makers, to researchers of the Wageningen Agricultural University and to governmental extension services. As they used to say "Those studied people do not listen to our farmers' visions, do not understand what our farmers' problems are and they come with solutions which we have never asked for". These criticisms pointed to me personally, when I started to study at the Wageningen Agricultural University. I thought in the beginning that knowledge of technical issues would be enough to convince farmers about the required changes on production systems. Later on I discovered that the constant communication with farmers and the participation of farmers in the development and implementation of innovations is as important as the technology itself. These kinds of communication problems between farmers and scientists kept on intriguing me during my study of Horticulture in Wageningen. I could not see agricultural production as the sum of plants and animals. It is the work of people. In the final stage of my M.sc. study, I chose for the action research methodology, for well-defined target groups. But it was not so easy to establish a real dialogue, to define a joint research agenda and to design options for farm innovation.

In 1987, when I left The Netherlands for Cochabamba, Bolivia, it was one of my personal objectives and challenges to find out how to manage - facilitate farm innovation processes with farmers, by farmers and for farmers. I started working in a local NGO. This institute carried out small-scale and integrated development projects. The fieldwork in agricultural production consisted of on-farm experimentation, an extension service program as well as credit facilities. In this period, problems that faced subsistence farming were intensively discussed. Cactus pear and cochineal production were studied and tested together with farmers as well as implemented at small-scale production levels. I worked more than 7 years in the periphery of the countryside in Cochabamba, first as an extensionist, later as a program coordinator in NGOs and finally as project director of the cactus pear and cochineal research project (PITC). At the same time, I maintained direct and intensive contacts with farmers and farmers' unions. It appeared to be very complex to facilitate and support local development processes, especially defined and controlled by farmers themselves. In the beginning I experienced the lack of overview of specific methodology in order to organise and support such local farm innovation processes. However, based on a step by step implementation, the Cochabamba experience turned out to be interesting, in relation to farmers' contribution to research activities and their pivotal role in control over research and development.

The main question became why the experience was so successful. This issue laid at the basis of the formulation of the research question for this Ph.D. dissertation. The intellectual challenge for me was to show to a large and diversified public that, from a particular project, lessons can be drawn to improve interactive learning for farm innovation. This challenge has everything to do with the cooperation and communication issue between farmers and scientists that have intrigued me since my youth.

In this book, the local research and development process of the small-farmers (campesino) union of Huancarani is discussed. Research activities were carried out by farmers themselves as well as by facilitators and scientists, but the farmers union kept control on planning, evaluation, decision-making and action. The book refers to a technical issue (the development of cactus pear and cochineal production) as well as a social issue (when the relation between farmers and scientists is addressed and applied methodology is analysed). The exercise covers a reconstructed logic of applied research, design and development methodology and is therefore abstract. The final result of this exercise was the production of the management toolkit for the design of interactive learning processes. This toolkit became a practical instrument for me while managing and facilitating farm innovation processes in other contexts. It is the *development* of this toolkit, the learning process, that I want to share with other scientists and development workers.

Acknowledgements

This book is the result of a joint farmer - facilitator learning process that covered a 7 year period of working in rural areas of Cochabamba. However, the client based and applied nature of my approach I developed already during my practical training, a component of my study at the Wageningen Agricultural University. I would like to thank farmers in the Netherlands: Johan and the late Ada Spee; goat keepers in Brummen, personnel of the Biodynamic farm Kraaibekerhof, the conventional fruit farmer Breunisse and my uncles. I got my practical experiences in farming there and discovered the different types of farming and styles of management. I want to thank also the people in Bolivia: the late Father Esteban Avelli, local extensionists and members of the small-farmer union of Misk'a Mayu, who showed me effective pathways for campesino-oriented development and participatory approaches.

During the Land Rehabilitation Program in Cochabamba, I was part of the multi-disciplinary teams of local professionals and farmers. The experience and the knowledge we obtained were the collective effort of many people. I benefited greatly from the support of my colleagues, especially Justiniano Vargas, Juan Rocha, Susana Mejía and Ann Coutteel. I am indebted to Victor Ortuño, who was my counterpart for more than 5 years. I am very grateful to the people of the NGOs FEPADE and TUKUYPAJ, as well as to Bert van Barneveld (DHV consultants), who was my supervisor in the PITC research project of the Bolivian Export Foundation.

I also thank the farmers of many campesino communities, who enabled me to participate in their struggle for life, who shared with me their cultural based knowledge and experience, and accepted me as an enthusiastic development facilitator. I am greatly indebted to Eloy Vargas, who was the key person of the Huancarani community. He was my "personal professor" with respect to the cosmovision of the Quechua farmers, traditional agricultural practices and religious contemplation.

Many people supported the writing of this manuscript. They commented on the drafts as regards content. I thank Sonja Barends, Jeffrey White, Coen Reijntjes, and Paul Engel. For English secretarial and editing help and lay out, I thank Mrs. Hanneke Drijver de Haas and Mr. Ed de Bruijn. I am grateful to the two supervisors of my doctoral work: Niels Röling and Eric Goewie. They stimulated me to write and restructure this book. Both contributed with interesting scientific viewpoints and also showed sensitive-human affection for the agricultural development issues of the Bolivian campesinos.

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Chapter 1

Introduction

1.1 Working with family farmers

This book describes five years of research and extension for the Land Rehabilitation Program (LRP) in the farmer community of Huancarani, a remote village in the Ayopaya province of the Cochabamba Department in Bolivia. At that time the LRP consisted of a group of farmer organisations and local and national NGOs (Non-Governmental Organisations working on rural development), organised in a platform. It appeared to be possible to design a process focused on the question 'How can resource-poor farmers learn to innovate their own farms in a degraded environment'. The result is a good example of what Röling (1988, 1995, 1996) called "interactive agricultural science".

Interactive agricultural science is about the cooperation between family farmers and scientists. Both differ in their way of looking at the production fields, farms and surroundings. They analyse, interpret and evaluate observations in a different way. So, the resulting knowledge of both will certainly differ as well. This difference may, however, also imply "opportunities" for fruitfully bringing observations, conclusions and ideas together. I was interested in the synergy. Therefore, I established platforms of regional and local decision-makers and opinion leaders. They had to learn to work together. They had to learn to produce hard results by soft methods. They had to learn to design the learning process involved.

My role became a mixture of being:
- an agricultural extensionist,
- an external informant with access to outside information on crops, agronomy, environment and methodological topics,
- a researcher on technical and economic subjects and their interface,
- a trainer for local extensionists and farmers, and
- the general coordinator of the Land Rehabilitation Program.

I started my work in Bolivia as an extensionist of the LRP. I continued as a project coordinator involved in research on cactus pear and cochineal production which I did as part of the non-governmental organisation Fundación Para el Desarrollo (FEPADE) from 1987 to 1990.

I was director of the Cactus Pear and Cochineal Research Project (PITC) of the Bolivian Export Foundation (funded by the Dutch International Cooperation and the World Bank) in 1991 and 1992. In this period, I stimulated and coordinated all cochineal promotion and production initiatives at the national level. I finally worked for TUKUYPAJ, a local NGO especially created for the support of farm innovation through cactus pear and cochineal production (from 1992 to 1994). All functions mentioned above facilitated my working for the Community of Huancarani without any impediment during 5 years. The LRP was not all smooth sailing in that community. Without access to modern libraries, knowledgeable people or appropriate hardware, the LRP had its limitations. The next paragraph considers these and compares them with the opportunities that are involved.

Fieldwork for the LRP: Limitations and opportunities

The methodology of the LRP was restricted from a scientific point of view. From the beginning it was clear, as is usual in Bolivian NGOs, that the LRP could not offer long-term research programs because of lack of human capacity, and limited funds. Scientists could not count on advanced research centres. They were dependent on farmers' involvement and contributions. Most agricultural experiments were, therefore, carried out on farms, and designs were made with generally available and low cost software. Only certain laboratory work, such as the chemical analysis of cochineal (a beneficial insect dye for selling), was contracted to the Cochabamba San Simón State University. It was a real challenge to do research under these conditions. It must be said though that the team, including the farmers involved, was highly motivated. There was an obvious sense of urgency and a clear notion that the LRP was a good opportunity to work together.

All limitations mentioned above could also be seen as challenges. I considered the LRP as a project-laboratory to carry out experiments on designing learning processes. Such experiments might provide information for testing hypotheses about methodologies on agronomic designing, on learning pathways of extension and communication science. In addition, the LRP, and especially this case study, was favoured with a number of perfect starting conditions. These were:

- successful methodologies for technical-agronomic designing were available,
- farmers were interested in technical as well as methodological aspects of the LRP,
- farmers and researchers had frequent contact,
- farmers wanted to participate in on-farm research activities,
- results of research could immediately be implemented in the local situation,
- researchers had no problems in getting their projects integrated into farmers' every day work and
- planning and elaboration of a working agenda was not difficult.

Under these specific working conditions, farmers and scientists were seen as co-researchers. The usual role of the extension worker (transfer of technology to farmers, supervision of verification experiments on individual farms, and provision of external agricultural inputs) was changed into that of facilitator of farm innovation processes. He (she) thus tried to avoid the traditional trainer-pupil relationship. So, researchers from outside the community, including myself, could not act independently. One may ask now: What is this all about? In the following paragraphs the scope of this book will be discussed.

Scope of this thesis

This thesis is about farm innovation by interactive learning. It is also about the analysis of problems, the synthesis of knowledge into solutions, and learning together.

This thesis also deliberately reports on efforts to develop farming systems, taking into account the farmers' traditions, religion, culture and survival strategies. Additional methodologies were inserted step by step in order to guarantee active farmer participation. An example taken from the problem analysis phase clarifies the unstructured looking activity agenda of the overall methodology of the LRP.

The steps in problem analysis did not follow the classical patterns I had become used to when presenting scientific reports. Neither time lines in rural development, nor classification of aggregation level thinking were followed. The problem analyses followed the think and work patterns used by Andean family farmers. This line looks unstructured, even chaotic, but it is not. For me, it was the first discovery of resource-poor family farmers in Bolivia having their own way of dealing with their fields and surroundings. They showed having great difficulties in handling strategies which are logical to scientists, extensionists or even policy makers. Figure 1.1 shows the farmers' logic presented in a two-dimensional co-ordinate system of scientific thinking by researchers or extensionists. The logical steps of research-oriented people, which prefer to analyse a problem from high aggregation levels to smaller parts, are followed in a completely different order by farmers.

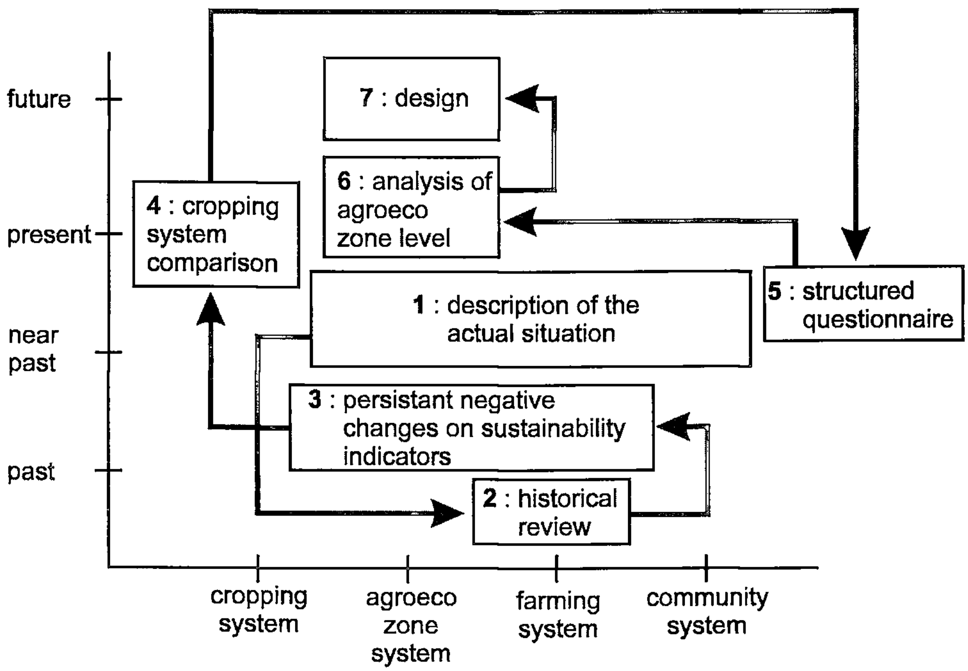


FIGURE 1.1 **Presentation of the logic followed by farmers concerning the problem analysis phase towards design. The abscis represents the various levels of aggregation. The ordinate represents discrete phases in time. The arrows indicate the chronological realisation of the problem analysis carried out by farmers. Each position on both axes adds new information and insight to the problem analysis.**

The sequence of activities for problem analysis was selected by the farmers, according to their opinions and enthusiasm, rather than by a predefined logical organisation of activities in time or according to levels of aggregation. More activities were added *ad hoc*, because new questions kept arising and farmers wanted to solve their problem of lack of information. Because the activity agenda of the problem analysis phase already had become complex, it was not difficult to expect that the complexity of the methodology for the whole LRP would be even more complex. This was observed by the farmers as well. So they started to think about how to achieve a manageable plan of operations for the LRP. Instead of a fixed organisation of farm innovation methodology supplied by me, they proposed to cluster and integrate the results of all activities afterwards. This flexible organisation of activities allowed them to discover step by step the construction of a problem solving methodology.

It is not realistic to state that all knowledge about the problem, necessary for the design of alternative production systems, was obtained in the beginning of the project only. On the contrary, knowledge obtained after realisation of other phases, such as experimental research and design, also appeared to be important. For example, neither the Participatory Rural Appraisal, carried out at the start of the LRP, nor the formal questionnaire, which was applied at the end of the LRP (in 1993-1994), determined their and my understanding of the problems of Quechua farmers. The whole project constantly delivered relevant information during the entire time span of activities.

One could say that in this way farmers discovered how to learn learning. They experienced that in-depth analysis of specific subjects, enriched by literature reviews, starter activities and unexpected events could be managed by themselves. I considered this step by step (unstructured) research journey of the LRP as a learning process by itself. I myself too, discovered that structured research approaches not always guarantee "optimal" results. I found that what farmers experienced from tools or methods are fundamental for getting them involved enthusiastically. On the other hand I had to admit that it was far from easy to abandon my trust in "learned methodologies". Questions such as 'When shall I intervene in the process' or 'Is the knowledge that farmers have acquired really true and valid' crossed my mind many times.

1.2 The Land Rehabilitation Program

In order to support the development of resource-poor Quechua farmers, local NGOs participated in a platform: the Land Rehabilitation Program (LRP). The LRP was the umbrella organisation for various development projects, which were implemented at different times (between 1989 and 1994), by several development organisations and at many locations (especially in the Departments of Cochabamba and Chuquisaca). Two local NGOs from Cochabamba (FEPADE and TUKUYPAJ) became involved in projects at national level. The Bolivian Export Foundation implemented the Cactus Pear and Cochineal Research Project (PITC) funded by the World Bank and the Dutch Government. The project coordinated all cactus pear and cochineal research and development activities.

In view of the difficult agricultural production conditions and the specific socio-economic problems in the Andes Mountain region, the challenge for agricultural development is to break the cycle of environmental degradation and to make agricultural production ecologically sustainable without affecting family incomes.

The Land Rehabilitation Program formulated two main objectives:
- to design ecologically sound and profitable farms, and
- to improve the countervailing power of Quechua farmers in order to increase their self-respect and self-help in creating better chances for their development.

The LRP strived in the first place for revaluating the cactus pear (*Opuntia ficus-indica* M.) as an arable crop and the introduction of cochineal (*Dactylopius coccus* Costa), a profitable scale insect that produces the important red dye carminic acid for the cosmetic and food industry.
The second objective refers to farm development started from the Quechua farmers' perspective. The task of the LRP was to prepare a stimulating atmosphere among the farmer population for the development of agroecologically sound and profitable types of farms. This kind of farming is considered to be important for reducing erosion, degradation of soils and further drop in biodiversity. The LRP focused on a participatory approach, which means:
- Farmers had to become interdependent in managing their farms in such a way that further aggravation of erosion would stop;
- Farmers and researchers had to cooperate in such a way that they learn from scientific results as well as from farmers' insights;
- Farmers had to become involved in the evaluation of their own result and
- Farmers had to become skilled and sufficiently encouraged in the management of their own rural development process.

The LRP underlined that farm innovation must be carried out by the farmers themselves. It accepted that farmers' expertise, the so-called indigenous knowledge, would be important for the success of the LRP. Indigenous knowledge contains strategies for survival of Quechua farmers in the past. There is increasing evidence that subsistence farmers of the Andes are very efficient in utilising scarce, renewable resources (Kessler 1994). This indigenous knowledge, which was the result of a collective learning process, had to be re-discovered and consciously applied. In other words, the whole project had to be based on the *mantra*: learning in practice, learning from practice and learning for practice.

1.3 Purpose of this study

Literature about theories and practical experience on design of interactive learning processes for farm innovation is not available. There are design experiences and interactive approaches that have been described, but they focus mostly on hard-exact results: either a technique, a farming system or a recipe for crop protection (see the literature review in Chapter 4). Design methodologies for learning processes were not found.

With this book I want to fill this gap. During my work for the LRP, I carefully observed all that happened, and made my notes in separate journals. I tried to understand why things happened as they did. I compared the information thus obtained with what I could retrieve from literature. But also, validation and evaluation-oriented discussions with stakeholders within the project area and others outside were important means of discovering the relevant methodological patterns and processes involved. I decided to publish my results, as I found a strong relationship between the success of the LRP and the identified interactive learning process among Quechua farmers, development workers and scientists. Interactive learning appeared to be at the basis of the success of the LRP.

I would like to characterise this way of learning in terms of three fundamental dimensions:
- Learning in practice (achieving a goal);
- Learning from practice (learning from applied methodology in order to improve practice);
- Learning for practice (making results of learning processes available to other projects).

Interactive learning is the result of these three dimensions. Learning about learning processes is thus to improve learning for future farm innovation processes: learning for new practice. In order to learn for new practice, two previous learning stages must be considered: "learning in practice" and "learning from practice". This insight is new. It makes the design of interactive learning pathways among farmers achievable.

The purpose of this study is to understand, manage and design interactive learning processes between farmers and support teams during farm innovation. In other words, take leadership in interactive approaches for farm innovation by which farmers take local agricultural development in their own hands. The question is to identify how social actors can be involved and interact successfully in complex agricultural development processes. This management question is related to other specific questions:
- What are suitable concepts and dimensions for the interactive farm innovation strategy?
- Which activities, methods and procedures are relevant for interactive learning processes?
- How is designing of learning processes for farm innovation related to experimental research and technical-agricultural design?
- How can relevant methodology be merged (structured) into a toolkit for the design of interactive learning processes?

1.4 Structure of the thesis

After the introductory chapter that leads the reader into the realms of this book, Chapter 2 presents the outline of the LRP. It identifies, among others, the cohesion between causes and problems of Huancarani, the selected case study areas and the project site in Bolivia. Chapter 3 makes the reader confident with the physical, abiotic and ecological characteristics of the project site. Chapter 4 focuses on the working process in the project. Chapter 5 identifies farmers' problems: the problem statement, as well as an outline of the basic questions behind the problems that farmers used to put forward. Chapter 6 continues with bringing the basic questions of the Quechua farmers into a set of assignments for me as "problem solver". In other words, goal setting was based on a perspective of the future. The design objectives are defined at three levels of learning: in practice, from practice and for practice. Chapters 7 and 8 show the results of research on cactus pear and cochineal as well as the design of the integrated cactus pear production system. It shows how hard-exact solutions were projected (learning in practice). Chapter 9 presents the results of soft design, referring to farmer and institutional organisation, knowledge integration and decision-making procedures (learning from practice). Chapter 10 shows the result of learning for practice by building up a management tool that works like a process agenda for managers to design learning processes. Finally, Chapter 11 brings the reader back to the initial goals and questions, referring to the applicability of the management tool. It reflects on the results at three levels of learning and abstracts a theory from it on how interactive learning can be designed for the benefit of future projects on rural development. Chapter 12 is conclusion-oriented at the level of learning for practice and gives recommendations for the roles of farmers and facilitators as well as for the use of the management tool for interactive farm innovation.

Chapter 2

The Land Rehabilitation Program

The Andean Mountains, especially in Bolivia, erode at a terrifying high speed. Complete slopes and upland plains disappear year after year. Fertile topsoil flushes away and mountain streams and rivers become clogged. People already have lived in these regions for many generations are now forced to abandon their land. Migration to cities and further aggravation in the rural areas evoke new and other problems. The LRP had to find methods for getting things changed. Obvious methods, such as high-input agriculture production systems, specialisation of production, mechanisation, introduction of new commodities, were out of the question. Moreover, Andean farmers seemed to have lost their trust in the so-called modern "Green Revolution" techniques. New diseases, high production costs, decreasing profit and loss of soil fertility made them feel trapped by people or organisations who need Andean farmers for their own profit.

The LRP focused on processes that might help to restore the self-confidence of Andean farmers. This chapter describes this program in detail. First, the cohesion between the causes of land hunger and migration in the upper parts of the high Andes mountain chain will be discussed.

2.1 Land hunger and migration

According to the Quechua farmers, during their lifetime (i.e. in each generation) a major change took place which had great impact on farming. They spoke, for example, about their grandfathers, who turned from agricultural (specialist) labourers of a colonial landlord "hacienda" system into small-scale (generalist) landowners (1953), and about their parents who started to produce cash crops such as tomatoes and hot peppers (1965). The next generation migrated in large numbers (temporarily) to the tropical rainforest and started coca leaf production (1975). The youngest part of this generation left their native villages permanently (1985). These mayor changes may be interpreted as survival strategies and structural innovations in agricultural production. The question becomes opportune what the innovation options are for the next generation. How to find a new strategy when, apparently, all options have already been tried out? Could, perhaps, sustainable agriculture be the new strategy? Before going into this kind of option, we shall consider some demographic data that illustrate the farmers' story described above.

Demographic data

At national level, the annual population growth rate in the period between 1976 and 1992 was 2 percent. In the same period, the rural population of Cochabamba increased by only 1 percent. In the Ayopaya province the population density decreased from 6.2 habitants per square kilometre in 1976 to the level of the fifties i.e. 4.2 (INE 1993). This means that the large number of emigrants leaving the province of Ayopaya has resulted in a negative population growth.

In 1953, the year of the Agrarian Reform, 162 families were living in Huancarani in Bolivia and created a local farmers union there. From then onwards, the structural immigration that had marked the previous period in which landowners used to contract workers from distant provinces, stopped. In 1994, 182 families lived in this community, with a total of 757 inhabitants. The average family size was 4.2 persons.

Causes and consequences of migration

In the last 20 years, 187 families emigrated (permanently) from Huancarani to the cities and other rural areas. Initially, this permanent emigration had nothing to do with wealth. Both rich and poor families left their community. The high emigration rate may be explained by:

- Economical problems arising from declining productivity and land quality;
- Erosion and decreasing profitability of commodities;
- Educational opportunities for young people;
- People without agricultural land.

With the conventional agricultural productivity and actual state of the natural resources, it is expected that the human population will in rural areas such as Huancarani decrease further.

Figure 2.1 shows the prevailing explanation of the impact on land use by migration. Before the land reform, landowners practising a *hacienda* production system cultivated cash crops without fertilisation and soil conservation measures (see Section 3.2). From then on, labourers who had little or no capital and lived isolated, were forced to raise an income on their own land. These people had three options: cash crop production on degraded land, deforestation of vulnerable ecosystems, or emigration.

When people emigrated from their native village, they brought with them their traditional agricultural practices. In that way, farmers introduced extensive production systems, characterised by lack of fertility and soil conservation strategies. So, the decline in soil quality was "exported" from the highlands and spread over Bolivia (Painter 1993). In the climatic conditions of the tropical rain forest areas, these agricultural practices were even more catastrophic.

However, there were more effects. Since people could hardly cut the strong (family) ties they had with their native community, because of emotional affection, community membership and the need for additional and diversified family income, continued with agricultural production in the highlands.

Some members of the community received agricultural land on a sharecropping basis. In this production system, income from agriculture is split up between two farmers and cannot recover the costs of investments in soil care. Emigrants also keep livestock on the communal land of the native community. These areas suffer from overstocking that does not allow regeneration of vegetation and soil quality on fallow land, exhausted agricultural land and vulnerable non-productive areas. In this way, the downward spiral of soil degradation continues, causing the problem of land degradation and land hunger to escalate. The result is, that the area of unprofitable and abandoned land increases.

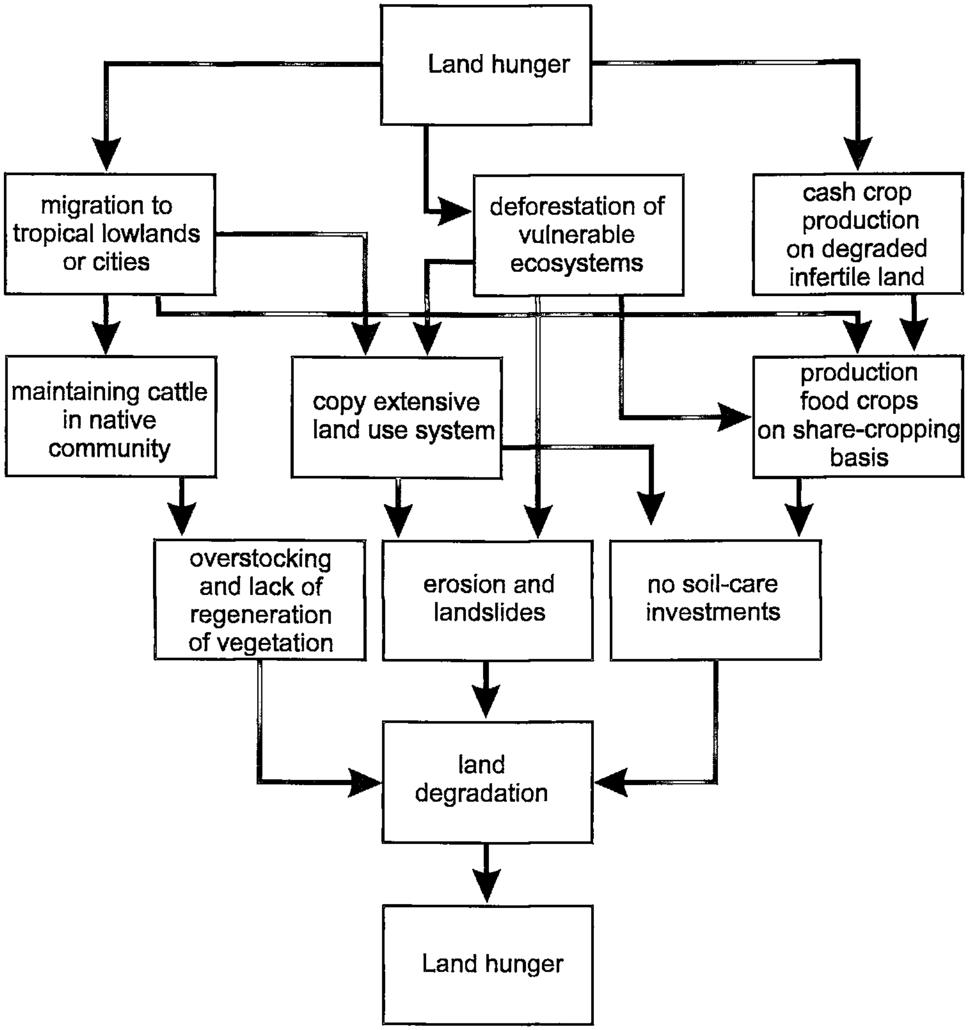


FIGURE 2.1 Explanation of the cycle of unsustainable land use.

2.2 Recovery of soil fertility as a key to rural development of the Andes

Land hunger in Huancarani was partially compensated by "permanent emigration" of the Andean people (Painter 1993). This means that migration may stop as soon as farmers find sufficient opportunities for subsistence.
Recovery of soil fertility may be the key to stopping emigration. Parallel to this, the problem of ongoing erosion may be tackled via research and extension that can contribute to strategies that keep resource-poor farmers at their presently exhausted soils.
The LRP agreed that such farmers will stay if they can make an income from these soils. Taking this as a hypothesis, we could say that a possible approach may be to help resource-poor farmers to learn how they can restore soil fertility themselves.
The LRP wanted to teach farmers to think about their future. It also wanted the farmers to act and not accept that they have to react passively to threats, either slow and on-going or sudden and new.
The LRP accepted that only learning processes, rather than packages of hard solutions, can help the farmers to become confident about their own possibilities for permanent farm innovation with special attention to soil management, the first objective of the LRP. In other words, a farmer had to be taught how to learn by improving his (her) skills in observation, registration of data and interpretation of phenomena, both in and outside the farm. In a group of farmers or with different stakeholders, learning also implies improving communication, interaction and joint learning. The farmer has to find the relationship between the quality of his/her own decision-making (the second objective of the LRP) and the quality of the soil.

In relation to the rehabilitation of exhausted agricultural land in the beginning of the LRP, we identified four fundamental aspects to be addressed in four different actions:
- Stop overstocking and protect the land from erosion;
- Re-establish a soil cover by natural vegetation or special crops;
- Recover soil quality and fertility;
- Establish a nutrient cycle.

The first two actions are the most difficult. However, they also contain the key to reaching the goals of the LRP. This action will be a mix of indigenous knowledge and soft and hard solutions. The third action is typically hard solution orientated. For instance, in this action we search for irrigation strategies, tillage and composting. The fourth action focuses on maintenance strategies and has a good deal to do with learning how to actualise farm strategies, cooperation and marketing.

2.3 Organisation of farm innovation

More than 25 communities of the Cochabamba valleys participated in the Land Rehabilitation Program (LRP). Each community started an independent development process because of the specific problem issues on each site and the farmers' involvement in the definition of the research and design agenda. These local development processes were facilitated and supported by several development organisations (mostly local NGOs).

The LRP started with the initiative of one local NGO (FEPADE). This NGO studied alternatives for fodder production on marginal land. This research question was the outcome of a participatory rural appraisal in the province of Capinota, Cochabamba. Farmers mentioned the cactus pear as a potential fodder crop. The NGO, in coordination with the farmers group, discovered later that cactus pear is an interesting multipurpose crop. Then other NGOs showed interest so that more than ten organisations started working on cactus pear and cochineal production at national level. These organisations kept frequent contacts and organised several meetings, seminars and congresses on the subject. They acted as a platform for knowledge exchange, promotion and coordination.

When representatives of farmers communities showed up asking for information and development support, one of the NGOs took care of the potential production zone. The "take-in" procedure was guided by a bottom-up approach. Farmers groups were interested and they looked for and selected support among NGOs and other development organisations (churches and syndicates) in the area. This can be seen as a non-centralised and autonomous community approach. Also, these local initiatives had some features in common. Because they had already heard about the multi-purpose plant, they pointed directly to cactus pear planting. Once involved, farmers communities defined similar development objectives concerning land rehabilitation, farm innovation and design of integrated cactus pear and cochineal production systems. However, each farmers group interested in the subject, was asked to start (independent of other experiences) with problem analysis and visualisation of future farming. This strategy was applied to prevent copying other development processes. Great emphasis was put on team building and generating knowledge by the new farmers group, more than on the promotion of a solution by way of technology packages.

Farmers organisations and development institutions that lacked information and experience, found each other in coordination platforms for project formulation, training, exchange of experiences and research, but also in planning and evaluation of project implementation and production. So, the introduction of cactus pear and cochineal brought people together, farmers as well as development workers. From these platforms of knowledge exchange, two national organisations were created: one specialised in research and training, the other in farmers organisation, coordination of production and joint sale of cochineal. This approach was in great contrast to the usual way of implementing national rural development projects. Generally, large headquarters for such projects were located in the capital. Centralised planning and promotion were worked out by a fine structure of local offices and extensionists.

In order to support several local development initiatives, interested NGOs formulated the national research project on cactus pear and cochineal (PITC; Proyecto de Investigación de Tuna y Cochinilla). The Dutch International Cooperation and the World Bank funded the project for two years (1991 and 1992). This project carried out and coordinated research, production planning and systematised experiences with introduction of cochineal as well as production rhythms of cactus pear cladodes and fruit. Several workshops and national congresses were held. The research team of PITC prepared a national production project, to be financed by the Bolivian Export Foundation.

On the basis of joint local initiatives, the National Organisation of Cactus Pear and Cochineal Producers was created. The farmers chose a product-specific organisation in which elements of the traditional syndicate structure could be found (election of representatives from local, regional into the national board), as well as elements of NGO organisations, such as project planning and evaluation.

The methodology, activities and outcomes of the LRP varied between communities. The local farmers interest groups, organised in platforms, remained independent in their choice of production objectives as well as in adapting cactus pear production technology to their own development goals and specific local environmental conditions.

2.4 Selection of the case study area

The Land Rehabilitation Program (LRP) focused on technical research, cost-benefit analysis and design of sustainable production systems on exhausted agricultural land. The program tried to learn from this experience in farm innovation. Most communities paid much attention to the technical results and did not systematise the methodology itself so that, at the end, essential data for the analysis of farm innovation methodology were lacking. Therefore, a case study area was looked for where gathered data on implemented methodology could be found. On the basis of this criterion, the Huancarani community in the Ayopaya province was selected. Here, environmental, socioeconomic, productivity and (methodological) process data were available. The community represented the typical mountain characteristics of all communities of the Land Rehabilitation Program, such as environmental heterogeneity, inaccessibility, fragility of ecosystems, marginality as well as comparative advantages for cactus pear production.
Huancarani was, therefore, representative for other communities with respect to development conditions. It did not have the strongest farmers organisation nor did it have the best cactus pear growing conditions, but referring to the interactive strategy, the community of Huancarani presented some important features:

- The local farmers union of Huancarani was well organised, concerned with farm development and had, in the recent past, implemented several development projects with positive results. Not all communities that participated in the LRP had such positive experiences;
- Huancarani counted on trained farmers with experience in participatory development processes. The community took an independent position with respect to offers and implementation by development organisations;
- Farmers were highly motivated to control the development process on their own, but were conscious of their lack of experience and adapted methodological tools for analysis, planning and decision-making, and asked for specific external support to improve this weakness;
- The farmers could express their opinions freely during meetings of the farmers union as well as during interviews and other participatory processes.

The farm innovation methodology as carried out in Huancarani required a minimum educational level and some notion of sustainable development of the farmers leaders. It was also important that farmers really wanted active involvement in planning, design, research and implementation. These elements appeared to be the criteria for success in the interactive approach. Therefore, the case study area, such as the community of Huancarani, could not be called representative for all communities involved in the LRP nor for all peasant communities in the Andes. For the farmers, a certain level of preparation with respect to issues such as development, communication and farmers organisation was required.

The farm innovation support team in Huancarani was built around the development facilitator Eloy Vargas, a farmer of Huancarani and former head of the local and provincial farmers unions. He had received his training from the Catholic Church and had worked in rural development projects in the 1980s, as a forester and agricultural extensionist for development projects of local NGOs. He was still a farmer, worked on his land in the community and owned cattle (leased on a sharecropping basis). He was greatly respected in the community. Eloy trained five Huancarani farmers for the LRP as local extensionist for cactus pear plantation, cochineal production and cattle husbandry. He coordinated the on-farm and communal research and supported the implementation activities of the program alongside with being the head of the farmers union. For his activities he was accountable to the communal farmers union. He periodically informed the provincial board about the farmers union.

2.5 Conclusions

Quechua farmers emigrate from the Andes because their possibilities for surviving in their rural community had become greatly reduced. They do not like to emigrate, as they are closely related to their family, religion, culture and the history of life in the mountains. Moreover, they are highland farmers by tradition.

The LRP started to work with farmers who had stayed in their community and who suffered from the negative impact of soil degradation such as lack of income. These people were looking for alternative and sustainable production systems that would provide them with a chance to survive as Quechua farmers. The program relied on their motivation and their basic knowledge about their surroundings. The LRP had to focus on soil care, reintroduce a forgotten "Inca crop" and teach them to learn from their own experiences and those of others.

Chapter 3

Getting in touch with the project site

To teach farmers how to manage their own local natural resources required the LRP project leader and his colleagues to have good knowledge of the situation on the project site. Such knowledge includes the wide range of biotic and abiotic characteristics of the area, production (sub)systems, social organisation and economic features of family farming. Without any basic knowledge of these aspects of farming, the support team of the LRP would not be considered as being strong discussion partners for the farmers. Such knowledge is essential for the design of production systems, as well as learning processes. To acquire this knowledge requires analysis of the actual situation of farming, approaching it from different angles, including the Andes farmers' views. It also concerns the art of listening, observation, registration of data, interpretation of phenomena in and around farms, as well as discussions and negotiations with the stakeholders involved. I experienced that if the development-aid worker does not see or know the obvious phenomena and processes in every day farming, he or she will not be taken seriously by the people he/she works for.

At this stage, the following three questions are essential:

- What are the physical potentials for rural development on the project site?
- What are the historical events and traditions that explain (1) the way the land is used now and (2) the natural resource quality?
- What are economic, social and cultural opportunities and/or limitations for farm innovation?

3.1 Description of the main abiotic and biotic characteristics of the project site

The community of Huancarani is situated in the Interandean valleys of the Ayopaya province in the Northwest of the Cochabamba Department, 17°05' S, 66°, 55' W (see Figure 3.1). In Bolivia, a rural community is an area of both private agricultural land and public natural resources. The state grants communal farmers organisations the right to use public pasture land and forests. The local farmers union governs the community. Huancarani covers 4700 ha. Farmhouses are scattered or clustered in the fields. Villages as such, hardly exist in the region.

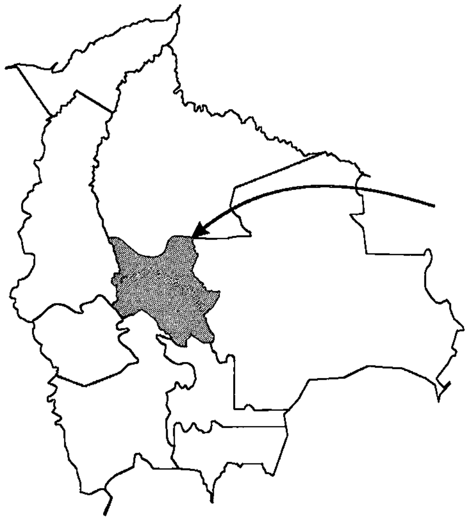


FIGURE 3.1 Localisation of the Huancarani community in the Ayopaya province, Cochabamba department, Bolivia.

The province of Ayopaya is characterised by high mountain chains of the Andes and deep valleys with wide riverbeds. Coming from the high to the lower zones, the landscape changes from bare land to subtropical evergreen hills (*yungas*) and tropical lowland. The community of Huancarani is situated on a slope of 2000 to 4300 meters above sea level. The river Ayopaya borders the community at the lowest altitude (see Figure 3.2).

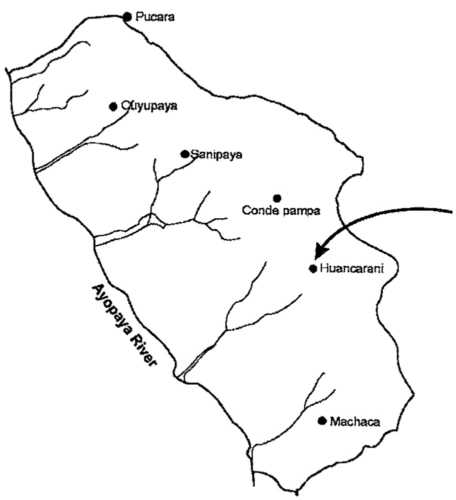


FIGURE 3.2 Map of the communities around Huancarani.

Agricultural zones
Aquino (1986) divides Huancarani, as well as most of the other communities of the region, into agroecological zones. An agroecological zone (agroecozone) is an area characterised by a combination of climate, soils, flora and fauna, favouring special agricultural production and livestock activities. One farmer community and even one farm may comprise more than one agroecological zone. This phenomenon of mountain areas is different from tropical plain areas, where farming systems are small parts of only one agroecosystem. Along the slopes of Huancarani three agroecozones can be distinguished (see Figure 3.3). The highest zone, named Puna, is situated between 3000 to 4300 meter above sea level (1800 ha, 38 percent of the total land in Huancarani). The middle zone, the "grain" agroecozone, is located between 2600 and 3000 meter (900 ha, 19 percent). Altitudes in the "subtropical" agroecozone, close to the Ayopaya river, range from 2000 to 2600 m above sea level (2000 ha, 43 percent).

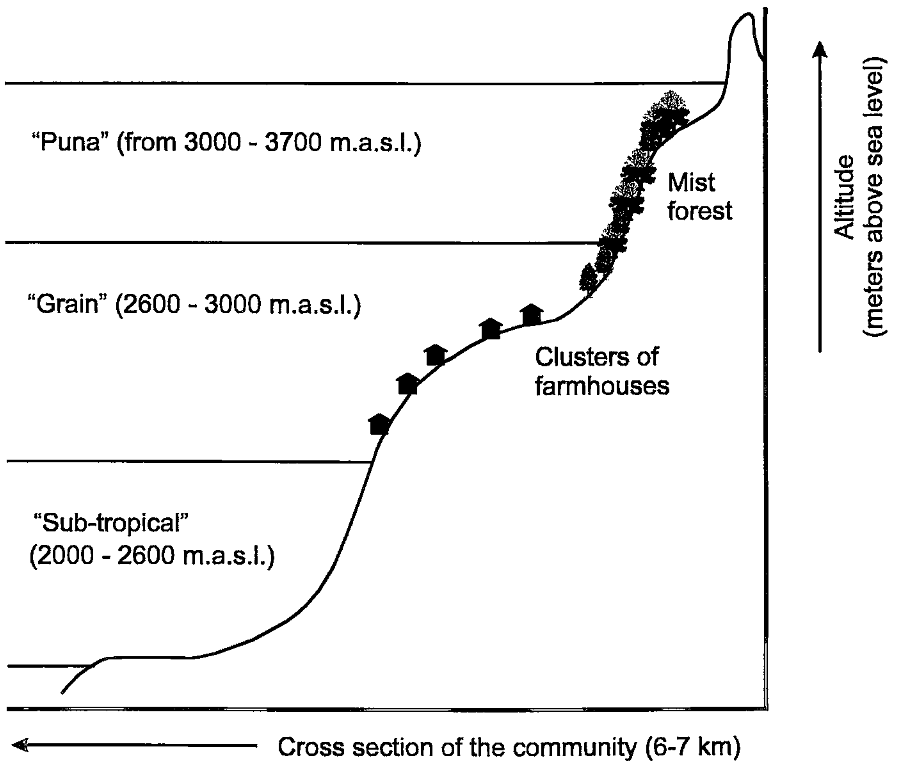


FIGURE 3.3 Agroecological zones of the Huancarani community.

It is difficult to find even one piece of land that is completely flat. The slope crosses the area from Southwest to Northeast. The average slope is between 20-25 percent.

Dry and rainy seasons
There are two main seasons: the rainy summer season, from December to April, and the dry period, from April to November. Precipitation in the grain agroecozone ranges from 670 to 888 mm per year (Aquino 1986). In the mist forest belt just above the grain agroecozone precipitation is more than 1000 mm per year. Rainfall in the subtropical agroecozone is about half of what can be expected in the grain zone. The agricultural season (without irrigation) starts in October when the first rains fall at the high altitudes and in November for the grain agroecozone.

Temperature
The average monthly temperature in the Puna agroecozone is below 10 °C. The temperature is about 15 °C in the grain agroecozone and more than 20 °C in the subtropical agroecozone. The amplitude between day and night temperatures in the Puna agroecozone (above 3000 m) is 30 °C (20 °C during daytime and -10 °C at night). This difference becomes smaller at the lower altitudes. In June and July frost may frequently be observed in the grain agroecozone (2600-3000 m).

Soil
The deep valleys, characteristic of the Ayopaya province are the result of natural erosion. The sediments in the oriental Andes are regular and contain quarts and sand (Villavicencia 1991). Andean soils are the product of climate, topography and bedrock characteristics. Most local soils used to be of an A horizont which is rich in organic material and nutrients. Original soil material (C horizont) may be found directly under fertile soils. Soil depth varies in relation to the slope. Soils of less than 25 cm deep can be found on steep hillsides. The best soils of the grain agroecozone reach a depth of 120 cm.
Man-made erosion and landslides are severe problems in the community. Fragile riversides are affected by erosion. More than 50% of the families have suffered loss of agricultural land caused by erosion and landslides in the last twenty years. Large runoff from high altitudes is the effect of the decreased water retention capacity of degraded agricultural and pasture land. In the centre and subtropical agroecozones between 70 and 90 hectares of good agricultural land have been lost by landslides. As these soils have no bedrock as a basis, landslides continue and gullies become deeper and wider each year.

3.2 History of land use systems

Land tenure systems, land use strategies as well as land degradation characterise the history of Huancarani. In this section these issues will be discussed as they have helped to identify relevant opportunities for farm development and restrictions. The following issues will be discussed:
- Which land tenure systems existed in the past?
- Which land use practices applied in the past can help to understand present land use?
- When and how did land degradation start?

The agricultural history of the Andes comprises four distinct phases as far as production is concerned. The *Inca* agricultural production system was practised until 1500. The *Spanish* introduced their European agronomic and livestock systems between 1550 - 1825 i.e. the colonisation period. During this time the Inca production systems were completely destroyed. The *hacienda* agricultural production system was introduced by 1825 as part of the independence of the Republic of Bolivia. The *hacienda* system ended with the *Agrarian*

Reform around 1953. *Hacienda*s, originally the property of one landowner, were divided into many small-scale units and granted to landless people. In this period, the freehold *campesino* (family farmer) production system became dominant (See Table 3.1).

The Inca agricultural production system

The Incas practised an intensive but remarkably sustainable agricultural production system. Large areas of terraces constructed on hillsides and a complicated irrigation system demonstrate the Incas' capacity to produce food in a hostile environment. They concentrated production on small areas of very fertile agricultural land with favourable climatic conditions, such as valleys and land close to Lake Titikaka (at 3900 meter above sea level). Soil conservation had always been the basic element of the Inca agricultural production. They minimised risks, uncertainties and exhaustion by effective soil-fertility conservation strategies and cropping systems. They knew how to keep their knowledge actualised and passed it on from generation to generation. Land of poor quality or fragile ecosystems were carefully preserved as large buffer zones. The powerful organisation of the Inca society provided rules for keeping intensively used production fields and natural resources in condition (see also: The Soft Side of the Land, Röling 1997).

Terracing and irrigation guaranteed a high and stable agricultural production. Specific Andes crops were (and still are) cultivated: tubers, such as potato species (*Solanum sp.*), oca *(Oxalis tuberosa)* and "grains", such as *tarwi (Lupinus mutabilis)* and *quinoa* (*Chenopodium quinoa*) (National Research Council 1989). The latter were very much in demand because of their high protein content. Incas developed food conservation and storage practices, such as frost-dried potatoes (*chuño*) and salted and sun-dried meat (*charque*).

Outside the agricultural production sites and buffer zones, the Incas kept the large natural ecological zones untouched. Along the borders of the Inca domain trade with neighbouring people took place. Due to the different climatic zones in the mountains (the vertical land use system), as well as food exchange, Incas could diversify their food and non-food production to a large extent (Condarco and Murra 1987).

The Spanish farming system

Directly and indirectly, Spaniards affected the intensive and sustainable production system of the Incas. In the sixteenth century they introduced a system of taxes to be paid on the production of fertile land. As this land belonged to the local people, these traditional owners gradually became subordinates of the Spanish government. Tax paying and introduction of a monetary economy forced local farmers to change their production goals. They did not have to think in terms of maintaining good production conditions anymore, but in terms of the money they could earn from their work within a certain period. They had, therefore, to neglect their traditional agricultural practices, always long-term orientated, and replace them with short-term profit-orientated production goals.

New animals and plant species, mostly less compatible with the Incas' intensive production systems on terraces (Earls *et al.* 1990), were introduced. "European" livestock (cattle, sheep and goats) and their habit to graze down complete plants, damaged the vulnerable vegetation as well as the delicately developed soil structure of the productive land. The soil conservation techniques could not be maintained because of the drastic reduction of the human population caused by the introduction of new, European, diseases as well as by forced labour in the silver and gold mines.

The Spanish Crown sold large quantities of low-quality land to the Spanish colonists. These started extensive agricultural production with contracted people. The successors of the first colonists already reported soil degradation problems, also in Huancarani (see Acta Notarial

1740-1750). As communal land (mostly land of low quality) formerly owned by local communities, changed into private, large-scale *haciendas*, the vertical land use system of the Incas became fragmented (access to more than one agroecozone was blocked). Communities quickly lost their ecological resources (read buffer zones) and the basis of their subsistence farming (Condarco and Murra 1987). Fragile societal human relationships were the result.

The hacienda production system

During the Bolivian independence war (until 1825), a new national land-owning elite arose (Santos Vargas 1982). The first governments of the Republic of Bolivia supported these landowners by the abolition of communal land tenure by Indian communities. Small farmers then had to buy their own, low-quality communal land and had to pay high taxes for it. They could not afford this and started to sell pieces of high-quality land. So, Indian communities also lost their ownership of fertile land. The new regulations created a *hacienda* type with monopoly on land. Indians were forced to work for the landowner because they lacked other opportunities for labour. As compensation for their work on the *hacienda*, they received production rights on small pieces of land. These rights helped them to produce food for their family and livestock and, at the same time, made it possible to maintain the traditional Inca intensive production systems next to the *hacienda* system (Rivera Cusicanqui 1987).

Due to inheritance rules, *haciendas* became divided into plots of land below the level of what was acceptable from a financial-economical point of view. This happened especially in the rain-fed production areas of the Ayopaya province. It confronted *hacienda* owners with a deep crisis in the first half of the twentieth century (MACA, INE and FAO 1985). The landowners then decided to increase their production levels by expanding the arable production area. New land for cultivation became available by reclaiming forests, spiny scrub and permanent grassland. These areas were mostly situated on steep hillsides, extremely vulnerable to erosion. In addition, the fallow period was shortened. Lack of locally produced manure led to inadequate fertilisation levels. Landowners were not interested in spending money on agriculture. A dramatic situation of mining natural resources was introduced. Positive cash flows were not reinvested in the maintenance of agricultural production conditions as the landowners preferred to invest their earnings from agricultural production in industries and commercial activities (Rivera Pizarro 1992).

The freehold- peasant production system

The national revolution of 1952 declared that unproductive *haciendas* must be expropriated (Kohl 1978). Farmers started to expel landowners by fights, assaults, and land seizures without considering the productivity of the *hacienda*. The government was, therefore, forced to declare the Law of Agrarian Reform on August 2, 1953, in order to control social agitation in the countryside. In Cochabamba, the reform was violent and carried out almost completely (Smith 1977).

Farmers who had served at former *haciendas*, finally received land. They started freehold peasant production systems. They also created cooperatives, but these were dissolved after some years of working together. The Agrarian Reform started with ensuring the property rights on land. It continued with extending agricultural land (legally and illegally) by reclamation of public areas. Communal land (the public area) included natural pasture land, forests, and spiny scrub. At national level, 550,000 farmers received 4 million hectares of agricultural land. In the valleys of Cochabamba the average property of agricultural land per family was 3.6 hectares. The farmers cultivated 2.2 hectare each year, leaving the rest fallow. In the 1980s the small farmers supplied 79 percent of the national food production (ILDIS 1988).

The intensive land use strategies on small plots for family consumption, as practised under the former *hacienda* regime, continued after the Agrarian Reform. However, farmers also copied the extensive cash crop production from the *haciendas*. In addition, they cleared forests and began to cultivate low-quality agricultural land as the landowners had done before them. Therefore, the present agricultural production system of family farming shows two contrasting types of land use: the traditional intensive and subsistence-oriented agricultural production system and the extensive *hacienda* production system for cash crop production only (See Table 3.1). This indicates the complexity of the *campesino* economy and the multi-objectives of present farmers' production strategies.

Reclamation of pristine and marginal land had a negative impact on the state of Andean natural resources. Furthermore, over-cultivation, short-term production goals and thinking mainly in terms of financial economics and, in addition, the introduction of artificial inputs, such as fertilisers and pesticides made the situation worse. The effects of total mining of local natural resources also had a great impact on the natural resources far from the places where these occurred.

TABLE 3.1 **Seven centuries of changes in land use, land tenure and land degradation in the Interandean valleys of Cochabamba (1300-2000)**

	Before 1500 Inca agricultural production system	***1500-1825 Spanish colonist farming system***	***1825-1953 Hacienda production system***	***Since 1953 Freehold farmer production system***
Land Tenure	Communal based	Limitations on communal land and growing importance of large private enterprises	Large private enterprises have monopoly on land	A mixture of private small holdings and communal land tenure
Land use	Intensive, terrace cultivation and irrigation systems	Occupation of low fertility land: extensive land use	Extensive land use for rain-fed production conditions and irrigation systems	Extensive land use intensified by external inputs and improved irrigation systems
Land degradation	Not reported, so probably not perceived	Few reports on soil degradation	First signs of landslides, erosion, and declining soil fertility	Severe landslides, erosion, few forest strips left, degraded pasture land and exhausted agricultural land

3.3 Production and family-farming economy

Economic living standard of peasant families

According to the farmers, there is enough food available for the people in the Huancarani community. However, family budgets are below the minimum standard of living. Huancarani farmers indicate that most families cannot afford schooling for their children nor buy clothes and shoes regularly or improve their houses.

Income is obtained from the sale of agricultural production surpluses and from additional off-farm and non-agricultural activities. The average net income of a family is 240 US dollars per year (57 US dollars per head of family), including income from off-farm and non-agricultural activities in the native community, but excluding income from temporary migration.

Land

The natural resources are divided into private ownership of agricultural fields and communally administrated land and forests. The farmers union controls the distribution of natural resources such as forests, water for irrigation, communal grazing areas, as well as the allocation of agricultural fields for family production in the *puna* (highest) agroecozone. The most important task of the farmers union during the nineties was to round off all administration related with landownership.

Agricultural land in Huancarani covers 686 ha, which is only 15 percent of the total area of the community (Tekelenburg 1994). In 1994, the average land per family measured 3.78 ha. The average size of yearly cultivated land by one family was 2.43 ha. Each year the crop-fallow rotation scheme in relation to soil quality and the availability of irrigation water determine the quantity of land under cultivation.

Labour

Agricultural production is organised by families. For their married sons and daughters, arable land is not available and they remain working with their parents and grandparents on the family property.

Each member of the family has a long list of tasks to fulfil. Even children have to "work" by watching over their younger brothers and sisters and to herd the sheep and goats. When they are older, they assist in sowing, harvesting and other labour-intensive tasks. The women are responsible for most of the work around the house. Sheep and goat pasturing is their responsibility when the children cannot do this. Moreover, they do all kinds of agricultural work when labour is needed in the seasonal peak time (Boogert 1992). They also have important social tasks. When the men are outside the community, the women attend the meetings and activities of the farmers' union. Women administrate family savings and are responsible for the sale of produce once it is stored in their houses. However, when large investments or sales have to be carried out, the husbands are the final decision makers. Only four of the households (2 percent) were headed by a female.

Men take care of the agricultural work and collect firewood. They drive the pair of oxen and manage the livestock in the *puna* and subtropical agroecozones. The transport of agricultural inputs and produce is their responsibility too. Men travel frequently outside the community and participate normally in the board and meetings of the farmers union.

Income generated by non-agricultural work at home and by other, off-farm, activities contributes to about 22 percent of the family income. Between families, variation in this parameter is high; some have hardly any additional income, others have full-time non-agricultural work. Examples of non-agricultural activities by women are manufacturing handicrafts, maize beer brewing and shopkeeping. Some non-agricultural activities by men are working as musician, carpenter, blacksmith, miller or truck driver.

Huancarani relies on three agricultural production subsystems, according to its agroecozones. During the LRP, the subtropical agroecozone, became very important. Therefore, we shall take a closer look at particular production systems. The data will be used for the design of alternative production systems in this agroecozone (see Chapter 9).

The production subsystem of the subtropical agroecozone
Forty six percent of the families own private land in the subtropical agroecozone. Income-generating activities are livestock and agricultural production in irrigated gardens. The rain-fed fields are generally not sown as the soil fertility is low and the rains frequently start late. The share of the total agricultural cash income from cattle production in the subtropical agroecozone is 17 percent per family, while the sale of vegetables, fruits and potato contribute 10 percent.

Labour and capital investments are low in the subtropical agroecozone. Livestock production requires about fifteen working days per family year. The irrigated gardens use up relatively high quantities of labour. For example, potato production requires up to 120 working days per ha/year. The total labour input in the agroecozone is calculated at 6500 working days.

At least 60 percent of the farmers pasture their livestock in the subtropical agroecozone. The livestock in the zone comprises about 700 cows and 2000 sheep and goats. More than 1800 ha degraded forest, grassland and exhausted agricultural land is available for livestock production in the subtropical agroecozone. Cattle is managed extensively i.e. farmers invest only minimum quantities of labour and capital in livestock production. They carry out castration and vaccination campaigns, and heal (not systematically) sick or wounded animals. Manure is not collected. The animals are given stubble from irrigated gardens in the zone. Productivity of livestock is low according to the farmers themselves (one cow per year to be sold for every ten cows living in the zone). The number of live births per adult cow and animals lost by accidents are not registered.

The extensive cattle management is not in balance with the environmental conditions because of free grazing on fallow land and overstocking. However, it very well matches the farmers' objective of stable income generation and minimal labour input.
The productivity of the livestock system of the subtropical agroecozone is extremely low (production of one cow per lifecycle on 25 ha) but the economic efficiency of the livestock system is high. This may be translated into a production opportunity. Farmers showed much interest in increasing their livestock production by additional production of forage, although extra labour would be required and the economic efficiency may decline. When livestock is managed by stabling at night, cattle can be concentrated around the forage production fields and manure collected. Manure then becomes available for application on the fields of forage production as well as on irrigated gardens in the zone. In this way, livestock becomes integrated into agricultural production. These features may be interesting points of departure for designing sustainable farms.

Vaccination, medical treatment and castration are carried out by farmers cost less than 10 dollars per cow in a lifecycle. Investment in irrigated gardens is about 50 dollars per ha. Local manure, certified seeds, chemical fertilisers and pesticides are nearly used (because of the long distances to the farmers' houses and lack of capital). Therefore, the yearly capital investment in the zone is less than 3750 dollars.

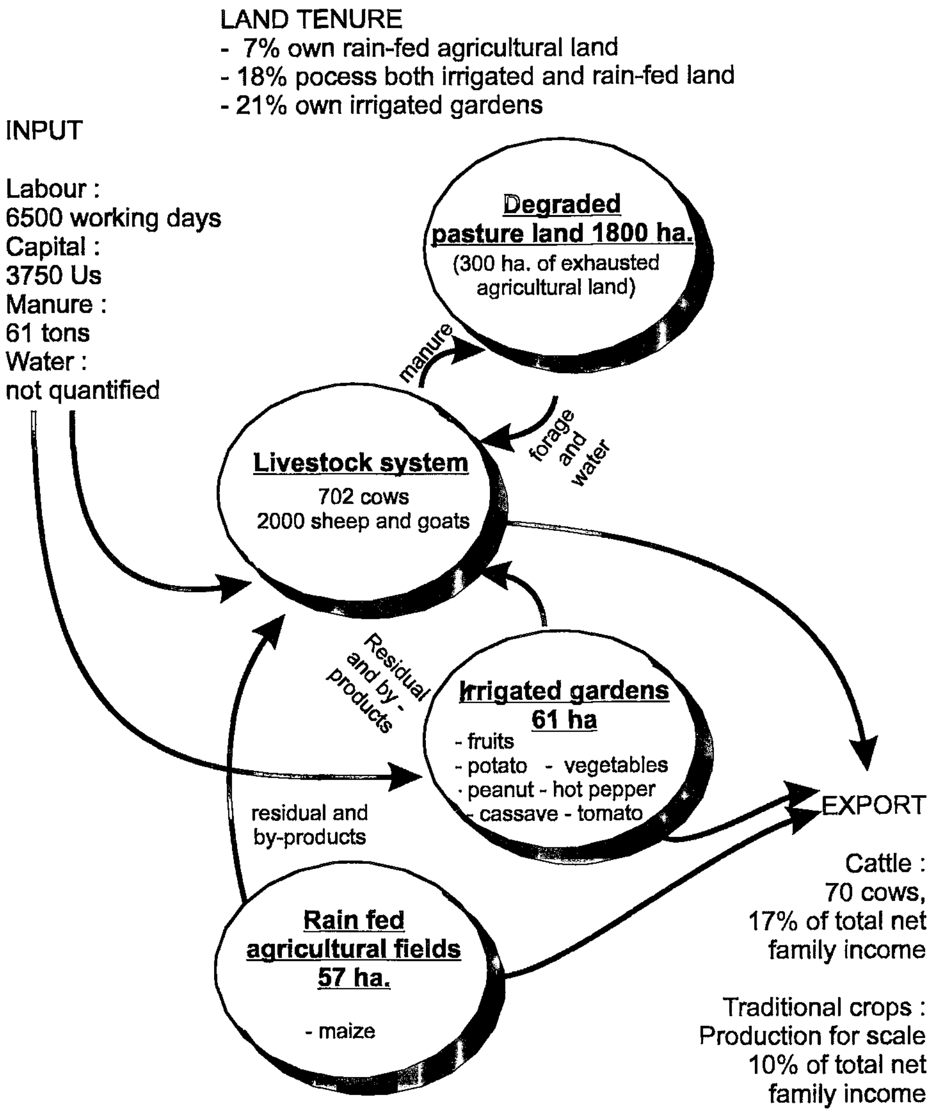


FIGURE 3.4 Visualisation of the production system of the sub-tropical agroecozone

3.4 Cultural aspects

Traditional (Inca based) farmers organisations do exist today, but have lost power in the community's everyday government. From the Agrarian Reform onwards, farmers have become organised in syndicates with strong representation from local to national level. At the same time, farmers became involved in NGO project organisations. These organisations explain the social and cultural strength of the Andean farmers very well. Table 3.2 shows a summary.

TABLE 3.2 Local farmer organisations and their main functions in Huancarani

Organisation	*Functions*	*Examples*
Inca based organisation Headed by the chief	Organisation of communal production	Potato production in the Puna agroecozone
	Local jurisdiction	Cases of animal theft or problems between families
	Organisation of local happenings	Patron feast
Union: (Central Unica de trabajadores Campesinos de Bolivia) with president at the head	Irrigation system organised	
	Coordination and acceptation of all kinds of visits, development projects and communal work	Infrastructure: construction and maintenance of roads, health post and primary school Reforestation
	Representation in provincial, regional and national boards of the union	Training, information exchange, planning and realisation of joint (national) policies
	Joint supply of inputs and sale of produce	Fertilisers
	Sports	Local and provincial tournaments
Non-Governmental organisations and the churches With native assistants as local coordinators	Health care	Vaccination campaigns Mother and child services Administration local health post
	Development projects	Reforestation Potato production
	Religion and education	Training, scholarships and Religious feasts

In the following, the differences between farmers and scientists will be discussed referring to their worldviews and ways of thinking. From these it will become clear that there is a need for interactive approaches to farm innovation. The differences in views will give some idea of how to conceptualise rural development based on shared decision-making. The examples are:
- differences in vision on development and
- differences in practising decision-making.

Different visions on development
Scientifically educated agronomists and veterinarians want to understand a problem first, while small farmers simply want to solve a problem by trying out things. The farmer see the world as an objective sum of bits and pieces, while the latter consider the world as more than the sum of its parts (Van Asseldonk 1987). What is seen as "more" varies from culture to culture and from region to region. Anyhow, both parties speak another language (Van Kessel 1990) and have different experiences. This makes development-aid work so complicated. Scientists and farmers may spend some time together until the moment comes when they have to make their views on the world explicit (Van Eijk 1999). From that moment both may split up mentally and joint learning by the farmers with scientists become marginal (Rhoades 1983). I paid special attention to this aspect of development-aid work. Apart from the vision of the farmers involved in the program, I accepted Brundtlands definition (WCED 1987) of "sustainability" as a leading vision. This vision is interesting for resource-poor family farmers with problems such as soil quality, as it refers to what the present generation has to do or leave for the benefit of future generations. Moreover, according to Brundtland "sustainability" goes further than the borders of farmland, rural areas and even of states. This definition appeared to appeal to the subsistence farmers of our program.

On the project side, the farmers' vision on development can be expressed best by the farmers' statement studied by German Vargas (son of the extensionist Eloy Vargas):

Desarrollo es vivir mejor sin dejar de estar bien. [1]

This statement requires some explanation. "Vivir mejor" stands for better living conditions and should be translated in terms of economic growth and better social welfare. The second part of the statement, however, restricts the idea expressed in the first words. "Sin dejar de estar bien" says something about the relationship between human beings and their surroundings (Jungerius 1985). Here "the surroundings" refers to the natural environment as well as to ancestors and gods. Freely translated, the statement may therefore be: "Human beings are allowed to exploit natural resources, however never without removing the resources' self-organising properties". Or in other words: "Never cut the branch on which you are sitting".

Different decision- making procedures
Most of the decision-making models for rural farm development, designed by extension scientists and agronomists, describe a direction from thinking to doing. This implies that we start by defining a problem in terms of what we can understand by measurements and proceed with (experimental) research in order to obtain new information. New information is considered to be essential for rational decision-making.

The farmers' way of decision-making goes from doing to thinking. Since farmers lack much information, they make decisions trusting on their practical experience and intuition (De Vries 1989). As farming systems come into being on the basis of many components and unknown or not understood relationships between components, decision-making within such systems is always something like a best guess.

The two ways of decision-making are usually causes of confusion, misunderstanding and conflicts of interests between scientists and farmers. During all our work, I constantly tested what scientists and development-aid workers on the one hand and farmers on the other, wanted to say or contribute. This approach was a learning tool in itself.

3.5 Conclusion

The project site of Huancarani is a perfect area for farm innovation. The interesting history of land tenure and land use, the severe problems of land degradation, as well as the climatic heterogeneity for crop diversification can lead to various production opportunities. Huancarani counts on strong and diversified farmer organisations. We understand its performance of the natural resources and production systems and also its inhabitants, habits and culture. We concluded that the project site met a number of important preconditions that are favourable for carrying out the LRP.

[1] Development is economic growth and increased social welfare, without crossing the limits of culturally based natural resource management.

Chapter 4

Structuring the working process

Problems such as lack of income and loss of soil fertility, as well as opportunities like sustainable development and learning to become a manager of natural resources, demand a good deal of creativity from resource-poor farmers. Problems arise faster than they can be solved. Farmers have to innovate continuously in order to be able to survive under marginal production conditions and, at the same time, to maintain competitiveness in a "global market". This makes resource-poor farmers uncertain when they start participating in development-aid programs. Often, they are expected to give up their past, traditions, as well as their own ideas about what they want from their future. Development-aid workers are expected to work rationally and on a low budget, and to induce great effects. Research on rural development, therefore, easily turns into a selection from "quick but short-term solutions" or into many more questions (more problem analysis and research) than they once started with. Right from the beginning the LRP rejected such development strategies. In their view, farmers should be prepared to adapt continuously to changing contexts of production and markets. Therefore, the program explicitly put problem solving by group learning pathways at the centre of its objective.

Innovations are not the result of sophisticated experimental research projects (Simon 1969; Van der Ploeg 1995), but the effect of accumulation of output from decision-making on many (relatively small) innovations in the everyday reality of practice. These innovations are prepared in discussions, interactions and cooperation between human beings. Thus, innovation is the result of interactive knowledge networks (Röling 1995; Röling 1998; Engel

1995) or of possibilities for human beings to learn from each other as well as from the results obtained in their every day work. Rural development is a matter of stakeholders, all living in one and the same area. Without their acceptation, implementation of new production strategies will not be reached easily (Röling 1994).

We accepted that the problem of the LRP, i.e. helping farmers how to learn from each other and from other stakeholders, had everything to do with empowerment, emancipation, management skills and effective communication. Therefore, we had to focus on new positions and roles for scientists, extensionists and farmers in the region. The art of raising good questions became more important than giving answers and recipes (technology packages). The problem of self-organisation within the LRP thus became a question of how to "create" innovative professionals. Apart from instrumental skills, such as good tillage, crop and/or animal protection or harvesting strategies, the LRP also had to face managerial skills, creativity, space for reflection, self-knowledge, self-education, acting in risky situations, and working with too little understanding. It also had to face knowledge and character traits such as perseverance, drive, enthusiasm, self-respect and courage.

The problem of the LRP was that farmers were generally not used to be taken into account nor to be invited to participate in the design of new agricultural production systems. The task of the LRP was to help farmers to learn from each other and manage their own development process. So, the work process involved had to solve a problem, rather than to explain related phenomena.

This chapter shows the work agenda for getting the LRP question solved. The work agenda looked more ordered than it was in reality. This had two reasons. Firstly, the adagium of the program was "let the farmer learn" and, secondly, the process was problem solving and not knowledge or conclusion oriented. That made reconstruction of the methodology and development action necessary.
The work agenda faced three basic questions:

- What levels of complexity of the problem can be distinguished in a particular situation and how was the management of knowledge processes among interacting farmers structured?
- What is a suitable theoretical basis for joint problem solving between farmers and scientists?
- Which steps should be taken in order to bring farmers to a state of permanent learning from their own experiences or from thase of others?

In the following sections these issues will be discussed further.

4.1 Complexity of rural problems and the art of identifying interactions between stakeholders

Rural development in Huancarani is complex because of three aspects:

- It acts upon complex farming systems in a heterogeneous environment;
- It is process-oriented;
- It involves many human beings.

The process involved cannot simply be split up in step by step approaches. The interaction between stakeholders is that of a permanent dialogue.

4.1.1 *The complexity of problems in rural development*

Problems in farming are always complex. Experimental research strategies cannot solve the problems, because these need to be reduced until experiments become possible that can be carried out under fully conditioned circumstances (experimental fields or laboratories). When agricultural scientists want to keep the problems to be studied as they are, they need other strategies such as modelling or farming system research. Rural problems, however, involve factors from many more sectors than only agricultural ones (think of water conservation, environmentalists, urban needs).

The generally known classification method in agriculture is the system of nested levels of aggregation (Fresco 1986). A farming system hierarchy, for instance, starts at DNA level, followed by the cell, tissue, organ, crop, field, farm, region, watershed level, etc. up to world level. For each level, specific research methods are available.

Although some projects applied this classification method with success, it did not work for the Land Rehabilitation Program. It became clear that a level of aggregation is especially useful to identify the structure and components of a farming system, but it cannot determine unilaterally the kind of research methodology at each aggregation level required. The selection of methodology became complicated when the LRP discovered that in Huancarani the problems of one farm or one farmer ranged from plant or animal to rural levels. Farms consist of several higher aggregation levels (such as agroecozones and the provincial market place). It is also known that specific methodologies, such as optimisation methods (hard system design), can be applied at farming system, cropping system as well as at plant aggregation levels of analysis (referring respectively to income optimisation by economists and plant productivity by ecophysiologists). The LRP showed that, at crop level, basic as well as adapted research was required. At community level, both hard (Cost Benefit and Sensibility Analysis) and soft system analysis (Multi Criteria Analysis and SWOT analysis) had to be carried out. And there is more. All sub-problems involved, at any aggregation level, needed in some way or another some soft system design, because final decision-making was difficult to model mathematically. There always was one component or aspect that remained undetermined. It was concluded that the choice for a particular methodology was more restricted by research conditions at a particular site, farmers' objectives, enthusiasm and capacity, as well as the complexity of the problem, than by aggregation levels.

Some ways of classifying rural problems are:
- Levels of the quality (poorly or well defined) of systems (Klabbers 1983);
- System complexity: static structures (frameworks), simple dynamic systems (clockworks), self-regulating cybernetic systems (thermostats), self-maintaining living structures (cells), more complex living and self-organising adaptive systems (Boulding 1968);
- Hierarchy by complexity levels of the problem situation: soft and hard systems, management practices and production factors (Bawden et al. 1985);
- Time horizon of planning (short-, middle- and long-term) (Klabbers 1983);
- State of knowledge (certainty, risk, uncertainty and ambiguity) (Van Pelt 1993);
- Phase of a development cycle (problem identification, option generation and option selection) (Geurts et al. 1985);
- A chain (hierarchy) of explanations of land degradation (Blaikie 1989).

The Land Rehabilitation Program preferred to work conform the system classification of Bawden et al. (1985). The description involved is very clear and applicable to the LRP. Four levels of complexity were identified: two for multi-problem objectives of the problem situation with a system perspective and two for single problem objectives at component level.

a) The highest level of complexity in the problem situation is soft system related (Checkland 1981) and the objectives involved are of a multifunctional nature. Soft systems consist of poorly defined causal relationships. In soft systems some of the elements or their interactions are not well understood, cannot be quantified or are influenced by visions and standards of the human beings involved. Scientists have to deal with great uncertainties in knowledge and include decision-making models and procedures that are based on interdisciplinary problems and the different views of actors involved.

b) The second level of complexity concerns hard (robust and exact) systems (Checkland 1981). Systems with more than one objective, such as optimisation problems in farm production or farm economy, belong to this level of complexity. Hard systems are generally mathematical or monetary models based on quantitative factors and variables. Some examples of models with well-defined causal relations are cost-benefit analysis and environmental plant production theory.

c) The third level of complexity refers to component analysis of which the main objective is to improve its effectiveness. This level includes agricultural practices carried out by the farmers, such as fertilisation, irrigation and crop protection. At this level research is carried out with an applied or problem focus.

d) The fourth (lowest) level of complexity of a problem situation concerns studies on isolated factors. The main question at this level refers to knowledge about how a factor works and why the phenomenon is as it is. Here, research has to explain phenomena and identify fundamental natural laws.

Table 4.1 shows an overview of the possible levels of complexity in a problem situation for farm innovation processes.

TABLE 4.1 Hierarchy of research approaches based on complexity levels of a problem situation (modified after Bawden et al. 1985)

Level of complexity	*Focus of the problem*	*Research approaches*	*Expected outcomes*
Improve the situation (conflicting multi-objectives)	How can the situati-on be improved?	**Soft system research**: Multi Criteria Analysis (Van Pelt 1993), SWOT (Hamilton 1995) RAAKS (Engel 1995) , Decision-making procedures (Bos 1974) Platform building for interactive learning (Röling 1999) Adaptive management (Jiggins and Röling 2000; Holling 1995) Permaculture (Mollison 1990)	Satisfaction
Optimise the situation (Multi objectives)	How can its performance be optimised?	**Hard system research**: System dynamics (Meertens, Ndege and Enserink 1995; Struif Bontkes 1993), Multiple Goal Planning: FLORA (van Rheenen 1995), Diversity of yields (Steenhuijsen-Piters 1995), Prototyping (Vereijken and Wijnands 1994)	Efficiency
Solve the problem (Single objective)	How can its effectiveness be improved?	**Applied research**: Communal, organised comparative on-farm experiments (Tripp and Wooley 1989) PTD (Reijntjes, Haverkort and Water-Bayer 1992; Van Veldhuizen and De Zeeuw 1994)	Effectiveness
Identify mechanisms Single objective (reductionistic)	Explain the phenomena	**Basic research**: Experimental component research under laboratory conditions (Collinson 1987)	Explanation and understanding

4.1.2 *The art of identification of interactions between stakeholders*

The LRP had to address the highest complexity level mentioned in Table 4.1. The LRP wanted to improve the rural situation and asked us to create a situation that would teach farmers to learn how to operate a management process directed at the improvement of their own situation. The question "How to bring farmers in a permanent state of progressive interaction?" may be compared to the question "What are the characteristics of a perfect dialogue?". So, the LRP wanted us to create a structure in the dialogue between farmers and outsiders about questions of which they were not sufficiently aware. Dialogues, discussions or debates in general, however, are hard to structure. By nature, they do not have a structure at all. The art of a fruitful discussion is that the debates constantly test the validity of their statements, arguments or definitions. A good debate is like a good game between two players or groups of players. They react to each other, constantly bringing more depth in their negotiation. Could this also happen when the debate becomes rationally structured? The answer is "Yes", that is, when a skilled debate leader guides the debate. "No", when the learning process (debate) is not evaluated and improved by its members and when there is no "umpire". Interactions between farmers and discussions at the highest level of complexity are normally not umpired. Farmers themselves must get some notion of what is important and thus become leaders in discussions. This picture led to the questions mentioned in Box 4.1.

BOX 4.1 Questions related to the guidance of a good dialogue.

- How to give farmers a sense of urgency, as the high level of aggregation of the LRP may give them a notion of "this is not about me"?
- Who are the partners, who should contribute to solutions?
- How to create a situation where stakeholders want to meet ?
- How to bring discussion partners into the debate?
- How to stimulate mutual trust and solidarity?
- How to observe emerging results?
- How to make such results explicit?
- How to consider results as a learning moment?
- How to let the group decide?
- How to let the group take full responsibility for their own decisions?
- How to teach the group to effectuate responsibilities?
- How to continue - keep the process open?

Bos (1974) made a profound study of the dynamics of good debates. He identified three different qualities in satisfying discussions:

- Partners exert themselves in order to get a complete picture of the subject in discussion (imaging);
- When the same image arrives in everybody's mind, partners start to give their judgements on what they have seen, heard or experienced (judging);
- After all judgements have been passed, good discussions usually end in something like decision-making.

Discussions ending in the imaging phase are seldom satisfactory. They bring conflicts between visions and purposes, convincing others of being right only. Such debates are seldom free from being a display of power.

When discussions end in the judgement phase, this usually means that the discussion partners are not capable of listening properly. The debate then takes the form of "work off steam". These debates may be useful, but without the skill of listening, they may continue to circle around the same issue.

Discussions ending with decision-making are often experienced as being satisfactory. Variations on Bos' observations can be found in Hamilton (1995), Van der Fliert (1993), Van Schouwbroeck (1999), Van Eijk (1998) and Kolb (1984).

Hamilton (1995) made clear how developing leaders can test the quality of each step in a debate. The quality indicator was interactive approaches. Interactiveness appeared to be a meaningful aspect of the quality of farmer participation. Interactiveness cannot be understood on a numeric scale of quality, but in terms of different types of interactive approaches. Nine types could be identified as proposed by Hamilton (1995). A zero level consists in no participation at all. Next, participatory types can be defined, without being interactive: physical participation, consultative participation and collaborative participation. These types are characterised by lack of real dialogue and even more by one-way communication approaches. Interactive learning types are subdivided into dependent learning approaches and interdependent learning approaches. Dependent learning approaches consist of feedback loop interaction. Interdependent learning approaches are: knowledge generation-based interaction, self-directed and contrasting based interaction and coalition building interaction. Finally there is the concept building interaction approach that results in the best quality of interaction.

Hamilton used the SWOT analysis technique as a tool for getting a meaningful insight into interactive approaches in debates: the strength and weakness on the one hand, and the opportunities and threats on the other. Table 4.2 shows the results.

TABLE 4.2 SWOT analysis applied to interaction in debates (modified from Hamilton (1995).

Strength: - leads to new thinking about the problem situation - encourages multi-disciplinary thinking - encourages multidisciplinary team approaches - is experimental learning in process approach - improves managerial skills and creativity - opens up implicit views	**Opportunities:** - gives rapid feedback to participants - can be used by anyone, anywhere and does not depend on the involvement of a "highly educated" specialist - is better suited to make sense - leads to self-confidence, self-respect - transforms farmers from apathetic beneficiaries to process leaders - improves countervailing power and project ownership
Weaknesses: - the outcome is unknown until it has been reached - the outcome is location- and group-specific	**Threats or constraints:** - requires freedom of expression - requires non-experts to work in experts' domain of expertise - requires openness and modesty - requires recognition of the potential to fail - requires a suitable work environment

The art of improving interactions that make sense for the creation of a learning pathway among the resource-poor farmers of Huancarani became structured according to the discussion dynamic theory of Bos (1974). Table 4.3 shows some examples of activities that worked when bringing Quechua farmers into advanced debates about their rural development

TABLE 4.3 Actions that worked for Quechua farmers in Huancarani in order to improve the dialogue in the platform. The centre column identifies relevant questions of interacting at high levels of aggregation. The right column shows the selected tools that were used to address each question.

Phases of dynamics in discussions	*Questions for guiding a good dialogue*	*Tools*
Preparation	How can a sense of urgency be reached?	- Show the relationship between their activities and observable effects at regional level - Analyse historical trends (Jhoda 1989)
	Who are the partners involved?	- Let the farmers mention names or groups
	How to create a meeting place?	- Allocate a place with a meaning for farmers (a house, a community place, a tree, a place where everybody can see them talking) - Insert discussions in traditional or actual meetings
	How to bring partners into the debate?	- Identify common interest - Social drama - Study tours
	How to stimulate mutual trust and solidarity?	- Starter activities (Reijntjes, Haverkort and Water-Bayer 1992) - Exchange of labour in case of experiments and pilot production - Agricultural rites (Salas 1992)
Imaging	How to make farmers' inner thinking more explicit and dynamic?	- Define the concept of development - Define a vision of future farming - Debate on key informant testimonies - Make a scale model of the area - Take examples out of their traditions - Take joint community walks - Unexpected events (Brouwers 1993) - Define the package of demands
Judging	How to observe emerging results?	- Change from imaging to judging - Analyse coherence in links among own opinion of today's situation, expectations for the future and experience from the past
	How to make such results explicit?	- Knowledge integration - Proposals for continued action - Call for decision-making procedures
Decision-making	How to reflect results as a learning moment?	- Evaluation of the impact on the LRP, farmer participation and the applied interactive approach
	How to let them decide?	- Multi Criteria Analysis - SWOT - With-without comparison
	How to let them be fully responsible for their own decisions?	- Let farmers organise implementation themselves - Let farmers invest with own capital and labour
	How to teach them to effectuate responsibilities?	- Social control: presentation in local and provincial farmers unions - Signing individual and group implementation contracts
	How to stimulate farmers to start new preparation and imaging phases	- Step by step implementation of the integrated cactus pear and cochineal design - Keeping the process open for further development (Reijntjes, Haverkort and Water-Bayer 1992)

4.2 Designing a learning process for Huancarani farmers: a theoretical basis for problem solving

Farmers are not alone in farm innovation. Many stakeholders can be identified alongside farmers: farmers organisations, scientists and policy makers at several levels, consumer and environmental action groups. Not only complex technological problems may be the object of study, but also social constructions. Perhaps the most important difference between farming system research and farmer participatory development is the latter's focus on the value and development of the potentials of farmers.

According to Scoones and Thompson (1992), there is a fairly widespread consent in literature on farmer participation that purely autonomous learning processes are inadequate. This "beyond farmers first" approach emphasises that neither indigenous knowledge (Rist 1991; Rist and San Martin 1991), nor scientific knowledge are unilateral pathways in development processes. Many cases have been described in which innovation was prepared by scientists unilaterally. In such cases progressive farmers were selected to test the innovation individually. Adaptation by neighbours happened when they could see that the innovation worked (Rogers 1995). Chambers and Jiggins (1987) concluded that the unilateral offer of science-based technology packages to farmers, being the ultimate users, simply does not work.

4.2.1 *Farmers' contributions*

There are only few cases published in which farmers systematically bring their insights, innovations or even farming problems into something like a forum. Da Silva (1999) observed the same as he reports that farmers have difficulty in discussing ideas or strategies at community level, especially when they think that their ideas may benefit others. Even the most open groups tend to exclude some part of their community and farmers, even in high competitive realms, and keep discoveries as "family secrets". Of course, pride and secrecy "push" the farmers to experimentation. Considering the complexity level of the LRP, we expected that the same would hold true for Quechua farmers.

But farmers learn fast, especially when they see the success of others (Diffusion of innovations, Rogers 1995), and their learning pathway is not necessarily individual. Da Silva (1999) and Van Schoubroeck (1999) report extensive information networks outside formal research and extension. Röling and Wagemakers (1998) accept that contextual factors are likely to affect the process of mutual learning. The same is true for the dynamism in the group. In the line of previous discussions (see preceding section) we concluded that learning pathways within groups of resource-poor farmers must have three mayor components: context, dynamism and outcome.

4.2.2 *New challenges for academic contributions*

The position is that powerful outcomes of the farmers' contribution to research and development are the result of sufficient dynamism in farmers' debates and that such debates are favoured by facilitating contexts. Scientists are needed for the facilitation of stakeholder platforms helping to structure and supervise learning pathways. The components of a structured learning pathway can be specified now. Farmers require (see also Figure 4.1):

- A platform for a powerless dialogue about each others' experiences, problems or results (Van Mansveld 1995). No member counts individually on complete knowledge and power to solve the problem;
- A platform that functions as a solidarity group, where insights and visions are shared, or as an advocacy group to raise power in debates at the national (political) level;
- A platform as the highest decision-making tool, where partners negotiate about trade-off between conflicting interests;
- A platform that legitimates the role and activities of (contracted) outsiders working in the area in question, thus keeping coherence among various activities in the development process (agency).

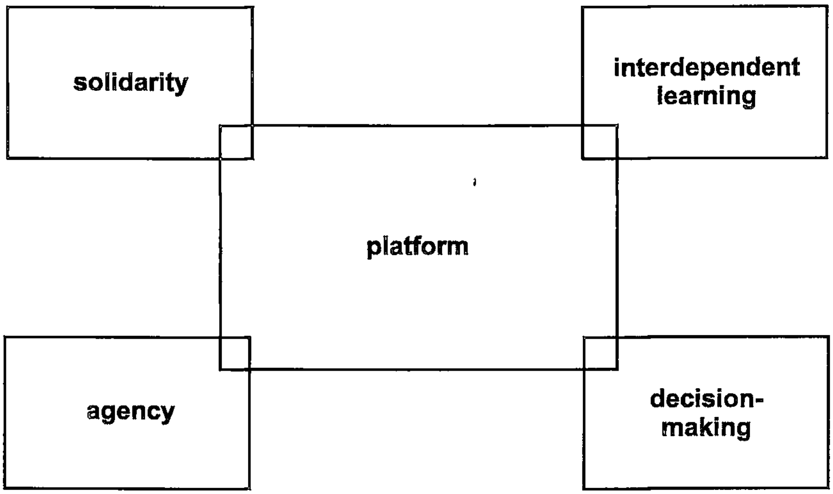


FIGURE 4.1 Relevant requirements for good functioning of platform discussions between stakeholders

The question is now how a platform with the four characteristics mentioned above can be designed. To start with, some scientific concepts of interactive science are explained followed by the analysis of "designing" as a scientific activity.

Interactive science

Complex problems, such as farm innovation, generally justify the intervention of many academic disciplines. This implies that natural sciences and social sciences must join problem analysis and must complement-integrate results from all kinds of angles into the "final" solution. So, on the one hand, scientists have to work together. On the other hand, they have to interact with stakeholders' opinions and work procedures. Röling (2000) called this the "beta-gamma" interactive approach in research and development: interactive science. "Beta" stands for exact natural science and "gamma" for social science. Development-aid workers developed this integration during practical research and development activities in the field with active participation of different stakeholders. This was done especially because of the need to find solutions to complex problems based on interaction among scientists and stakeholders. Interactive science is concerned about "land use negotiation" instead of "land use planning". The Land Rehabilitation Program can be classified as a "beta-gamma" interactive approach.

The concept of interactive science can be explained further by looking into the development in scientific paradigms. In a diagram, Röling (2000) showed how scientific paradigms are related, using a subdivision of four classes made by two axes: holism-reductionism and positivism-constructivism (See figure 4.2). Three main paradigms can be briefly described as follows. Traditional agricultural science was based on a "techno-centric" paradigm: positivism and a reductionism focus. Solutions were of technical and economic rationality. A complementary scientific paradigm was developed, moving from the "best technical solution" to the "most efficient natural-resource-use". Integrated Pest Management is one of the best-known examples of such an "eco-centric" paradigm: positivism and holism (Van der Fliert 1993). In addition, a new scientific paradigm is developed, based on constructivism (Röling 1995) and holism (Van Eijk 1998): the "holo centric" paradigm. The beta-gamma integration as well as "interactive science" must be found in this third paradigm, because of shifts to constructivism. The focus is on the construction of critical learning systems, i.e. the design of a collective cognitive system with an ecological rationality. Because environmental problems, as well as sustainability of production and natural resources, are in the first place human decision and action systems, we must consider these interactive learning processes as soft systems (Checkland 1981).

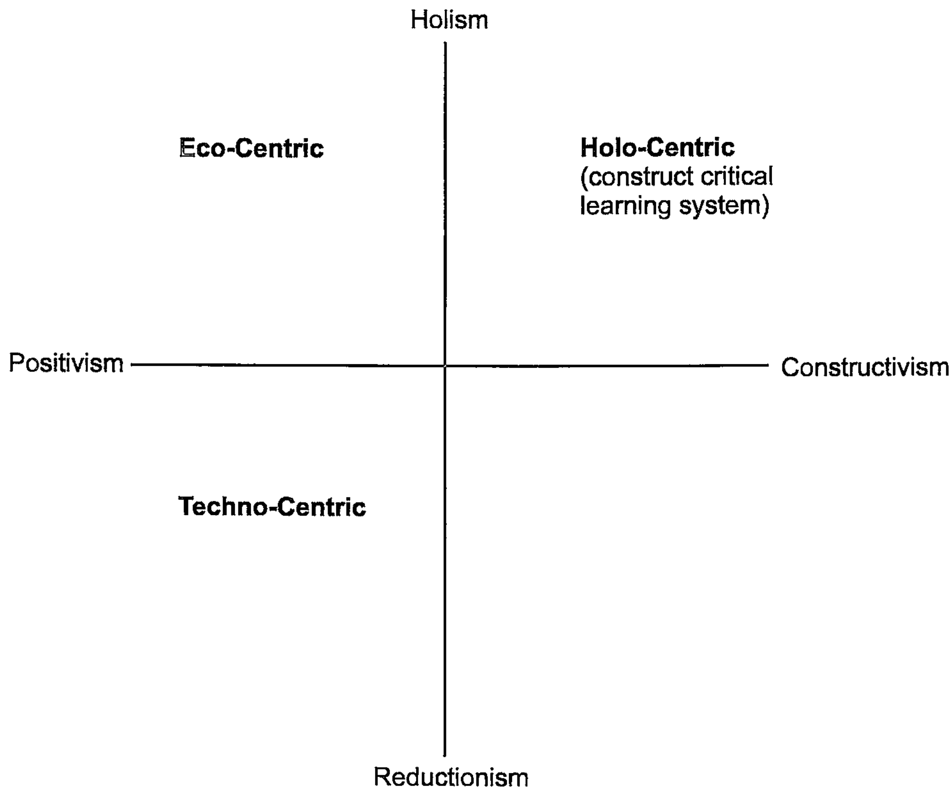


FIGURE 4.2 The development of scientific paradigms (from Röling 2000)

The interesting point of the beta-gamma approach is that it is not exclusive to the exact natural sciences, nor to a positivist paradigm of science. There is no need for hard feelings. So, although agricultural research and hard system design are very important to farm innovation, a new and complementary area of science is needed that refers to the contribution of stakeholders to problem solution. It is their participation and opinion, worldview, human intensionality, agreement, conflict and forward looking collaborative adaptive management that contributes to a large extent to the success of long-term learning processes. Agricultural development can be considered therefore and to a large extent, as an interactive science based on a constructivist paradigm (Röling 1996).

The development of beta-gamma science was on the scientific agenda with a traditional focus on economic rationality. The newly developed challenge for science had to do with design and management of sustainable ecosystems more than discovery of physical laws from nature. It is known as the "eco-challenge" (Lubchenco 1998). Social learning has been determined as the key to a sustainable society (Holling 1995). Social science can do a good deal for the eco-challenge decreasing the attractiveness of selfishness. One can think of the following tasks for social science: participatory platform building, creation of institutions, interactive planning and realisation of research and development agendas, development of complementary (not necessarily common) learning pathways for scientists and farmers, procedures for negotiation on agreement and joint decision-making, etc. This can be summarised by formulating the need for the design of applied collective cognitive systems with an ecological rationality.

Design

Designing is a specific form of problem solving. There is a problem when somebody wants to achieve a goal without having experiences at his/her disposal in solving the problem. Problem solving is a creative "think and do" process (Simon 1969; Kroonenberg 1992). It has been systematised and described by Van der Fliert (1993) and Da Silva (1999). Systematisation is needed when the process of creative thinking and doing must be learned for own use or for teaching others (Jara 1994; Kolb 1984). The cycle of creative problem solving has been described as follows (see Figure 4.3): observation, presumption, expectation, testing and evaluation. Presumption has to do with problem analysis and identification. Expectations refer to the vision on the problem's future solution.

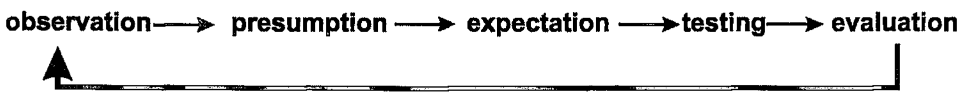


FIGURE 4.3 The cycle of creative problem solving.

This cycle is followed successfully when the participants of a platform engage in the following activities:
- Skilled observation and problem identification;
- Visualising the solution;
- Translating observations into objectives;
- Participate in the identification of various solutions;
- Predict possible consequences;
- Select the solution that gets the best support.

Note, that these activities may be considered as detailing the three phases in the dynamics of powerful debates (Bos 1974). Checkland (1981) brought such activities together in his system approach.

In reality, we must say that a problem solving designing process never ends, simply because the resulting product will never be perfect, completed or hundred percent satisfactory (for one's entire life). Therefore, it is better to speak of iterative cycles of designing or, in other words, designing without a final goal (Simon 1969).

The farmer must become aware that the process of continuous problem solving (the methodological process) is the main objective. Improvement of the practical situation today is just a means of that process. This is the most difficult aspect of the LRP. Learning to learn is pivotal. This implicates that stakeholders had to engage in the following extra topics:
- Platform building;
- Communication and interaction with scientists;
- Integration of opinions and results of research;
- Decision-making procedures.

This difficult challenge is comparable to aggregation in which a farmer must be told that he has to keep the soil quality high for the next generation(s), in case that not enough money has been generated by agriculture in order to guarantee basic needs.

The learning pathway of Huancarani farmers can be designed when a platform of dedicated stakeholders regularly comes together and shares own ideas and questions with others. Such meetings are not simple social happenings. The participants must experience a sense of urgency and a pleasure to come. Each meeting had to perform one or more of the phases of Bos' discussion-dynamism: imaging, judging, or decision-making. But this is of course an abstraction. Getting farmers involved means that they must experience that all platform work is about themselves, about their families, their farms or their future. Long-term (process-oriented) learning objectives must prevail over short-term technical problem solution. The following sections give information on how a learning system was created.

4.3 Steps for farmers learning to learn: the three levels of learning in the complex context of Huancarani

From the preceding sections it will be clear that designing learning pathways for resource-poor farmers in Huancarani differs from technical designing. We found that:
- Agronomic production happened by managing the production factor "life";
- Farmers and outsiders contributed to analysis, research and design in a complementary way;
- Agronomic production took place in an open system or in other words in a surrounding that cannot easily be controlled;
- Organisation of agronomic production very much depended on policies and interests at high (national, international) levels of aggregation.

This demanded a good deal of skill in analysis and decision-making for the farmers' own benefit. A learning pathway therefore, must include many learning moments that train the farmers how to optimise plant or animal productivity, how to manage complete production systems without exhausting the natural resources involved and how to become the "manager" of their rural development (the highest level of complexity of the LRP).

A learning pathway for farmers must have a goal i.e. they must have a reference (Millar 1996). In addition, there must be a set of activities that helps farmers to achieve their goal; for example, they must talk, train and do (Röling and Wagemakers 1998). Also, they need to have access to facilities such as experienced resourceful persons with special knowledge, written material that helps them to reread at home what they have done or learned. Another important facility is autonomy. A sense of autonomy gives farmers the feeling that the platform is all about them. It works as a basis for responsibility.

The role of the development-aid researcher is very important. This person must let farmers experience that the success of their platform activities is learning-oriented, not solution or technology package oriented. They must feel that platform work demands skills such as raising questions, reflection on others, and careful observation. Farmers must expéience that the better they get on with each other, the more their environment improves (Da Silva 1999). Here, improving means replenishment of mainstream thinking with new ideas (mostly from others), experiences and thus with possibilities.

Therefore, the development-aid worker must train him(her)self in timely recognition of deadlocked patterns in thinking or working among farmers. Many scientists discovered, for example Simon (1969) and Röling (1995), that new solutions or ideas are not necessarily the results of logic and rational think processes. Due to lateral thinking they may find solutions that otherwise would never have been discovered (Table 4.4)

TABLE 4.4 Comparison of linear and lateral thinking in the case of methodology for the LRP

	Linear thinking	***Lateral thinking***
Think pathway	Go from problem statement to solution	Venture a solution and consider whether that matches with your problem. Goals and boundaries are permanently (re)negotiated
Reliability	Each step must be sound for reaching a reliable solution	It is possible to reach a solution along a range of best guesses
Completeness	Do research step by step so that it becomes complete	Do your research randomly; it does not need to be complete
Logic	Be logical in one unilateral positivist scientific paradigm	Compare between different views on your problem
Trust	Only rely on the power of reasoning in each step of the research process	Rely on your way of reasoning but follow your intuition
System perspective	Hard ecosystem	Linked hard ecosystems and soft platform systems
Role of extension science	Find acceptable ways to make scientific results ready for use in practice (recipes)	Systematize interdependent learning processes in order to improve them
Role of development workers	Train and visit final users of scientific results	Facilitation of communication and joint learning processes

Lateral thinking is about the support of the decision-making pathway from doing to thinking, as described in Section 3.4 (De Vries 1989). Lateral thinking gives the platform the room and flexibility that is needed to find solutions for farm innovation in the short term and a permanent learning process in the long term. Linear thinking may be included, for example, when the platform decides to contract scientists for doing research.

We have come to the conclusion that designing a learning pathway for Huancarani farmers must be a mix of reality and dreaming, of quantity and quality and of cooperation and individualism. In dialogue with the farmers of Huancarani, we discovered that they want to learn to improve their farming system as well as to learn learning for continuous adaptation of their production.

Farmers started to learn in the LRP with all the strategies needed for the analysis of the problem and the visualisation of future perspectives for family farming. This procedure finished with research on and promotion of production of cactus pear and the introduction of cochineal. We considered this step as learning in practice. By careful observation of all procedures and interactions involved, obtained by learning in practice, we were hoping to learn from practice; that is to say from the learning process. Abstraction from this methodological issue could help us to learn how to address new and future problems: learning for practice. Figure 4.4 visualises the preceding considerations together in one diagram.

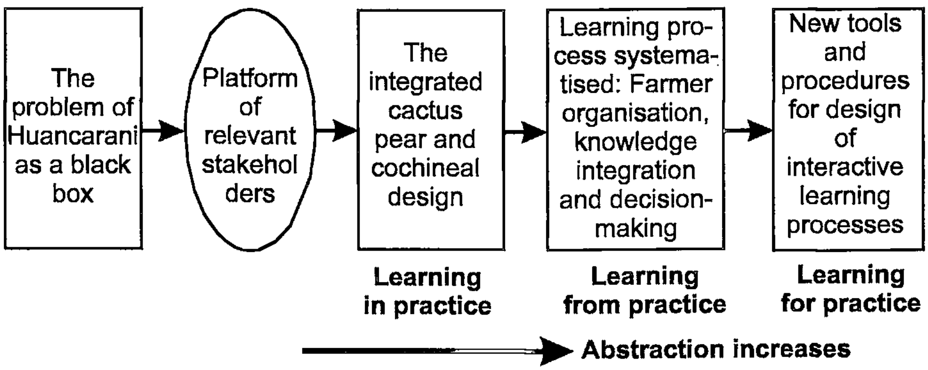


FIGURE 4.4 Three levels of learning in the LRP in Huancarani

4.3.1 *Learning in practice*

The Land Rehabilitation Program became the tool for learning in practice and was governed by achieving a purpose. It is concrete, result-oriented and farmers can extract many learning moments from it. The LRP objectives are hard. The LRP wanted:

- To know about the possibilities for production of cactus pear and cochineal (quantitatively and qualitatively);
- Adequate agricultural management techniques;
- Production systems of integrated cactus pear and cochineal;
- Utility for evaluation of scenarios;
- Integration of the cactus pear and cochineal production system in the actual subtropical agroecozone;
- Implementation of cactus pear and cochineal production at Huancarani.

4.3.2 *Learning from practice*

The results obtained from the "learning in practice" level were collected systematically. We studied them by analysing the notes from discussions in the platform by stakeholders about what had happened during realisation: problem analysis, research, design as well as implementation. The LRP functioned as a case. The objective of the joint platform of stakeholders was to obtain knowledge about the "physiology" of case-oriented group work. This was carried out by evaluation of each activity or methodology with the following three main indicators: importance (impact) to the LRP, farmer participation levels and applied interactive approaches. We joined the discussions and observed the position, enthusiasm and action of the farmers during each of the activities that were carried out. We experienced that farmers had a good understanding of the situation of their production sites and community. Therefore, we were able to identify improved procedures leading to better results, to be obtained in the learning-in-practice phase. This knowledge was further discussed in the platform and proposals for methodological (methods and procedures) changes were implemented during the LRP. In this way, the methodology of the farm innovation process was improved step by step during the execution of the LRP. Methods for reflection on action (Jara 1994; Lammerink 1995) appeared to be helpful. This is what we called the learning-from-practice phase of the LRP. It concerned validation of information and processes in order to improve learning in practice. It was important to let everybody free and feel comfortable. Honesty towards each other might be experienced as criticism or being negative. We trained ourselves constantly in making observations, asking the right questions and also expressing an opinion, when we were actively involved in a certain activity.

4.3.3 *Learning for practice*

The highest level of learning aimed at learning how to take one's future into one's own hands. Or, in other words, farmers who have learned to make a profit from their properties and who have learned to make a profit as a concerted action that benefits the whole community, must also learn to become empowered in getting things conditioned. This is to say, farmers must learn to think about their future and in conformity with insights, they must learn to do things for their own future. Doing things for the future are, for instance, long-term soil care, tree planting, but also planning the process of continuous farm innovation. The aim of this learning level, learning for practice, was to find a methodology for policy making in the hands of resource-poor farmers, together or not together with people from outside. This can only be achieved by conceptualising learning processes on the basis of systematisation of the experience of a practical case. We strongly believe that such a tool may be the beginning of effective empowerment.

4.4 Conclusion

The resource-poor Quechua farmers of Huancarani were drawn into a complex process. Complex because the heterogeneity of the natural environment of their region, the complexity of their farming systems to be redesigned, the process approach with a long-term objective and the complexity of the need for a participatory-interactive approach. Our work agenda was therefore structured in discrete phases. We considered each phase as a project in its own, this is to say, each phase began with problem identification and had to end with problem solution. This does not mean that each phase was carried out in an ordered sequence. This was not a problem as long as the platform could understand which data gathering activity they were engaged in at any moment. The work agenda started with learning in practice:

- Describe the history and actual situation of farming in a problem statement (Chapters 3, and 5);
- Formulate the perspectives of future farming and design objectives (Chapter 6);

- Determine production factors of cactus pear and cochineal (Chapter 7);
- Design the integrated cactus pear and cochineal production system (Chapter 8).

In the mean time, reflection on methodology and analysis of relations between activities resulted in learning from practice:

- Experiment with new farmers' organisations as well as support institutes (Section 9.2);
- Identify mechanisms to integrate knowledge obtained in the LRP (Section 9.3);
- Study a methodology for selection between options and decision-making procedures (Section 9.4).

Finally, the results of learning for practice can be presented as follows:

- Find patterns of applied methodology and develop a management toolkit for the design of learning processes of complex problem situations for resource-poor farmers (Chapter 10);
- Evaluate the results of the three levels of learning with the help of the toolkit (Chapter 11).

Chapter 5

Description of the actual situation: Problems of Quechua farmers

Asking resource-poor Quechua farmers what their problems are, normally results in a cacophony of voices. Most of them will speak about everyday and obvious things such as "We have no money for pesticides", "Give us good roads and transport facilities and we will produce more" or "The government does not guarantee stable and reasonable prices for our produce". Relying on such reactions makes any development-aid project a failure. Going on asking, probably evokes other reactions, such as: "Extension workers only see us as being stupid", "Scientists are stubborn" and "Politicians only want to change one small part of what actually is one big and interrelated system". When asked what they think of all the help they get from development-aid institutes results in Huancarani in muttering about "Problems among NGOs or between these local institutes and churches". I experienced myself that coordination between development organisations is difficult and sometimes impossible, due to their differences in political and/or religious worldviews. Strong differences in priority setting and ways of carrying out projects can frequently be seen, although in Huancarani experiences were not so bad. Salas (1992) states that technical solutions do not arrive properly at the interface between scientists and farmers. Scoones and Thompson (1992) consider this phenomenon as a rural conflict of interest, knowledge and power.

Arrellanos and Petras (1994) conclude that the privatised position of Bolivian NGOs may be the problem. They report two orientations in their work. One group is active in promoting long-term socio-economic development and another in short-term action programs in order to relieve basic shortages, all within the realm of charity. The latter group offers gifts, food, buildings or roads and, by doing so, break down the carefully constructed strategies aimed at self-help, autonomy and learning to learn. In general, NGOs have close and strong relationships with farmers communities, which is not a bad thing, considering they are part of a relevant agricultural knowledge network (Crespo et al. 1991). On the other hand, however, criticism can be heard too: resource-poor farmers become too dependent on NGOs. Paternalism by NGOs and lack of autonomy for farmers, are sooner rule than exception in the Bolivian realm.

Being aware of the unfavourable aspects of rural development aid, the LRP put participation and motivation of farmers at the centre of its plan. The central question was to get to understand the problems in farming on a time horizon (past, present and future). Which positive or negative tendencies can be identified? Do farmers see them clearly? Resource-poor people may have no other option than to complain about their actual problems, as they think of everything in the past as being much better. Johda (1989) found that this is mostly not true or at least doubtful when the analysis is focused on the differences between past and present and not only on the present farming situation. He advises to look also for the changes between the actual and the wanted situation. It is important to understand under which kind of circumstances resource-poor farmers perceive their problems and for which they ask help. It is also important to know who suffers from problems, because various groups within one community may experience the same problem in a different way and therefore need different solutions. Two obvious groups are for instance men and women (Rodriguez and Schoute 1992). Being a facilitator, I was aware of my task to improve the context of the platform: that farmers should be able to say what they wanted to say, to ask questions about conflicting interests, side effects and what they did themselves in order to improve the situation that caused their problem.

This chapter describes and analyses the actual problems of Quechua farmers in Huancarani as a trend, i.e. the problems to be identified must be considered as part of the past in relation to the present in view of the farmers' demands for a better future. The tools and methods, which were used in this phase of problem identification, are listed in Annex Table 1.1.

5.1 Farmers' problems in Huancarani

Our study on farmers' problems in Huancarani took into account the three categories of aggregation levels mentioned in Table 5.1 i.e. farm level, community level and regional level. Farmers indirectly focused on problems formulated as being negative changes in the near past, as proposed by Johda (1989) with, respectively:

- of hard nature (e.g. farming practices and results) and
- of soft nature (e.g. regional development, the agricultural knowledge network, policy making and access to resources).

TABLE 5.1 Negative changes in agricultural practices in Huancarani, Bolivia

Aggregation level	*Negative changes*
Farm	- Increased mist forest clearing
	- Increased need for irrigation water
	- Decreased economic margins for cash crops
	- Reduced efficiency of pesticides and fertilisers
	- Insufficient labour
	- Too much cash crop production
	- Decline of productivity of traditional crops
	- No fallow and small rotation schemes
	- Declining soil fertility
	- No fodder available
	- Insufficient technical assistance
	- Poor husbandry management
Community	- Depopulation: brain and capital drain (people with money or experience leave)
	- Low seed quality
	- Donkeys appear, horses and mules disappear: declining quality of pasture land
	- Goats replace sheep
	- No restoration of original vegetation during fallow and low quality pasture land
	- More landslides
	- More individualism (higher differences between poor and rich farmers in Huancarani)
	- Reinvestment ceases
Regional market	- Decreased gene pools in the Andes: lack of local varieties and declined biodiversity of typical Andean crops
	- Increasing cost of external inputs
	- Increased dependency on the market (knowledge, seeds, fertiliser and pesticides)
	- Increased dependency on foreign capital (share cropping agreements)
	- Market trends push farmers (new varieties and crops)

5.2 Analysis of farmers' problems

The farmers mentioned a long list of problems, initially without any structure. From this point onwards farmers were invited to analyse the problems using three techniques. The first technique consisted of arranging the problems into cause and consequence in a three-way system based on the regional market, the family and the natural resources. The second technique consisted of an in-depth analysis of causes and consequences of land degradation in Huancarani. The third technique tackled the classification of problems as well as their importance and prioritisation.

These problems of everyday farming are, of course, interrelated and cause and consequence relationships can easily be discovered. Farmers arranged their problems mentioned before in a three-way system model, which consisted of three elements: the Huancarani family, the regional market (outside world of the farming system) and the local natural resources. The objective to do this was, in the first place, to obtain insight information on the farmers' vision on the problems and, in second place, to help the farmers analyse problems and not take them merely for a simple fact. If solutions are to be found for complex problems, the underlying causes should be tackled instead of eliminating the consequences. Figure 5.1 shows the results of the exercise.

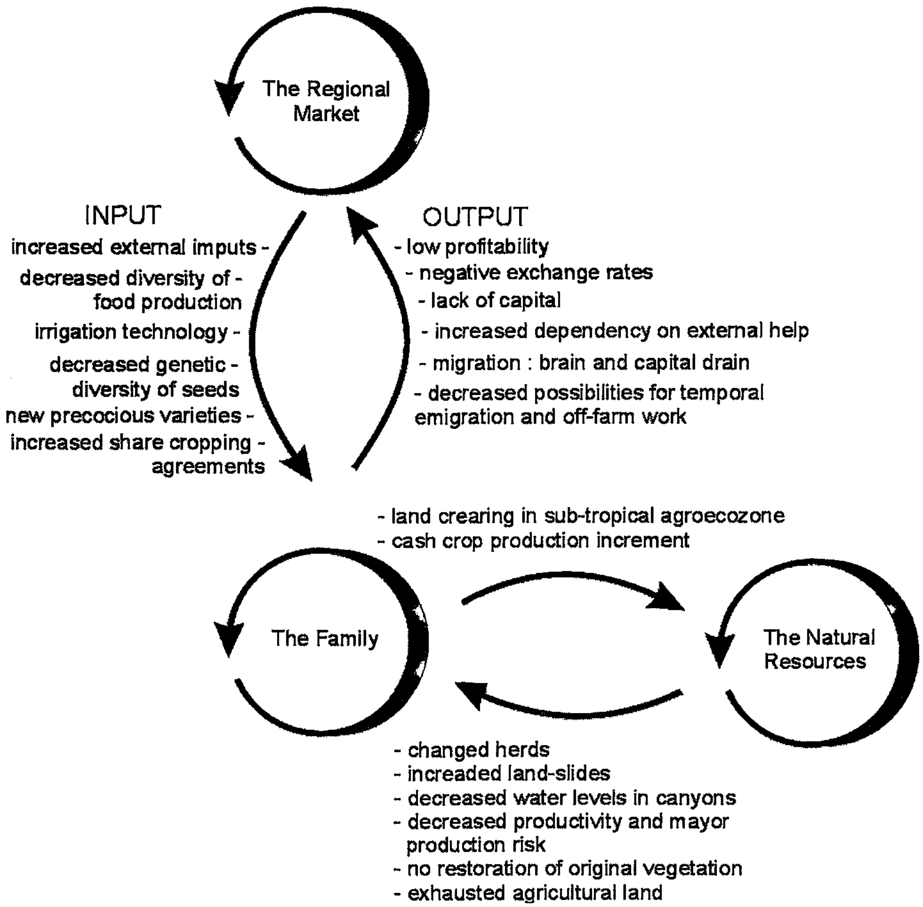
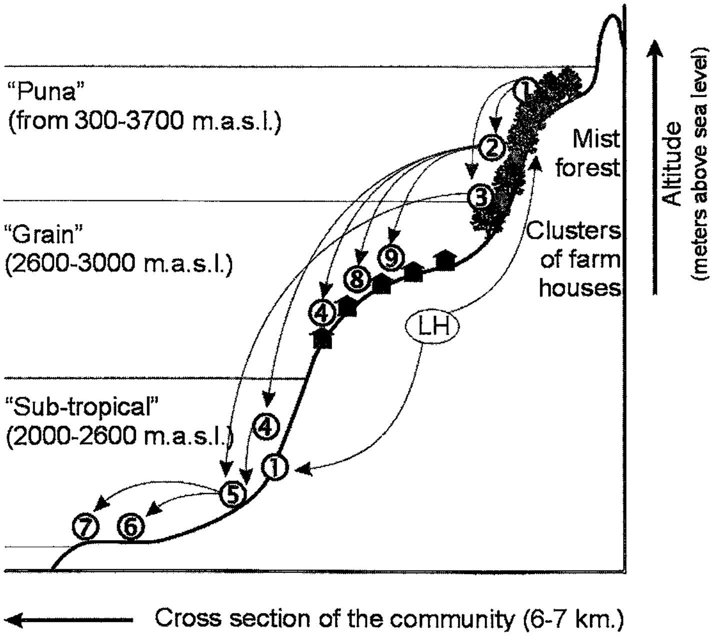


FIGURE 5.1 **Persistent negative change trends between regional market, environment and the farming system of small farmers**

The figure shows that the performance of the Huancarani farming system is blocked by the quality of the local natural resources as well as by its relationship with (dependency on) the regional market. Land degradation is both cause and consequence of the conventional farming system. Farmers are both dependent on and "exploited" by the regional market. This can be explained as follows. Poverty and poor market relations push farmers towards intensive production strategies. This leads to exhaustion of natural resources. The natural resource base becomes threatened. Productivity declines, resulting in poverty as well as increased dependency on the market (the need for more external inputs). This dependency on the market implies higher production costs and declining competitiveness. If farmers cannot afford external inputs, they must exploit the natural resources even further. So, farmers are trapped by an ever decreasing quality of their surroundings. There is no beginning or end and so nobody can say which was first, the egg or the hen. Quechua farmers, therefore, renamed the three-way subsystems as being cycles of doom (cycles of underdevelopment). The regional market was called the cycle of exploitation (Lagos 1988), the natural resources became the cycle of land degradation, and the family was the cycle of poverty. In the following a closer look will be taken at the cycle of land degradation.

Incas used to practice vertical integration of production between agroecozones. Farmers knew these original practices of intensive land use and conservation of fragile ecosystems. They showed good insight into what exactly happened when the problem of disintegration of agroecozones (within the Huancarani community as a whole) became a discussion topic. Figure 5.2 presents their opinion.



LH = Land hunger
1 = forest clearing
2 = no restoration of original vegetation
3 = lack of irrigation water
4 = increased land slides
5 = dried up irrigation channels
6 = increase of exhausted agricultural land
7 = extensive livestock keeping
8 = changing herd: sheep to goats
9 = changing herd: mules and horses to donkeys

FIGURE 5.2 Ecological impact from one production area on the other caused by land hunger in the grain agroecozone

According to the farmers, the clearing of land and forest in the "puna" and "subtropical" agroecozones was the beginning of disintegration. They said this was due to "land hunger", i.e. shortage of agricultural land in the grain agroecozone.
Environmental degradation occurred upstream first, i.e. in the high agroecozone. The negative effects cascaded downhill, always increasing the extent of the damage. The subtropical agroecozone is affected most. This may be explained as follows.
One of the consequences of forest clearing as well as degradation of pasture land in the high agroecozone is a decrease in water retention capacity. Rainfall is then converted to large and strong run-off and peak flows in rivers downstream. This process destroys riverbeds, causing landslides and eliminating irrigation water systems in the grain and subtropical agroecozones. Lack of irrigation water is one of the factors that forced farmers to change traditional intensive land use into extensive production practices, characterised by low investments in soil fertility and further lack of soil conservation measurements. Therefore, exhausted agricultural land in the subtropical agroecozone is the effect of unsustainable agricultural practices at the site as well as the effects of land clearing in the higher agroecozones.

Until now, farmers had done an excellent job in identifying and analysing their problems. They performed problem identification themselves with the help of a set of participatory tools and methods. By relating causes and consequences, farmers learned from their problems. The result is, of course, a diverse set of answers, all important to each individual farmer (see the preceding list in Table 5.1). The issue is now how to attach importance to each problem. Judging by scores (how many times was a particular problem mentioned) may be correct but, on the other hand, may be biased because farmers like to echo what they have heard in their community and what the opinion is of the farmers' leaders, especially when questions raised by outsiders are at stake. They do not like to talk about their own problems, nor about their successes. They simply do not want to be seen as bad or unsuccessful farmers. To judge by what opinion leaders in the community say is not advisable either. Opinion leaders obtained their positions because they are skilled in expressing the general feelings of the community by using the right words, and also because they were once successful in negotiating with outsiders or just because it was their "turn". The development-aid worker needs to live in a community long enough in order to unravel the position of farmer leaders:
- Are they used by the community?
- Are they using their position for family goals?
- Or are they speaking sincerely about their community?

This makes priorisation of problems as put into words by farmer leaders and hence also by the count of the sum of the frequencies of opinions in the platform at best a questionable affair.

Priorisation of problems
Conway (1985a, 1985b) suggests that the importance of problems must be analysed before problem solving can start. If this priorisation is not done, the development worker, scientist or extensionist may risk a highly inefficient approach both time and finance wise. It makes no sense to apply the simple approach of a work agenda that starts by solving the first listed problem "A" and ends with problem "Z". Vereijken and Wijnands (1994) and Kabourakis (1996) discovered in a great number of problem identification studies that all the farms clustered in one community always mention the same type of problem. Conway (1985a, 1985b) states that most of the problems that farmers encounter, irrespective of the level of aggregation, are modalities from some basic dimensions (essential aspects) to "construct" (define) each farm. For example, solving one problem may solve another problem at the same time, if we know that the problem mentioned first is constructed by the same basic dimension as the latter. But the reverse is true as well, when nobody mentions a problem with key

characteristics, then we must expect that the connected problems will not be solved either. For example, nobody is able to measure the content of a box, when only its length and width are known. When the student does not recognise the third dimension of the box, the problem can never be brought to an end. It is the task of the facilitator to identify the basic dimensions of a farm in a certain region. So we must know whether the identified problems are part of basic dimensions of sustainable development. If one starts a farm innovation process on the basis of the most obvious dimensions only, productivity and profitability may lead to long-term failures.

TABLE 5.2 Priorisation of problems of Huancarani farmers clustered according to five dimensions defining a family farm (Conway 1985a, 1985b). The last column indicates in which relation between the "cycles of underdevelopment" a problem dimension scored high.

Priority	*Dimension*	*"Location" of related problems**
1	Productivity	From the regional market to family farming and from family farming to cropping systems
2	Sustainability	Effects of cropping systems on family farming
3	Accessibility	From the regional market to family farming and vice versa
4	Autonomy	Present in all relations at a low profile
5	Profitability	From family farming to the regional market

* see also Figure 5.1

According to Conway (1985a, 1985b) each farm has five basic dimensions: productivity, profitability, sustainability, accessibility and autonomy. For categorising each farmers' problems Conway's dimensions were used. The assignment of the problems of Huancarani farmers to the basic dimensions results in a set of fundamental problem clusters. We recapitulate them in Table 5.2.

We started working in the LRP on the first and second problem clusters (productivity and sustainability), as part of learning in practice. Accessibility and autonomy were simultaneously addressed by facilitation of meetings and by the creation of permanent discussion and planning platforms. We did not follow the priorities of the table successfully. I preferred to follow what farmers wanted to do, which depended much on sudden questions or special events that demanded all their attention (Reintjes et al. 1992; Brouwers 1993). Unexpected questions concerned for example: weather problems, seed quality problems, accidents and ritual demands. The special events were among others: the visit of the only living ex-hacienda owner of Huancarani and the local administration of justice in a case of incest.

5.3 Conclusion

The problems of Quechua farmers are not limited to production on the farm. On the contrary, farmers are trapped in three interrelated cycles of underdevelopment: exploitation by the market, land degradation and poverty of the family. This makes clear that if solutions of problems at cropping system level are looked for, the continuous exploitation of the economy of the family farmer by the market should be broken.

When farm development in the subtropical agroecozone is considered, environmental problems in higher agroecozones should also be taken into account. From a scientific point of view, development should be concerned with how to attack the causes of environmental degradation. Therefore, it would be logical to start farm innovation in the high agroecozone in order to tackle the causes of land degradation. Possible solutions are: reforestation, protection of vulnerable ecosystems such as the mist forests and/or changed practices of livestock and agricultural production, all with the purpose of restoring the natural vegetation and the water retention capacity, thereby eliminating further erosion downstream. From a farmer's point of view, however, a development plan for the lowest subtropical agroecozone would be more interesting and effective. So, farmers and scientists do not arrive at a common view on the solution, although they agree on the analysis of the problems in general terms. This brings the discussion from the search for practical-technical solutions to the subjects 'autonomy' and interactive learning.

We also know that no problem can be solved if questions related to farmers' autonomy and accessibility (knowledge, capital and natural resources) are not taken into account. These dimensions of problem identification are of another order than productivity, profitability and sustainability. The question is not only about what should be done in order to solve the identified problems. It addresses questions on how to arrive at consensus between farmers and development-aid workers, and how to guarantee final decision-making. Basically, autonomy and accessibility involve human relationships with other actors who play a role (directly or indirectly) in farming. Productivity, profitability and sustainability link farmers with their surroundings: natural resources and production fields. Therefore, at least two different learning processes are required to address the five dimensions of problem analysis. The dimensions productivity, profitability and sustainability can be addressed by "learning in practice". Learning the dimensions accessibility and autonomy will only happen by adequate forms of "learning from practice". This problem analysis justified the LRP to continue facilitating both learning in practice and learning from practice.

Being the facilitator myself, I was enthusiastic about the results reached by problem analysis. However, problem analysis did not indicate directly how to start farm innovation. In this sense it is important to remember that farmers had some difficulty in talking about their problems, especially in the present. Problem analysis could be biased towards analysis of the past and ideas for the future. When farmers were analysing their problems, on several occasions they showed the ability to mix what is the reality of farming today with what they expect from agriculture in the future. So, the final decision-making on which action to undertake are heavily influenced, guided and restricted by the farmers' future perspective of farming. Therefore, it was necessary to open the discussion on what the farmers expect from the future.
In the next chapter the farmers' vision and preconditions for future farming will be developed and made explicit.

Chapter 6

Assignments for the design of learning pathways

In the preceding chapter an overview was given of the relationships between the professed concerns of resource-poor Huancarani farmers and the real problems behind them. One thing became clear: what began as a simple call for progressive empowerment of resource-poor farmers in a highly degraded and complex environment, turned out to become a entanglement of theoretical and practical issues of technical and process design. In such a situation the researcher in charge has to be sure that he (she) can manage the process without giving the farmers a sense of panic, despair or indecisiveness.
At this stage of the process it was very important to be able to recognise the phase at which our work with the farmers had arrived. It was also important that farmers, being part of a participatory process, would feel themselves comfortable with the researchers involved. Also, the farmers needed to feel involved in the initial problems and the actual program activities. This chapter focuses on how the team took care of all this. The assignments within each of the respective phases that could be identified by structuring the work process, were carefully considered (see also Section 4.3).

In the following, first the goals, functions, criteria and boundary conditions of the platform comprising both farmers and facilitators will be discussed (Section 6.1). For a summary of the applied methods and tools for goal setting, see Annex 1, Table 2. Subsequently, attention will be paid to the setting of criteria that farmers like to see if a result is to be considered successful (Section 6.2).
In the following sections (Sections 3, 4 and 5) the goals, functions, criteria and boundary conditions for the design concerning learning in practice, learning from practice and learning for practice will be discussed.

6.1 Designing a platform

A platform of farmers can be viewed as a means by which communities learn about the processes in rural development, including identification, ways for testing ideas and implementation of agreed practices. Platforms are also a tool for encouraging an entire community. Scepticism among community members and even scientists, which are mostly the result of disappointments experienced in the past, ruins new initiatives. Also, ideological predisposition of NGOs or other groups may interfere with newly started activities (Arrellano and Petras 1994). The role of suppliers of chemical inputs or seeds should not be underestimated either (Strategic Environmental Analysis by Kessler et al. 1997). These inputs look effective as the representatives are good at quickly convincing the knowledge-poor farmers with spectacular short-term effects.

All farmers interested in the LRP were invited to take part in the platform, which was promoted during the frequent meetings of the farmers' union. However, not everybody was likely to join the platform. The quite serious situation of Huancarani caused a large number of people to be fatalistic, they had no trust in their future. Therefore, it was easy to predict that "innovators" would form the majority in the platform and that the number of participating women would be low. Innovators are important in a platform because they are keen on new experiences, willing to carry out new experiments and easily share their knowledge with researchers. We discovered that innovative people are rarely considered as representatives of their community, although many people find them interesting. Therefore, some conservative but highly respected people were also asked to join the platform. Although mostly older and resistant to change farming practice, these people also participated very actively in the platform. They were not there to frustrate the work of the group, but had a real interest in helping to develop the "best" production systems. These people tried to control, to a certain extent, the socio-economic and cultural impact of the activities of the LRP.

The platform started its activities with a group of 20 to 30 people who participated regularly. However, all community members were informed about the activities and results by way of at least three meetings about the LRP during the sessions of the local farmer union meeting. In that way we achieved that:

- All people were informed about the progress and could vent their opinions and suggestions;
- The farmers' union supervised the LRP and decided on main issues at community level;
- The LRP coordinated activities with the farmers' union;
- The farmers' union (in coordination with the LRP) informed the provincial and regional boards of the farmers' federation;
- The farmers' union evaluated and supported planning and realisation of the LRP activities.

We stimulated the involvement of those farmers who were considered to be the "wise" or the real representatives of the community. In the case of Huancarani, it appeared to be important also to have a local process leader of the platform who could combine the different characters. Eloy Vargas was such a person. He was not only one of them, but also a dedicated, wise, highly respected person and farmers-union leader. He was also an innovation-minded person and, moreover, a farmer himself. Together with him, we created the beginning of a decision-making platform. We did not strive for full coverage of all interested farmers of the community. We just started with a small and well-chosen group of people, accepting that others, becoming curious or changing their minds later, could also take part of the group. This raised the confidence that everything was kept open, public and detached from personal interests. With Eloy Vargas we developed a very successful cooperation. I considered him as the eyes, ears and soul of the Huancarani farmers. He trusted me because of my unlimited energy to travel to the community, the good contacts with most farmers, participation in religious and agricultural rites, and because I did what I promised and respected what he said, even when initially I did not understand his do's and don'ts.

6.2 Criteria for success according to the Huancarani farmers

The impact of development projects in resource-poor conditions may be limited, especially when taking the (short) duration of most projects into account. However, quick changes two or three years after the introduction of new production strategies also occur in resource-poor conditions. This is often the case when problems caused by extremely limiting factors such as shortage of water or phosphate, are solved successfully. The impact of agricultural research and development in the community is then measured by an increase in crop yields, better incomes or better efficiency from inputs.
In conclusion, these obvious criteria of usually short-term development projects such as those mentioned before, may not be useful for "measuring" the success of our efforts. The LRP agreed with Jara (1994) that these criteria may be used for the evaluation of the technical results. But they are not useful for evaluating the success of farmers' participation or the success of the LRP in terms of learning processes. By their very nature, in the LRP agro-ecological and interactive learning issues are long-term processes.

Platform discussions showed that the Huancarani farmers do not think in the short term as much as we feared. Of course, they think in terms of profitability in farming. But they also brought up criteria of a long-term nature that were related to the economy of their community as well as their political and cultural affairs.

In the following the farmers' opinions on future farming according to the consensus reached by the platform will be described. The farmers' perceptions were subdivided into subsystems as they occur in daily life i.e. political organisation, economy of family farming, nature and agriculture (Van Pelt 1993).

Political organisation
The family should remain the centre of decision-making for production as it is today. However, the local farmers' union should increase its control over scarce production factors such as irrigation water, forest and pasture land. The farmers union should also initiate and supervise great communal efforts in order to take advantage of certain production factors or services, such as road infrastructure for local markets, construction of a health post and schooling facilities, and reforestation of communal land. The communal dependency on these production and welfare factors is fully accepted. Moreover, it should be reinforced by traditional forms of reciprocal relationships between small groups and families, according to the Huancarani farmers. Communal control of scarce production factors and great development efforts were seen as meaningful strategies for agricultural development.
Governmental farm development support and intervention in the market are not expected in view of the national neo-liberal agrarian policy and the influence of the World Bank policies. Farmers expressed the opinion that the local farmers' union must remain the highest authority to guide agricultural innovation processes. The local union should intervene in conflicts of interest between nature conservation and human needs. This in addition to the traditional political tasks of the union: (a) to represent the farmers in national political conflicts and (b) to remain a strong social partner for the Bolivian state, the government and private development institutes (NGOs).

Economy of family farming
Farmers of Huancarani defined the future economic subsystem as a family-farmers' (*campesino*) economy in which they want to remain *campesinos* as they are today. According to the farmers, agriculture should continue to be the most important activity, that feeds their

economy. The means for production should be privately owned land for arable production and partly communally owned for livestock production and forest management. Temporal emigration, off-farm income, and non-agricultural work should remain essential parts of the survival strategy.

Nature

According to the Huancarani farmers, nature has become subordinate to economy as a result of the economic system. Ecological sustainability should be aimed at if the basic needs of the Huancarani inhabitants are to be satisfied. However, farmers also showed serious concern about environmental decay in their community and related effects on agricultural production. Therefore, they were greatly interested in strategies for protecting nature, such as rare vegetation and ecosystems from further degradation by giving them ecologically sound production functions. If this is done, erosion will be controlled and soil fertility maintained. Starting point for the management of already degraded land is the rehabilitation of nature as part of the farming system. The people themselves were keen to participate in such rehabilitation processes.

Agriculture

Farmers were interested in developing their farms and communities, and change their production strategies into cash-crop production. However, they could not accept that family food production would not be guaranteed, in view of the tradition of subsistence farming strategies. This can be understood as a risk-avoiding strategy against adverse climatic conditions for agricultural production and unstable markets. Farming should be focused on food crops, livestock, as well as cash crop production. Farmers showed their concern about the increased dependence on the market for agricultural inputs. Agriculture should maintain its high diversity for food crops as well as for cash crops. The increased dependence on a small number of cash crops was evaluated as being negative.

Agricultural production requires intensification by means of improvement of natural processes in the field with locally available resources. Integration of agriculture and livestock production should be aimed for.

Specialisation of agriculture based on comparative advantages for production and specific markets is not aimed at. Diversified agricultural production and additional income generating activities were proposed in order to maintain high flexibility with regard to changing environmental conditions and markets.

The farmers agreed that the quantity of food production should be increased and the nutrition value of food improved (first production objective). They said to strive for a better variation in nutrition and to pay more attention to high-protein consumption.

The second production objective referred to selling commodities at regional and departmental markets. The importance of sale on the market cannot be expressed in percentages of the total production. Production and prices fluctuate hugely between seasons. Agricultural produce is only put on the market when the family's food security is guaranteed (Regalsky et al. 1994). The income obtained from the sale of produce is destined for buying agricultural and non-agricultural commodities which the farmers do not produce themselves (which is still part of the subsistence farming objective).

Farm development criteria

The preceding opinions were the result of some initial discussions in the platform. It appeared that all meetings, irrespective of the kind of subsystem in discussion, showed activity and involvement and were relevant. The same occurred during the definition of development, as already discussed in Section 3.4. In future, this may pose the problem of too high concrete expectations, which could make the farmers vulnerable to disappointments later on in the project. Irrespective of the farmers' previous opinion on a preselected pathway to farm development, the LRP promoted the exercise of formulating farm development criteria in order to guarantee the underlying opinions and criteria to be expressed and weighted. In other words, although the Huancarani farmers had already heard of cactus pear and cochineal production, they started from their own future vision and with the help of the LRP, to fill in their criteria for farm development. With this knowledge the group could compare development pathways.

It was essential to make the farmers constantly aware of the fact that political demands or requirements with regard to markets are highly dependent on outsiders. In contrast, the quality of biodiversity is very much dependent on what the farmers themselves want to invest in and around their farms. They gradually came to understand that changes and effects such as time saving, efficiency in debates with each other should also be considered as a positive outcome of their work in the platform.

We decided to start discussions by concentrating on the "hard" side of the LRP: learning in practice. We suggested to the platform members to address the issues concerning production objectives first and then return to the criteria of community development in general.

Farmers defined a long list of criteria (package of demands) by which their perceptions and objectives (as described above, including the farmers' definition of their concept of development) were worked out in practical preconditions for farm development. These criteria were further split up and accentuated by attributes. The attributes made the farmers' opinion more explicit, by which these became more useful for discussion, weighting and decision-making as well as for facilitation of farmer-guided development processes.
Initially, about 50 criteria were formulated. The package of demands represented socio-economic, cultural and ecological objectives for farm development, because of the farmers' holistic view on farming. Farmers needed several sessions to restrict the number of criteria and it was difficult to define precise targets or threshold values. Most indicators were defined in qualitative terms. Table 6.1 shows the final selection of farm development criteria and attributes, as defined by the farmers themselves. Related indicators are presented in Table 9.1.

After completing the package of demands, it was suggested to continue its adaptation during the LRP, according to the ever-changing vision of the farmers on farm development. It was a learning process for them to define development criteria. The definition of criteria and attributes was a participatory approach, normative affair and platform specific.

TABLE 6.1 Farmers' development criteria and attributes in relation to farm innovation for Quechua farmers in Huancarani, Bolivia. The percentages indicate the relative value (weights) of each criteria and attribute to a total score of 100%.

Criteria	***Attributes***
1 The culture of the Andes must be maintained 20%	Maintaining Andes crops (based on local knowledge and technology) 5%
	Community tasks in agricultural production 5%
	Maintained possibilities for further development; more than one production function per crop or activity 10%
2 No competition with traditional food production (risk avoidance strategy) 15%	No competition with occupied agricultural land 10%
	Minimal labour input 2.5%
	Minimal capital input 2.5%
3 Economic efficiency 30%	Increased productivity of the land 10%
	Internal rate of return is more than rate of interest 15%
	Yearly economic result and cash flow are positive 5%
4 Socially just 6%	Active participation of the families in the program 6%
5 Gender focus 4%	Increased role for women in agricultural production and sale 4%
6 Protection of vulnerable natural ecosystems 10%	No further land clearing of forests and permanent grassland 10%
7 Rehabilitation of degraded land 15%	Improved biodiversity at field level 5%
	Soil conservation: minimised water and soil losses 5%
	Integration of agricultural and livestock production 5%

Weight sets

The assessment of the overall performance of farm development options (scenarios or alternatives) was based on the package of demands (see Chapter 8). The criteria did not

necessarily have to be equal in importance. Therefore, farmers were interested to assign a score of relative importance (weights) to the criteria and attributes.
The farmers made the weight sets themselves. This was done with a priority setting of criteria and attributes by each of the members of the platform involved. Next, a frequency count was carried out followed by a final discussion, which resulted in final scores. In the Land Rehabilitation Program, farmers attached more importance to the economic criterion (30 percent) and related risk avoiding production strategies (20 percent). The cultural criterion received 15 percent, the environmental criteria 25 percent and the social criteria 10 percent (see percentages in Figure 6.1).

6.3 Assignments for learning *in* practice

In the subtropical agroecozone of Huancarani 350 ha of exhausted agricultural land, 1500 ha of degraded pasture land and an unproductive livestock system with animals not suited for the situation of the high Andes can be found. In the case of a status quo of the actual farming practices, soil degradation will increase. Young farmers, without opportunities for schooling and without any change of income, have only one choice: to survive on exploitation of the poor natural resources. Due to extensively managed livestock, mostly in wild areas, farmers build up their own private living "bank account". Their design objectives for the development of sustainable production systems were: improvement of their livestock system, diversification of farm production, rehabilitation of exhausted soils, improvement of family income and restoration of biodiversity.

This was the moment to help farmers learn about the relationship between what they found by analysing their history of land use and what they expected in the future. This exercise unveiled that the first concern about their future is the land rehabilitation issue. From the analysis they could identify five important routes that, together, bring them to their main problem: rehabilitation of exhausted land so that they do not need to emigrate anymore.

The next step was to lead the farmers to operational solutions. Progressive discussions took place about all possible solutions. Where the first set of discussions focused on imaging a shared view on the problem and possible roads towards a solution, the second set of discussions had to focus on judgements about the solution that communal brainstorming could provide. It was noticeable that the "imaging-producing" phase catalysed synergy among platform members. They lost their "pleasure" in grumbling or their need to pretend a certain detachment from the problem of their neighbours. Apathy and lack of trust, the result of short-term efforts made by charities or the result of classic positivistic types of scientific research were again and again serious thresholds that had to be overcome.

Once the platform members experienced the effects of synergy, the meetings continued with exploring the farmers' knowledge about how they could operationalise their five objectives. The question then was: find (again) one or more commodities that:
- Can be grown on exhausted soils;
- Produce fodder;
- Produce other commodities;
- Improve soil life;
- Provide opportunities for improving family incomes;
- Enhance biodiversity.

The discussion brought the participants quickly to several commodities in combination with specific agricultural practices. One of these production systems had to be selected. Of the various cropping systems, cactus pear growing in combination with cochineal production was the most interesting. Cochineal is very precious because of the carminic acid it contains. This dye is much used in the food and cosmetic industry. Farmers had no problems with identifying cactus pear, as their sense for history made them remember the commodities of their fathers and grandfathers. They had already heard of the cochineal production experiments in other communities. But they did not understand precisely why the combination of cactus pear and cochineal were so profitable for the Andes, nor how to attain all their objectives with this production system.

Further meetings were used to improve the farmers' understanding. For myself, it became important to find literature and experiences about the cactus pear. The LRP was already contracted by other platforms to gather data on the production of cactus pear and cochineal. A good deal of the information needed could easily be retrieved for the farmers in Huancarani. The most interesting information, however, came from the farmers themselves. Together we gathered all the knowledge that was needed for a common understanding of why the cactus could be the key to solving their problems.

Some farmers remembered that the young cladodes (flattened stems, adapted to reduce water loss) of the cactus pear plant were always eaten by livestock in the dry season (Tekelenburg 1988). This means that cladodes can also be harvested and fed to animals as complementary feeding when they are stabled. These cladodes are palatable and contain moisture and sugars. The cactus pear also produces a delicious fruit which contains sugars and vitamins and is much appreciated as part of the farmers' nutrition.

Farmers observed that animals cannot enter fences of dense cactus pear, especially when species with large spines are planted. This means that this multipurpose plant can also be used for the protection of land and hence for restoration of the natural vegetation. Sufficient grasses and weeds can be harvested for animal feeding, at the same time improving the coverage of soil and soil life.

Farmers also reported the production of cochineal on the cactus pear, the use of cladodes for construction purposes, clearing water, etc.

Figure 6.1 gives an overview of the results after an intensive platform discussion.

Cactus pear production was rediscovered as the best opportunity, being an old but very promising crop. The assignment of the first learning level "in practice" was to:

- Optimise the production of cactus pear for fodder production;
- Improve the quality of cochineal and to adapt its production to local growing conditions;
- Find out how cochineal production affects fruit and forage production;
- Create an optimal cropping system for the integrated cactus pear and cochineal production;
- Insert the new production system satisfactorily into the actual farming system of the subtropical agroecozone of Huancarani, including the occupation of exhausted agricultural land.

The design objective for livestock improvement required further specification: maintaining cattle weight during the dry period and manure collection for organic fertilisation of traditional irrigated fields in the subtropical agroecozone.

Objectives of land conservation and land rehabilitation were addressed by the transformation of exhausted agricultural land into permanent farmland with increased and diversified plant productivity.

Cochineal production was identified as an important factor for increasing family incomes. In Peru, most cochineal is collected in wild cactus pear plants in natural bush type vegetation. It was the challenge of the Land Rehabilitation Program to adapt this traditional collection practice into integrated and sustainable farming with cactus pear plantations (Tukuypaj 1993a).

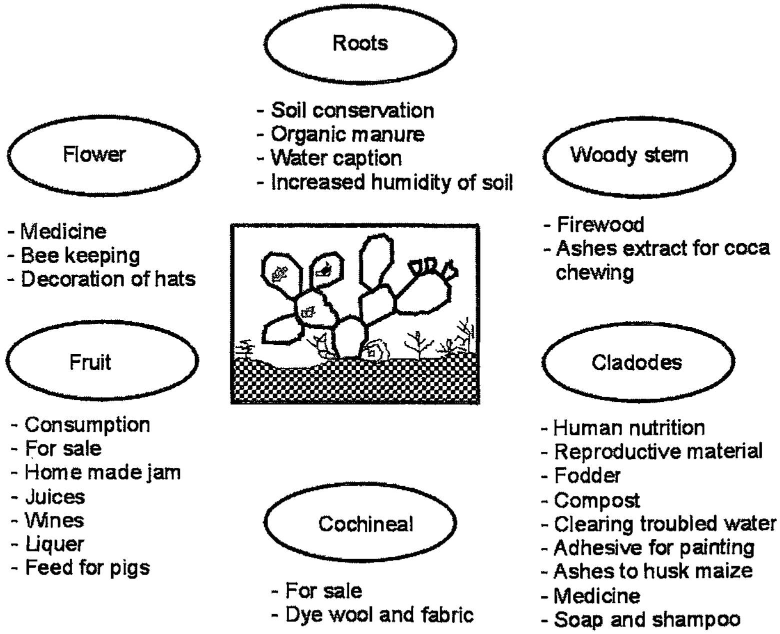


FIGURE 6.1 Multiple uses of cactus pear

6.4 Assignments for learning *from* practice

The second objective of the LRP concerned empowerment of the resource-poor Huancarani farmers. There was no doubt that this objective had to become the ultimate outcome of the project. The question of learning from practice is not focused on the technical goals of the LRP, but is related to the learning process itself: methodology, procedures, participation and farmers' attitudes. It is about the position of the farmer in farm innovation processes. Were they able to steer a development process in an ever-changing context? And what did they do to improve their contribution to farm innovation? It must be clear now that learning form practice is not technical goal oriented but process oriented.

The LRP, being a typical cost-effective approach to smallholder development, wanted to shift from the classical Farming System Research (FRS) trend. The new trend was to be FRS in combination with ideas such as empowerment and participation. Research as such got new names: Participatory Technology Development, Farmer Participatory Experimenting (FPE), or Participatory Rural Appraisal (PRA). But it became clear that most of these models did not work in the context of the Huancarani farmers. Their poverty was too great, their apathy against scientific results too intense and their lack of trust in any kind of development policies too obvious.

What did the farmers themselves have to say about empowerment? It appeared that hey were happy with the subject as it was, but had not realised that they and only they themselves as well as their way of communication and decision-making were at the heart of the subject.
In the beginning the discussions were quite unsatisfactory. There frequently was an attitude of: "Give us your recipe and we will do it". It was the model that they had become used to. For us, as facilitators, dissatisfaction and irritation arose. Having no literature, libraries, networks or money to contract extra specialists, we had to find out by ourselves what should be done. We decided to withdraw as much as possible. Meetings were held, but we always started with strategies, which reflected the farmers' questions, and tried to motivate their dedication by making them aware of the fact that their knowledge or activities had good chances for problem solving. After a couple of frustrating meetings, we sensed that the farmers did not like to be responsible for the failure of their program, so a more constructive attitude came into being. Some farmers began to evaluate what they had done so far. In fact, in their meetings they walked back on the pathway that we called "learning in practice". They realised that they were walking this path in two stages:

- First, by making an analysis of the problem analysis, resulting in an image of the relation between causes and consequences;
- Next, by observing the methodology of problem analysis as a cluster of separate smaller projects. We could propose methodological improvements and further research and experiments to them.

This way of reasoning made them realise that the results from problem analysis had to be brought back to the aggregation level from which the initial problems had come.
We considered this insight an important moment. The farmers began to realise that their activities used to stop as soon as scientists, together with them, had found some important solution at crop or cropping system level.
At this stage, the assignment to design "learning from practice" became operational. We had to find out how the Huancarani farmers think about the best way to reach solutions, found in experiments, applied without excluding the complexity of the original context of the problem statement.

Literature on how farmers learn from practice could not be retrieved from any agricultural research or technical agricultural design. We registered our observations on meta-processes during discussions among platform members according to Jara's (1994) systematization of the experience. Other approaches making use of learning processes in practice were found in participatory learning and action research (PLAR) (Hamilton 1995; Lammerink 1995). The systematization of the experience guided the participants of a specific development process to learn from their own experiences and improve practice.

Three initial questions for systematization (objective, object and angle of analysis) were put into direct relation to the second objective of the LRP. The objective of systematization was to contribute to the validation of information and processes as well as to improve practice. The object of systematization was the farm innovation methodology as used in the Land Rehabilitation Program. The technical case consisted of the development of sustainable farming systems based on the production of the multipurpose cactus pear and the cochineal scale insect, while focusing on the in-depth experience of one case study community: Huancarani, Ayopaya province, Cochabamba. The angles (central aspects) of systematization referred to the participatory levels of farmers in the platform, applied interactive approaches during farm innovation processes, and the relative importance of activities for the success of the LRP.

By classifying all our observations according to the four levels of complexity as mentioned before we, as facilitators obtained a good basis to reflect with farmers on what happened during the LRP team.

The LRP methodology was analysed for farmers' learning processes. The assignments of the second learning level "from practice" was to:
- Evaluate how farmer organisations were created;
- Determine how knowledge integration took place;
- Analyse how decision-making was carried out;
- Determine the opinion on the relative importance of the activities of the LRP that were carried out;
- Determine the opinion of the stakeholders involved about their level of participation;
- Determine applied interaction strategies as an indicator of the quality of farmer participation.

6.5 Assignments for learning *for* practice

In learning from practice, I considered farmers, being part of learning in a practice situation, as students who have to learn professional skills in a heuristic way. In other words: "The farmers must learn from their good as well as wrong decisions". During the meetings they even said so themselves: "We come together to learn from our successes as well as from our failures". Professional skills are, among others, efficient talking during meetings, dealing with organisations, feelings and interests, making appointments, creating new activities, getting people together, effective lobbying, etc.
I wanted to evaluate how farmers learn and which attitudes play a role in platform discussions. I accepted that those professional skills, as part of a learning pathway, must be trained. So I had to distinguish the farmers' learning stages. These become visible when they are observed as skills of individuals or a group of individuals, all sharing one task or assignment. I had to observe the following:
- When do farmers show that they are unaware of doing things wrong (tacitly unskilled);
- When do farmers know that they make mistakes, but do not know yet how to do it better (consciously unskilled);
- When do farmers think profoundly and take their time, i.e. when they are conscious in applying their skills (consciously skilled).
- Farmers do not need to think carefully, because they take the right decisions automatically and in time (tacitly skilled).

When learning for practice started, the context of the platform was left aside. I left the scene, while the LRP continued in Huancarani together with the platform and with Eloy Vargas, the local development worker, as facilitator. This meant that the farmers themselves did not discuss much about how other farmers groups could learn form their experiences and improve their development process. Learning for practice (high participation of farmers) is different from learning for practice because of a jump towards more abstract thinking.

The LRP methodology was further analysed for designing farmers' learning processes. The assignments of the third learning level (learning for practice) were to:
- Discover patterns of applied methodology;
- Structure methodology in such a way that learning processes can be designed;
- Evaluate how farmers can grow in their learning;
- Determine elemental conditions and basic characteristics of the tool for design of learning processes.

From this point onwards, I shall take a closer look at the practical outcome of the LRP. In Chapter 7, introductions and results of research on cactus pear and cochineal will be presented. This is part of learning in practice. Chapter 8 will be dedicated to the design of the integrated cactus pear and cochineal production system. This is also part of learning in practice. It must be remembered here that some information about the LRP in Chapter 2, and the presentation of the project site in Chapter 3, also need to be considered as part of learning in practice. Next, in Chapter 9, the design of the learning pathway is analysed as part of learning from practice. In Chapter 10 the development of a management tool for the design of interactive learning processes will be discussed (learning for practice).

Chapter 7

Cactus pear (*Opuntia ficus-indica* M.) and cochineal (*Dactylopius coccus* C.) production

In this chapter farmers continue learning in practice. After the problem analysis phase, the platform introduced cactus pear and cochineal as their main focus in the experiments. Both, cactus pear and cochineal will be described extensively in the first two sections respectively. Next, two important issues needed for the design of the integrated production of cactus pear and cochineal, are described: cactus pear productivity and cochineal quality. These were studied as part of the activity agenda of the LRP.

7.1 Cactus Pear

Cactus pear (*Opuntia ficus-indica* M.) is one of the traditional pre-Columbian crops in the Andes. In South America, cactus pear can be found in all (semi-) arid regions of the Interandean valleys from Colombia to Chile. It is an important crop for peasant populations in marginal areas. Therefore, it is a crop for the poor. Governmental agricultural support did not pay much attention to this plant. Recently however, following the farmers' interest, development institutions discovered the importance of cactus pear for innovation of current farming. Bolivian research centres started to investigate, validate and promote cactus pear in relation to agricultural production demands at farm level. Other countries in South America, such as Chile, Argentina, and Brazil did the same. Now, cactus pear is one of the scientific items on the congress agenda in many Latin American countries.

In 1992, a world-wide group of specialised institutes and scientists created the FAO International Technical Cooperation Network on Cactus Pear. The group issued joined publications (Barbera et al. 1995) and produced a newsletter as well as an e-mail newsletter at the A&M University in Texas. It also organised international congresses and workshops. All these actions were intended to contribute to knowledge exchange and promotion of the crop.

From an ecological point of view cactus pear is a pioneer plant. The plant succeeds to grow on fresh volcanic soils and easily adapts to different ecological conditions. Therefore, cactus pear may be found from the coast to more than 3500 meter above sea level in the Andes. *Opuntia* species can also be found in all climates with 250 to more than 2000 mm precipitation per year or from absolute minimum temperatures of -40 °C in Canada (Nobel 1995) to tropical zones with mean annual temperatures above 25 °C.
These characteristics and agricultural possibilities (see Section 6.3) made the plant a popular species for rural populations. In very difficult climatic and remote situations of subsistence based farming, cactus pear appeared to be the plant that could help small-scale agriculture on marginal soils to survive. Cactus pear production fits perfectly well into the farmers' risk avoiding strategy and crop diversity increment. Cactus pear is also useful for rehabilitation of exhausted soils.
The cactus pear plant is a succulent. It survives in dry seasons because of its highly efficient water uptake and storage mechanism. Cacti are long-living perennials and may become woody (Gibson and Nobel 1986).

Cactus pear belongs to the order of Caryophyllales (among 40 others) and the family Cactaceae (among eleven other families) (Nobel 1988). The cactaceae are divided into Pereskioideae, Opuntioideae and Cactoideae. The Opuntioideae are divided into seven genera, of which one is *Opuntia* (160 species), which consists of the Cylindriopuntia and the Platyopuntia (140 species). Cactus pear is classified as a Platyopuntia. The *Opuntia* are divided into several sections and series. This study focuses on the section *Opuntia* and series Opuntiae (Britton and Rose 1963; Benson 1982; Bravo 1978; Sheinvar 1995).

Identification of the entire complex of *O. ficus-indica* and other cultivated *Opuntia* species is subject to investigation (Benson 1982). In Bolivia, where local taxonomic studies are not available, cactus pear is classified as a genotype of *O. ficus-indica* Mill. for both glabrous and spiny types. Genotypes are further classified according to fruit colour: white (or green), red, purple, yellow and white-pink (with almond taste).
Cactus pear can be found in climates of many departments in Bolivia. The red and white almond genotypes are rare. The purple type is only cultivated to be sold on the markets of La Paz. The white or green cactus pear types are most widely distributed in the Departments of Oruro, Chuquisaca, Potosí, Tarija and La Paz. The yellow variety is cultivated more in Cochabamba and Santa Cruz. In addition, a large number of "wild" *Opuntia* species can be found, for example *Opuntia soehrensii* Br & R and *Opuntia cochabambensis* Cárdenas (Cárdenas 1953). These are well known for their production of a local red-purple dye, *airampu*, which is extracted from the fruit pulp.

Production conditions
Cactus pear is widely distributed all over the world. The plant requires the following (semi-) arid conditions (Sanchez 1985; Inglese 1995):
- a pronounced dry period;
- a relatively mild winter; no absolute temperatures below -10 °C;
- the dry season must coincide with short day length; summer rainfall;
- low night temperatures (10-15 °C);
- high solar radiation;
- moderate annual mean temperatures between 14-18 °C;
- relative air humidity of 55 to 85 percent.

The soil requirements of cactus pear are not determining factors for production. They should be considered as general indications and not as absolute limitations. Cactus pear development has been found on soils with rocky underground, steep hillsides and soils low in nutrition. The general requirements are (Enserink 1978; Sanchez 1985; Inglese 1995):

- light or sandy soils, not very deep, with stones and rocky underground, clay content less than 20%;
- well drained and aerated soils;
- alkaline pH;
- chemical requirements of the soils play a less important role;
- regular to high soil content of calcium;
- NaCl content in soil water below 70 mol per m^3;
- neither flooded (plain) areas nor high water tables in the soil (cause die off of roots and plants);
- preference for foothills; taking advantage of the water run-off and microclimates (protection of frost damage and wind problems).

Productivity

The cactus pear's production potential depends on climatic conditions, soil fertility and irrigation. Variation in the cladode production of mature plantations is between 20 and 400 metric tons of fresh cladodes per hectare per year (Enserink 1978; Matter 1984). At precipitation above 400 mm per year 30-100 metric tons of fresh cladodes can be produced in a natural environment. Productivity of cactus pear cultivated in special production fields may reach double the normal amount. Under arid conditions (150-300 mm.) cactus pear production reaches only 10-50 tons of fresh cladodes per hectare per year (Enserink 1978). So, even in dry climatic conditions cactus pear is still a very productive plant.

In many countries of the world cactus pear became an important crop. Its fruit is well known and highly appreciated in all producing countries. Italy, Mexico and Israel are cactus pear exporting countries. Fruit production in Italy is 25 tons per ha per year (Barbera and Inglese 1993). In Cochabamba, Bolivia, the average fruit production is 8.1 kg per mature plant. This works out at 6.5 tons per ha for plantations with the traditional density of 800 plants per ha (Tukuypaj 1993b).

In contrast to the cactus pear fruit, the vegetable *Cladode* (*nopalito*) is not consumed world-wide and remains a specific Mexican culinary speciality.

Cactus pear is also cultivated for forage in order to assure emergency stock feed in times of drought. It is used as complementary feed to traditional pasturing and to other cultivated forage. This kind of production is found mainly in North African countries i.e., Brazil, Mexico and in the South of the USA.

Cactus pear also showed to be productive as a host to the scale insect cochineal, whose "blood" produces carminic acid as a red dye for food, cosmetics and pharmaceutics industries. Together, Peru and the Canary Islands produce 95 percent of the world's cochineal.

Cactus pear has also been identified as a suitable crop for the prevention of long-term degradation of ecologically weak environments. Therefore, cactus pear may help to conserve the soil quality of marginal pastureland and regenerate (exhausted) agricultural land (Marroquín et al. 1964; Abraham 1981; NN 1993; Medina Acuña and De la Cruz 1985).

In important cactus pear producing regions, such as the province of Capinota and the Valle Alto (the valley upstream) of Cochabamba, farmers feed their animals in the dry period with low rations of cactus pear as a complement to their insufficient diet from pasturing. Measurements of traditional cactus pear intake have not been carried out so far.

Because of its low crude protein content, cactus pear is always used as a complementary feed. Production objectives of complementary feeding with cactus pear may be maintenance of animal weight, growth or even lactation. When weight maintenance is the aim, cactus pear should be administrated unlimited, complementary to traditional pasturing or limited rations of high quality forage. Cattle fed with a pure cactus pear diet lag in growth, in comparison to animals on a maize-silage diet (Matter 1984). When pure cactus pear is given to sheep, growth is not expected but weight maintenance has been recorded for a very long time. Sheep were kept in "good condition" for 30 to 90 days. In times of emergency sheep were kept alive for 200 days on a diet of pure cactus pear (Enserink 1978).

It is concluded that when forage of high quality is lacking, cactus pear can be fed to up to 30 percent of the dry matter intake without affecting growth. Cattle can consume large quantities of chopped cactus pear such as 50-90 kg per day (Enserink 1978; Westphal 1984). In this case, the animals hardly need complementary water. A diet of 1 kg of 40 percent protein cotton seed cake, 0.4 kg of a balanced mineral salt mixture and 45 kg of cactus cladodes can provide a ration on which cattle can grow, reproduce and lactate (Felker 1995). In the LRP, the expected result of complementary feeding with cactus pear in the case study area Huancarani was weight maintenance during the dry period.

7.2 Cochineal

Cochineal is a species of the scale insects and is classified as *Dactylopius coccus* Costa. These insects develop specifically on *Opuntia* and *Nopalea* genera. The male insects are small white "flies" of no commercial value. Females in their final stages of development remain in the larval stage and contain an appreciable amount of carminic acid, generally between 19-24 percent of the dry weight. Carminic acid is a chemical substance of natural origin with a wide range of beautiful red colours. Today the dye is of special interest to food, cosmetic and pharmaceutical industries because of its natural origin and its stability against oxidation, light and high temperatures (Kooistra 1990). Unfortunately, carminic acid is only slightly water-soluble.

For millennia, in the Old World, several kinds of insects were used for their dyes. One of these is Kermes *(Kermococcus vermilis*), which breeds on the kermes oak around the shores of the Mediterranean Sea and in parts of the Near East. Laccain acid, LAC, (*Lakshadia* spp.) is produced in India and Indochina (Thailand). The oriental kingdoms preferred purple. The source of this dye was the rare purpura shellfish (*Murex* spp. and *Purpura* spp.). *Purpura* dye is highly superior to any known red dye of botanical or insect origin, and is very attractive. Cochineal (*Dactylopius coccus* Costa) was mainly found in Mexico and Peru, where it was considered endemic.

In the course of history, in Europe the use of red dyes changed because of the extinction of the *Purpura* shellfish and the increasing demand for red dyes in the textile industry. *Purpura* was then replaced by *Kermes*. When the Spaniards landed in the New World (America), they were astonished to find a highly developed textile and dyeing industry. The cochineal dye, however, remained superior to the European Kermes (Baranyovits 1978). The Spaniards brought cochineal to the Old World where it replaced Kermes. The Spanish were secretive about the origin of the new dye, which had for a long time been considered to be of botanical origin, such as dried fruits or seeds.

In the nineteenth century artificial (and cheaper) dyes were developed for the expanding European textile industry. Peru and the Canary Islands continued cochineal production on a low scale. Other countries, such as Mexico, gave up growing cochineal insects. In the beginning of the 1970s, the demand for cochineal rose again owing to the prohibition of some chemical red dyes for the food and cosmetics industries, because of their carcinogenic effects. Cochineal is still, but rarely, used in the textile dyeing industry for certain fine silks. Peru and the Canary Islands supply the demand (Fundación Bolivia Exporta 1991).

Origin and evolution of cochineal
Mexico is considered the original centre of cochineal, however, without any satisfactory evidence. There are several species of cochineal insects. The cultivated cochineal insect is twice the size of wild species and takes about twice as long to complete its life cycle (Donkin 1977). The carminic acid content of the cultivated cochineal is much higher than that of the wild type. Another typical difference between the cultivated and wild species is the coating of fine, waxy powder on the cultivated cochineal and the cotton-like tomentum on the other species. The wild species can be found in a much larger geographical area with different climates, since they are more robust and resistant. They also attack more *Opuntia* sp. (De Lotto 1974). The cultivated cochineal insect is very delicate and sensitive to adverse weather conditions. This is why it depends so much on people for its reproduction and survival.
According to Santibañez (1990), the differences between wild and cultivated species should be attributed solely to the gradual and prolonged process of domestication. Without the help of mankind, the original cochineal insect would have been extinct already.

Taxonomic position
The real cochineal insect (*Dactylopius coccus* Costa) is a scale insect (more than 6,000 species are known) that belongs to the order of the Homoptera , suborder Sternorrhyncha, superfamily Coccidae (initially named Coccus) and family Dactylopiidae (Perez and Kosztarab 1992). It is closely related to the ill-famed mealy bug (*Pseudococcus* sp). Scale insects are one of the main pests in agriculture.

Biological cycle
Marin and Cisneros (1977) and Perez and Kosztarab (1992) give a complete characterisation of the various stages in both sexes, by means of sexual dimorphism and polymorphism in the initial stages. A summary of the biological cycle is presented in Figure 7.1. The development of the female is shown in a Box 7.1.

Plant/insect relationships
The species of the Dactylopiidae are plant pests. Cochineal insects can only be found on two genera of cacti: *Opuntia* and *Nopalea* (Perez and Kosztarab 1992). The main host plant for cochineal in pre-Columbian Mexico was *Coccus cacti* (Lineus), also known as *Opuntia cochenillifera* or *Nopalea cochenillifera*. Now cochineal is mainly produced on *Opuntia ficus-indica* M.
Although the cochineal insect's attack is normally weak, it must be considered as a plague. In Bolivia, the natural population levels of cochineal insects after artificial infestation were so high (when development conditions for cochineal were optimal: drought and in the shade), that the cactus pear plant tended to die. The requirements for optimal plant development are opposed to those for maximum cochineal production. When cochineal production is intended for a long period, a good balance must be found between cochineal production and plant maintenance. Cochineal productivity should be kept at optimal (not at maximum) levels.

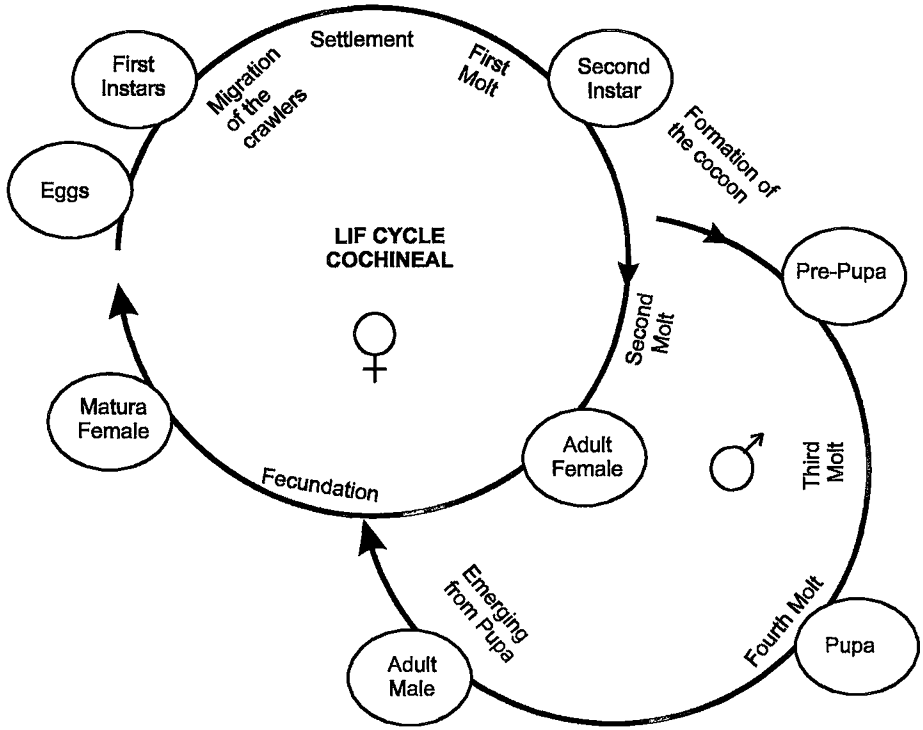


FIGURE 7.1 Outline of the biological cycle of cochineal females and males

BOX 7.1 Development of the female

The cochineal does not lay eggs in a heap under its body, as other coccids do. The eggs hatch immediately upon delivery. They are oval shaped, 0.72 x 0.33 mm and brightly red. The newly born *first instar* consists of a migratory (crawler) and settlement phase. In this phase the insect migrates upwards to the top of the host plant, in search of a place to settle. Attachment of the first instar occurs when, within two days, it inserts its stilet into the cladode to feed. The insects prefer to settle on the spine base or irregularities in the plant's surfaces. The crawlers appear to be negatively phototactic. From this point onward, the insect stays at the same place until its development is complete.

The first molt takes place 25-35 days after hatching. Within a day the insect is covered again with a powdery white wax that conceals the segmentation of the body. It does not display filaments or easily discernible characteristics. The second molt occurs 11-23 days after the first molt, and can be distinguished by the larger size of the insect.

The *adult female* is oval shaped, reddish-brown and shiny. It measures 2.81 x 1.87 mm. In a few hours, it is covered with powdery white wax and excretes droplets of a viscous liquid. Fecundation occurs a few days after molting, after which the female increases rapidly in size, up to 6.24 x 4.71 mm. This period of pre-oviposition takes from 30 to 68 days. The complete mature female, in full oviposition, has a slightly darker appearance compared to virgin females, which tend to appear white. The complete biological cycle of the female ranges from 102 to 181 days in traditional cochineal production zones. The ratio between the sexes varies according to temperature, and ranges from 5 to 20 females per male. Reproduction without fecundation has not been recorded. The female produces on average 425 eggs. Mature females detached from the cladode also release eggs for about 15 days if they are kept in the shade and at moderate temperatures.

It is assumed that cactus pear is the specific host plant for cochineal insects and that the immobile insects are perfectly adapted to their single food and water source, the fluid of the plant. But cochineal does not necessarily obtain all its food from the host plant. As most Homopteras do, carmine cochineal insects possibly have a symbiotic relationship with micro-organisms to complete their diet (Southwood 1973). It is doubtful that cochineal insects, like the majority of plant consuming insects, have a surplus diet (Southwood 1973). The precarious feeding relationship between insect and host plant must be considered especially when the nutrient levels and physiological aspects of the host plant are altered.

Cochineal insects do not attach themselves to very turgid cladodes (Tekelenburg 1995a). Previous dehydration of cladodes guarantees a much higher crawler settlement. The first Bolivian cochineal growers suggested that the high turgescence of the cladode does not allow cochineal insects to penetrate the stylets. Apparently, the interior pressure of the cladodes' liquid content is too high. This is confirmed by Southwood (1973), who stated that most sucking and sap feeding insects that feed on liquid from the phloem vessels of the plant are conditioned to suck under positive liquid pressure. The pharyngal muscles must therefore serve more as a selective constricting “tap” than as a "pump". High internal liquid pressure may damage this tap.

Production conditions

The production conditions for cochineal insects can be subdivided into abiotic (climatic) and biotic (host plant) factors. The abiotic factors are temperature, solar radiation, precipitation and relative humidity of the air. The biotic factors of cactus pear concern variety, turgidity, age, plant disease incidence and nutritional state of the cladode.

Temperatures and solar radiation

The cochineal insect thrives in most of the regions where cactus pear is produced. Temperatures during the day are optimal in the range from 24 to 28 °C (Flores and Tekelenburg 1995). The differences between day and night temperatures (up to 20 °C) do not have a negative effect on cochineal production. High temperatures, which exceed the mean daily temperature of 25 °C, accelerate the life cycle (until egg releasing) from 95 to 72 days. This result was obtained by a comparative experiment on the biological cycles of cochineal insects between altitudes from 3000 meters above sea level in the Cochabamba Interandean valleys and the tropical lowland of Santa Cruz (at 600 meter), carried out by PITC (The National Cactus Pear and Cochineal Research Project).

In the migrant stage, crawlers have the opportunity to look for the best growing conditions. From then on the cochineal insect does not move anymore. During the migratory stage a settlement preference is observed for shade or the least sunny places on the cladode and with maximum protection against rain and wind. The joints are mostly well populated on one side. In Bolivia cochineal populations are mostly found on cladodes facing east, south-east and south.

Precipitation and relative humidity of the air

Cochineal develops best without any precipitation. A shower generally washes the first instars, both crawlers and settled ones. This causes up to 98 percent of instar mortality in Bolivia. Due to heavy rainfall or hail, the complete population including all insect stages may be damaged. Adult females appear to be affected also by a simple shower. In such cases, the wax that protects the insects, is washed away. The Land Rehabilitation team observed that washing of wax causes lengthening of the biologic cycle.

Cactus pear infested with cochineal insects requires a higher water uptake for plant maintenance. However, cochineal production is only of interest when the yearly precipitation does not exceed 800 mm in combination with low rain intensity and a short yearly distribution pattern (Sanchez 1985). A long drought period is needed for optimal cochineal production. In regions where heavy rainfall or hail is common, cochineal production is not recommended. Cochineal requires dry air for optimal development (results of research on cochineal production in sheds by PITC). High relative humidity levels (> 90 percent) over a long period, accompanied by low temperatures, result in a prolonged pre-oviposition period. Adequate relative humidity of the air ranges from 45 to 85 percent (Tekelenburg 1995a).

Biotic factors of the host plant

Opuntia ficus-indica appears to be a good host plant in semi-arid zones. In Bolivia, the white variety of *O. ficus-indica* shows greater susceptibility (receptiveness) to the cochineal insect, and provides higher cochineal production per kg green weight (cladodes) in comparison to the yellow variety (Tekelenburg and Ortuño 1992). Unfortunately, cladode production of white cactus pear per hectare is lower than that of the yellow genotype. This means that the yellow genotype produces the highest amount of cochineal per hectare.

To avoid damage to the pharyngal muscle of the insect, the level of cladode turgidity should not be at its maximum. Cladodes that appeared to be in optimal condition to produce cochineal, namely thick, heavy, dark green cladodes showed less settlement of crawlers (Tekelenburg 1995a). The practical recommendations are (1) cactus pear should not be irrigated or fertilised with nitrogen just before cochineal infestation, and (2) the cactus should not be infested soon after a long period of rainfall (when the water content if the cladodes is at its highest).

Maximum cochineal production is obtained with cladodes between one and two years old. This means that production is determined by the number of new cladodes and not by the total number of cladodes per plant. Eighty-nine percent of the infestation occurs on one-year old cladodes, Ten percent takes place on two-year old cladodes and less than one percent on the older parts of the plant (Marin and Cisneros 1983). In addition, farmers confirmed that crawlers do not settle on immature, 3-7 months old cladodes.

Drought, low fertility levels of the soil and plant diseases may cause deficiencies in the insect's diet. Under such conditions cochineal insects cannot develop normally, especially when the crawler populations are large. Two cactus pear diseases (scab and blisters) and another scale insect have a negative impact on cochineal production. The production of cochineal decreases when the cladode surface is affected. When disease incidence is high (25-50 percent of the surface), the general health state of the cladode becomes affected to such an extent that cochineal does not develop at all (personal observation).

In the same way the nutritional state of the cladode is related to cochineal production. Yellow coloured cladodes are seldom infested with cochineal insects. Production loss in relation to disease incidence and nutritional state of the cladode were not quantified in the LRP studies.

Cochineal insect infestation

Natural infestation between plants is slow. It takes more than four years in the Central Valley of Cochabamba to cover a cactus pear garden of less than 0.25 ha following the natural cochineal insect infestation process. The cochineal insect is an almost immobile and non-aggressive invader and needs the help of people to expand. Once the insect is on the plant, the plant is generally covered entirely within a year and a half (in three generations) by natural infestation.

Therefore, special techniques were developed for infestation of cochineal insects on new plants (artificial infestation). When hail or heavy rain damages a cochineal insect population, these techniques are also carried out on already infested plants in order to increase insect densities. There are two proven methods to transport mature female cochineal insects to the plants to be inoculated; (1) with infested cladodes; and (2) with small bags made of tulle or another gauze or netting material containing an optimal number (about 20) of mature female insects.

Harvest

The harvest of cochineal insects consists of selecting mature females only. Small and immature cochineal insects have a lower carminic acid content and should not be mixed with mature females. Therefore, farmers have invented/adapted specific local harvest techniques. These consist of brushes made of local roots, wooden sticks or spoons. Care needs to be taken when handling the larvae as these are full of red liquid, and can easily break open. Harvesting is a very laborious job, since the insects have to be harvested one by one. Farmers (women and children) have developed the skill to do this work, but they cannot harvest more than 10 kg fresh cochineal per day in plantations with well-populated cochineal insect colonies. Generally, 3 kg of fresh cochineal per day is harvested in the first year (at low cochineal insect density) and 4.8 kg per day from the second year onward. Next, the cochineal should be properly dried in order to prevent putrefaction.

In Peru, production technology differs according to capital input and climatic conditions on the site. Cochineal insect collection on wild cactus pear populations can be found in the Andes valleys. This contrasts with cactus pear plantations in the Ayacucho (desert) valley that are planted especially for cochineal production and have a high plant density (5.000 to 20.000 plants per hectare). In order to produce cochineal in the interandean valleys of Cochabamba, a production technology was developed through adaptation and validation of the Peruvian technology.

In traditionally managed production systems, cochineal yields are low. The yield from a cactus pear stand as part of natural scrub, based on 800 plants per hectare, ranges from 21.5 to 33.3 kg first quality dry cochineal (Sanchez 1985). When cactus pear is managed in special production fields, based on 2500 plants per hectare, the yields are increased to 125-208 kg cochineal per hectare per year.

In Bolivia, the first yields of cochineal production were promising. From each plant between 250 and 400 fresh cochineal insects were harvested. However, farmers observed that cochineal yields declined after two production years. Farmers wanted to control this phenomenon. They began to look for a stable cochineal production system in combination with maintenance of the plant and additional production of other cactus pear uses, such as fruit and forage. Therefore, a maximum cochineal production was not aimed at and a rest period was proposed for the host plant after cochineal production. During this rest period the cactus pear plant was rejuvenated. It was, therefore, recommended to prune the plant periodically and stop cochineal production in order to allow the plant a recovery period.

7.3 Cactus pear plant productivity

In the case study area plant growth was recorded in more than 50 percent of the recently planted fields. Thousands of plants were evaluated during a period of five years. Each family wanted to count cladode and fruit budding and production on their own fields. They compared growth and production data between them at three points in time: September (early spring budding), December (late spring budding) and March (summer budding). It was found that the cactus pear plants did not produce cladodes in all three budding periods. Generally, two cladode flushes could be observed in one growing season if enough rain was available to start the first budding in September. When there was no intermediate drought stress until the rainy season, then a second flush occurred from January to March. With a second cladode flush in the previous year, the cladodes were too immature to bud in the early spring of the next season (although precipitation was adequate). These plants started budding in late spring. With late spring budding the second flush did not occur. This information formed the basis for the local production curve from planting to year 5. From then onwards plant growth was estimated with the help of growth data recorded in older plantations.

Without irrigation plant growth was slow and showed strong variation per year. During the years 1991-92 and 1992-93 precipitation levels in November and December were adequate. On average, three new cladodes per plant were obtained in newly planted fields. In years of drought (1993-94), plant growth stopped at 0.5 cladodes in the first growing season. The plant budding percentage ranged from 37 percent of the plants in years of low precipitation to 147 percent in seasons with good rains. In the latter case, plants produced two budding periods within one growing season.

In the second growing season production was between four and six cladodes per plant. The cladode production increased to 8.5 cladodes per plant in the third growing season, 10.5 in the fourth and 14.5 in the fifth year. However, on average, in total 27 cladodes per plant were reached after five growing seasons. This is lower than the sum of annual growth and indicates the number of cladodes that were pruned during plant development, with the objective of plant structure adjustment or removal of diseased parts.

One-year old cladodes weigh from 0.8 to 1.5 kg with an average of 1 kg. Cladodes can reach a final weight of 1.5 kg in three years, except for the main frame of the plant, the cladodes of which reach over 4 kg (these are generally not pruned, nor adequate for forage). An average cladode weight of 1 kg was used for calculations of forage production.

Five years after planting the cactus pear plantations in Huancarani produced 40 metric tons of fresh cladodes per ha per year, with a density of 2500 plants per ha, in rain-fed conditions. Irrigated fields produced more than 100 tons per ha per year. Irrigated fields (planted in the first planting campaign in 1989) reached 85 cladodes per plant in five growing seasons. Irrigation consisted of watering once or twice in the early spring budding period of August and September each year.

Fruit production

In Huancarani, fruit production was recorded for nearly all newly planted cactus pear fields (more than 25 fields and 1000 plants recorded) as well as for the only two 25 years old cactus pear fields (40 plants recorded). Fruit production on old plants was 47 fruits on average i.e. 5.9 kg fruit per plant. This worked out as 11.75 tons of fruit per hectare (2000 plants per ha in special fruit orchards), if cochineal is not produced simultaneously.

In new plantations, fruit production started already in the second year after planting (0.25 fruits per plant on average = 50 kg per hectare). Farmers observed that only 5 percent of the plants carry fruits in the year after planting. These plants did not show cladode budding. Production increased slowly to 3000 kg of cactus pear fruit in year 6.

Forage production

On new plantations with an integrated production objective, it took six to seven years before forage could be harvested systematically. Cladodes were pruned in the first years of growth, but the quantities did not reach high enough levels for cattle feeding. However, in the period of the first five years after planting, 2.9 tons of fresh cladodes per hectare were pruned i.e. 53 percent of the produced cladodes in this five-year period. Cattle feeding may start earlier if only forage production is projected.

7.4 Cochineal productivity and quality

Cochineal production factors
After having introduced the cochineal insect in Section 7.2, in this section the results of basic and applied research by the Land Rehabilitation Project will be discussed. The production factors of cochineal can be divided into abiotic (climatic) and biotic (host plant) factors. Here, the abiotic factors are temperature, solar radiation, precipitation and relative humidity of the air. The biotic factors of cactus pear concern variety, turgidity, age, plant disease incidence and the nutritional state of the cladodes.

Cochineal production in the field
In traditionally managed production systems the cochineal insect yields are low. The annual cochineal yield on a wild cactus pear stand as part of natural scrub, based on 800 plants per hectare, ranges from 21.5 to 33.3 kg first quality dry cochineal (Sanchez 1985). When cactus pear is managed in special production fields, based on 2500 plants per hectare, yields may increase 5 to 8 times.
Production levels, which were initially calculated for the Cochabamba Department, can also be reached in Huancarani, because of the good climatic conditions for cochineal production and the relatively high cactus pear growth. However, the first artificial infestations with cochineal were partly damaged by strong winds. Therefore, cochineal production is estimated lower in the first year of infestation. Natural infestations did not suffer from wind to the same extent. It was also observed that cochineal production in Huancarani leads to greater damage of the host plants than in other provinces.

In Bolivia, the first yields of cochineal production were promising. Farmers observed that the cochineal yields declined after two production years. Therefore, the Cactus pear and Cochineal Research Project started a study on production strategies based on methods of fast cochineal insect infestation and short periods of high (but not maximum) cochineal insect production.

In the first year, two cochineal harvests were obtained by applying 20 g of mature females divided over seven small tulle bags per plant. The first harvest, after three months, was between 15 and 25 g fresh cochineal, the second harvest (7-8 month after infestation) was between 45 and 75 g fresh cochineal per plant. This meant that the average production per year was between 40 and 67 kg dry and first class cochineal per hectare in the first year of infestation. In Huancarani cochineal production reached on average 95 g per plant in the first year on 25-year-old plants.

Because the production levels could not be maintained, production rhythms had to be established, which varied according to local conditions. Three to five years of continuous cochineal production are projected, depending on plant size, vigour and nutritional state, soil quality and precipitation. The highest production rhythm for small farmers was reached by PITC technology; a production cycle of five years with 110, 130, 130, 100 and 0 kg dry cochineal per year (based on a cochineal production objective only). With a more traditional

technology, a production rhythm of 50, 110, 130, and 0 kg was obtained (for the Huancarani case) considering a multipurpose cactus pear production objective.
The average yearly production of cochineal insects with PITC technology for small farmers is 119 kg per ha per year. The moderate production scenario for the Huancarani region resulted in 60 kg per ha per year.

Cochineal production in sheds
In order to prevent strong cochineal instar washing by rain or detachment by wind, protection techniques were developed. These were already practised by indigenous people of Mexico before and during the cochineal boom of the Spanish colonial period. Cut-off cladodes were placed in closed environments (sheds) to produce cochineal without climatic disturbance (Santibañez 1990; Portillo and Zamarripa 1992).
The PITC project and the Land Rehabilitation Program in Huancarani promoted the multipurpose use of cactus pear and its integration into the conventional farming system by which the development of cochineal production, separated from fruit and cladode production, would be an interesting option (Tekelenburg 1995a). In that way, competition between cactus pear fruit, forage and cochineal production could be avoided. The technology for cochineal production in sheds was developed for both medium-sized enterprises and small farmer production.
Several sheds, mainly constructed from locally available material, were tested. Cladodes were placed on separate wooden shelving units, and planted in nursery beds. However, productivity remained below expectation, in spite of the apparently favourable climatic conditions and the highest production levels on isolated cladodes ever seen. The white variety of the *O. ficus-indica* gave the best results: 15.1 g fresh cochineal per kg cladode, while the yellow variety produced 10.4 g fresh cochineal per kg cladode. The quality of the dried cochineal did not exceed 20 percent carminic acid and had to be sold as second quality. Cochineal production in sheds was, therefore, not recommended.

Cochineal quality
The quality standards for cochineal had not been changed for a long time. The Institute for Technical Research and Technical Norms (ITINTEC) in Peru set the regulations for cochineal quality for the internal and external market (ITINTEC 1987). Since 1985, however, the first class quality requirements of dry cochineal were raised from 17.5-19 percent carminic acid (CA) to 20-21 percent CA (Fundación Bolivia Exporta 1991). A preference market exists for cochineal of higher quality i.e. 22-23 percent CA. The water content of the dry cochineal must not exceed the maximum of 7 percent and the product must be clean, free of heavy metal contamination, and suitably packed.
Cochineal quality depends on production conditions and management practices in the field as well as on harvest and post-harvest management. The effects of several environmental and agricultural production factors in the field on cochineal quality were studied during the PITC research project. These factors were agroecological zones (from 700 to 2800 meters above sea level m.a.s.l.), harvest season, adaptation to local climatic conditions, cactus pear variety and influence of shade.
Different altitudes (m.a.s.l.) resulted in a range of four percent carminic acid. The underlying cause is the difference of environmental temperature that influences the length of the biological cycle. In the tropical lowland of Santa Cruz, a short biological cycle of the cochineal was recorded (71 days) and low cochineal quality. This means that rapid growth affects cochineal quality in a negative way. The other factors did not have any major effect (a maximum difference of two percent of carminic acid between treatments). Statistical

differences between treatments where not found for environmental and agricultural production factors except for the length of the biological cycle.

Cochineal production was successfully adapted in several provinces of Bolivia. Cochineal quality ranged from 18 to 24 percent CA. Often the reasons for these differences could not only be explained by the earlier mentioned environmental and agricultural factors. In Peru, without knowing insect age, size and quality, farmers collect mature as well as immature cochineal insects (Bustamante 1985), which could be the main reason for low cochineal quality.

From literature, it was suggested that the final quality of the cochineal could be influenced by post-harvest techniques. Post-harvest management consists of killing the cochineal insect, drying, cleaning of the product, and classification by size. The killing and drying processes are not always clearly distinguished (Arias 1988; Bustamante 1985). Full oviposition of the female insect was considered negative (Montes de Oca 1985). According to Arias (1988) three negative factors lower the quality of the cochineal: solar radiation, high temperatures and chemical agents.

The following hypothesis was formulated from literature: adequate post-harvest management (techniques) results in higher and more stable cochineal quality than improvement of production conditions in the field. Therefore, PITC started research on cochineal quality in relation to post-harvest management (Tekelenburg 1995b). The objective of this study was to identify (a)biotic factors that guarantee high and stable cochineal quality.

The following variables were studied:

- *Degree of oviposition*
  Female insects were allowed to deposit eggs for periods of 2, 9, 15, and 24 days. The quality after killing and drying was measured and recorded.
- *Temperatures during drying (20, 30, 40 and 50 °C)*
- *Solar radiation during drying*
  The treatments received the following quantities of light: 434.2, 326.3, 277.4, 154.3, 102.6, 70.7, 44.6 and 0 W per m^2 of average solar radiation. The specific radiation levels were obtained by covering trays (filled with cochineal) with different sizes of black mesh.
- *Cochineal insect size*
  Five samples were obtained by using three meshes: slightly larger than 7; between 7 and 10; between 10 and 14 ; smaller than 14; and an unsifted sample.
  The mesh sizes were:
  - mesh 7: 49 (7 x 7) holes per square inch;
  - mesh 10: 100 (10 x 10) holes per square inch;
  - mesh 14: 196 (14 x 14) holes per square inch.

Results of experimental research

The oviposition degree appeared to be the key to high cochineal quality. Quality increased with an increase in the number of oviposition days (Figure 7.2). Immediately after the harvest (without any oviposition) cochineal quality was low but increased rapidly within a week of oviposition and was levelled and nearly constant after 20 days. The quality curve can be explained best by the similar curve (on the timetable) for total number of eggs and crawlers born (Marin and Cisneros 1977). When more eggs were released, the cochineal insects were of higher quality. To guarantee a cochineal quality of 22 percent CA, at least 12 oviposition days are recommended.

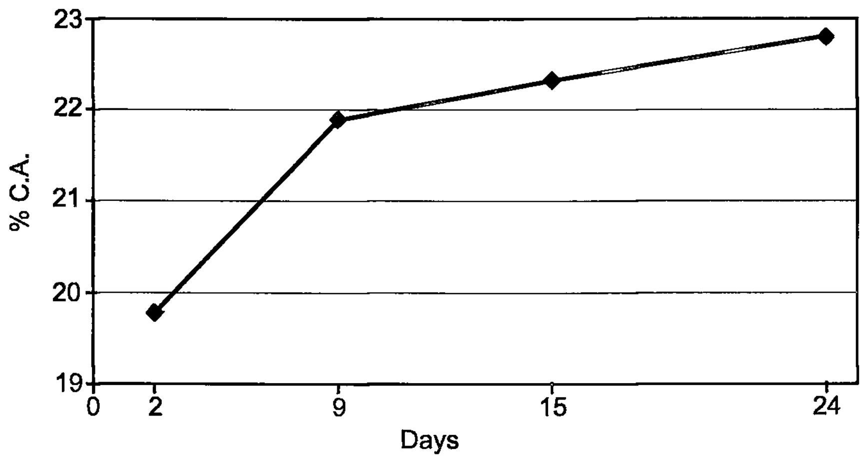


FIGURE 7.2 **The effect of oviposition on cochineal quality (percentage of carminic acid)**

During the drying process, temperature and solar radiation did not have an effect on quality. Cochineal drying can therefore be carried out in the sun as well as in drying ovens. Solar dryers with moderate temperatures (50-60 °C) can also be used. The non-purified dye in cochineal insects appeared to be as stable to heating and solar radiation as the chemical extract of carminic acid (Branen et al. 1990).

A large sample of freshly harvested cochineal was put in the shade, by which a large oviposition period was obtained. All sub-samples showed, therefore, relatively high qualities. This sample was classified by size through sifting with meshes 7, 10 and 14. Five portions, including the original sample, were thus obtained. Carminic acid content and final weight of the sample and sifted portions were evaluated (Table 7.1).

TABLE 7.1 **Quality and relative weight of a dry cochineal portion classified by size (sifted with meshes 7,10, and 14)**

MESH NUMBER	*RELATIVE WEIGHT (%)*	*CARMINIC ACID (%)*
ABOVE 7	13	24.4
7 - 10	57	26.0
10-14	10	26.0
UNDER 14	20	9.1
UNSIFTED SAMPLE	100	22.4

The quality of dried cochineal varies according to size. As shown in Table 7.1, the largest insects (above mesh number 7) did not have the highest carminic acid content. This can be explained by a higher percentage of large but immature insects in the portion. These insects already contained eggs but did not release them. They could maintain the largest cochineal size because they did not loose extra weight by oviposition. The highest cochineal quality was obtained between meshes 7 and 14. These consisted of mature insects, which had lost extra weight and size because of egg releasing. The quality of the small insects that passed mesh 14 dropped to 9.1 percent carminic acid. Eighty percent of the unsifted sample was first-class cochineal for export. This study confirmed that cochineal must be sifted with mesh 14 before selling.

The farmers analysed these results, which were obtained under laboratory conditions at the Cochabamba State University. They translated the results into post-harvest management practices. Before any final conclusion could be drawn, different practices needed to be tested on-farm. The treatments consisted of combinations of killing methods with mesh numbers for sifting. The latter experiments were part of adapted research, which tried to improve the effectiveness of agricultural practices.

TABLE 7.2 Effect of killing methods on cochineal quality (percentage carminic acid)

Killing method	*Characteristics*	*Quality (% CA)*
Shade	25 days, 20 ° C	26.04
Refrigeration	3 days, 8 ° C	24.89
Immersion in hexane	10 minutes, 20 ° C	22.05
Suffocation in plastic bag	2 days, 40 ° C	21.38
Sunlight	3 days, 25-30 ° C	21.33
Heat shock	3 hours, 75 ° C	21.12
Warm, nearly boiling water	2 minutes, 90 ° C	20.75
Spraying with gasoline	5 minutes, 20 ° C	20.39
Suffocation in steam	5 minutes, 90 ° C	20.24
Freezing	3 days, -10 ° C	18.18

Ten ways of killing cochineal insects were studied. Killing is needed to guarantee rapid drying and to avoid putrefaction. The cochineal quality (expressed in percentages of carminic acid) differed according to the effectiveness of the killing method. Two treatments (shade and refrigeration) were unsuccessful in killing the cochineal insects. They resulted in high oviposition and thus high quality levels. The obtained range of almost 8 percent CA between treatments reconfirmed that the practice of killing cochineal insects is not an interesting practice when highest quality is looked for. Natural death in the shade resulted in 26.04 percent CA , while the frozen cochineal contained only 18.18 CA, which is 30 percent less than the optimum result (see Table 7.2). Spraying with hexane is accepted, because it does not contaminate the natural product. The use of gasoline is not permitted.

The final dry weights of the samples were compared with cochineal quality (obtained using the various killing methods). Bad killing methods such as shade and refrigeration showed low final weights, because the small eggs were sifted out in the procedure for first class cochineal. When these non-killing methods are applied, thirty percent more fresh cochineal is needed in order to reach the same final weight of first class cochineal.

Cochineal size below mesh 14 showed a cochineal quality of below 10% carminic acid. So, cochineal classification by size is required. Two classification moments can be determined:
(1) classification carried out before drying (to sift out immature insects) and (2) after drying (to sift out released eggs). The final result of the on-farm experiments was a general recommendation. In order to obtain minimum quality standards for export (21 percent CA) post-harvest management techniques must conform to the following steps:

- Selected collection of mature females during harvest;
- Manual cleaning of major impurities;
- Optional sifting before drying the cochineal with mesh 10 (100 holes per square inch);
- Storage of ovipositing cochineal insects in the shade, at low load densities, for at least 12 days;
- Rapid drying in solar dryers (200 micron agrofilm plastic foil or in the sun);
- Second sifting after drying with mesh 14 (196 holes per square inch);
- Final check for impurities;
- Storage in bags made of jute or other plant fibers.

These practical recommendations were developed by and for the farmers of the Andean valleys in Bolivia. The technology does not require large investment. Local materials may be used for infrastructure to store cochineal insects in sheds while releasing eggs, to dry cochineal in the sun, and to protect it from rain, dust and damage by animals during post-harvest management.
Post-harvest management must be considered as the major factor for obtaining good quality cochineal. Export quality standards can be met with appropriate handling. Even higher qualities can be obtained if desired by the market. Unfortunately, increase in quality also results in considerable weight loss. A system of market pricing based on quality and calculated to account for the accompanying weight loss, is required.

7.5 Conclusions

Farmers highly appreciated being involved in on-farm research. They observed growth, diseases and cochineal infestation. They could also follow Huancarani experiments on cochineal production under protected conditions. Directly after having presented the results, the obtained differences between farmers and between communities were discussed. Farmers became conscious of the fact that cactus pear and cochineal insects can grow very well in their community and that gave the platform more confidence to continue. The creativity of the farmers was stimulated by the research. By themselves they defined new research studies in order to complement their lack of knowledge.

However, final decision-making was not improved by the research results. Farmers observed that their knowledge, although very important, was highly fragmented and did not provide an overview on the integrated cactus pear and cochineal production. They required methodology in which all their knowledge can be integrated into one production system. From such a production system the output could then be assessed.

In the next chapter the development of the design of a satisfactory cactus pear and cochineal production system will be presented, which will be integrated into actual farming in the sub-tropical agroecozone of Huancarani.

Chapter 8

The integrated cactus pear and cochineal design

The farmers in Huancarani carried out research in order to improve their knowledge of all relevant aspects of cactus and cochineal production. The previous chapter showed that scientists were contracted to do laboratory research and that farmers themselves carried out on-farm research. Many important production techniques were discovered. However, these discoveries were the result of isolated research trials. Farmers needed to put together new knowledge into an integrated production system.

This chapter deals with the development process and final results of the design of a satisfactory cactus pear and cochineal production system in which the results of research are integrated. Such a design may then be evaluated for development criteria and eventually contribute to the process of final decision-making.
In the following, first, production will be assessed and labour requirements calculated. Both production and labour will be integrated into a cost-benefit model, which then will be optimised. Finally, the design will be presented that appeared to be the most satisfactory according to the Huancarani farmers.

8.1 Assessment of plant and insect production

Cactus pear production
The projection of integrated production of cochineal, fruit and forage production started with an estimation of cactus pear growth. The production of these three main uses of cactus pear cannot be calculated individually. Cochineal production seriously affects other produce. Therefore, an integrated production scenario was looked for, based on optimal (instead of maximum) production of cochineal, forage and fruit as well as a production rotation scheme at field level (with the aim of sustainability).

Figure 8.1 shows the cactus pear plant size from planting to year 13 (13 years were needed in order to calculate profit against investments: Internal Rate of Return). Recording growth and calculating the average growth for the first five years after planting was carried out by the

LRP. From year 6 onward plant growth was adjusted because of forage production as well as rejuvenation pruning, as both fruit and cochineal production exhaust the production of cladodes. From the fifth year onwards cochineal production was planned. Especially after a period of high cochineal production, a general pruning is required in order to rejuvenate the plant and reactivate plant growth (at the end of year 7). Pruning was planned for after three years of cochineal harvest. The best period for pruning is before the start of the rainy season. The next pruning is planned for year 11 and so on.

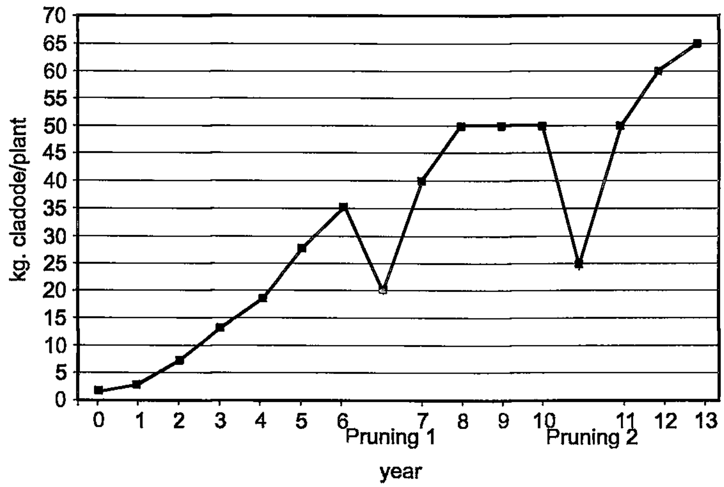


FIGURE 8.1 Cactus pear plant size in Huancarani

Fruit production increases in the first years and than decrease again as a consequence of cochineal production and severe pruning. The plant-recovering period allows a new fruit production period. When fruit is combined with cochineal production, the mean yearly fruit production will be 750 kg fresh fruit per hectare on average.
From year 7 the average yearly cladode production for cattle feeding was calculated at 3.12 tons dry weight per hectare (15.6 kg fresh cladodes per plant and 2000 plants per ha) (see Figure 8.2).
The rejuvenate pruning produces almost three times more forage than a normal production year. Farmers do not like such a high fluctuating production rhythm because of possible problems of labour shortage. Therefore, farmers looked for a strategy to stabilise cladode production in the course of years. It was proposed to divide the plantation into three or four areas and implement a pruning rotation scheme.

In addition to cactus pear cladodes, undergrowth of the natural vegetation became available for forage. On average, the projected forage production on 75 ha of cactus pear plantations was 138 tons of Total Digestible Nutrients (TDN) per year. It was composed of 234 tons of dry weight cactus pear cladodes (59 % TDN; NN 1976) and 60 tons of dry weight natural vegetation of poor quality (TDN = 35 %; NN 1976).

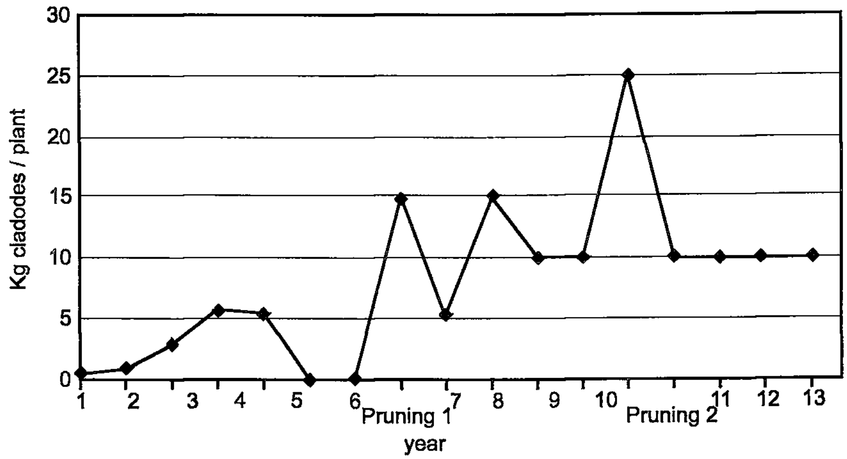


FIGURE 8.2 Cactus pear forage production on cactus pear fields of Huancarani (1 ha)

Cochineal production

Cochineal production cannot be maintained over many years. This means that production should be limited to the period of cactus pear plant growth, as well as to that of the planned fruit and forage production.

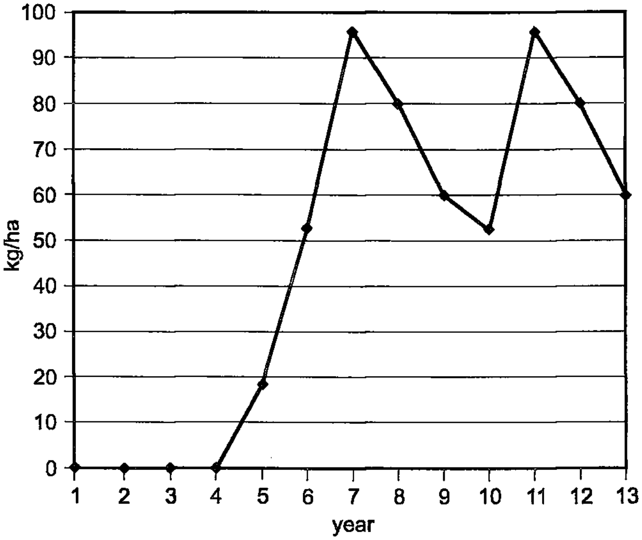


FIGURE 8.3 Projection of yearly cochineal production for Huancarani (kg dry and first class cochineal per hectare)

For Huancarani, a four-year production rhythm of 50, 110, 130 and 0 kg of dry and first class cochineal per year per hectare was proposed. This was a small adaptation to the prototype design of the Cochabamba integrated cactus pear production system. The maximum production level of 130 kg per hectare (PITC projection for the Cochabamba region) could be maintained, but the length of the production rhythm was shortened from five to four years. After a production cycle of cochineal, the cactus pear plant requires a recovery period of one and a half year (including two rainy seasons) before cochineal can be infested again. Such a production rhythm has one strong negative side effect: it results in a high variation in production and requires labour and family income. This means that the proposed rotation scheme of three years for forage production is also essential for stabilising cochineal yields over the years. With this rotation scheme, cochineal production ranges between 53 and 91 kg per year (see Figure 8.3).

Calculations for cattle feeding

In order to complete the data for scenario optimisation, further modelling of cattle production was required. Because local data were not available, calculations were based on assumptions found in literature.

In the short rainy season cactus pear cannot be fed to cattle. When, in the dry period, other palatable forage is not available, cactus pear feeding is an interesting option. We estimated a period of maximum 270 days for complementary feeding with cactus pear (the length of the dry season). Further calculations were based on this period. The specific farmers' objective for feeding cactus pear in addition to free pasturing in the subtropical agroecozone was maintenance of animal weight during the dry period.

For a period of 270 days and for 702 cows living in the zone, 611 tons of TDN (Total Digestible Nutrients) were needed, based on the theoretical energy requirement for maintenance (Em). The energy demand to maintain the total number of animals was obtained by:

- Multiplication of the number of cows in the zone by the average weight of the animals (300 kg);
- The energy needed for maintenance per kg weight (32 g per kg);
- A correction factor for activity (1.4: free pasturing on land with steep slopes and long distances to watering places). The formula is then:

Requirement of daily TDN = number of cows * Em * cattle weight$^{0.75}$ * Activity Index. (Oomen and Veluw 1994).

The quantity of forage produced on 75 ha of cactus pear (138 tons TDN) consisted of 23 percent of the required TDN for the maintenance of 702 cows during the defined period.

The total quantity of crude protein (CP) required for cattle maintenance in the defined period is 76.4 tons. This is calculated as follows:

Tm (maintenance) = 5.6 g CP kg^{-1} cattle weight * cattle weight$^{0.75}$

(Oomen and Veluw 1994).

The cactus pear fields produce 234 tons of cladodes (2 percent protein of dry weight; cochineal production decreases protein content) and 60 tons of natural vegetation (8% protein of dry weight). The total quantity of produced crude protein is 9.5 tons CP. This means that cactus pear fields produce 12% of the required crude protein for cattle in the dry period.

Cattle production
Farmers themselves estimated the (very low) production of cattle at that time as ten cows per year from 100 animals grazing in the subtropical agroecozone. Under the actual grazing conditions cattle lose weight in the dry period. It is assumed that cactus pear forage is given as a complement to pasturing and that cattle maintain the traditional uptake from degraded pasturelands when cactus pear is fed. When the daily diet is not optimal, and this is the case in Huancarani, cactus pear forage cannot substitute grazing (Enserink 1978). Therefore, 138 tons TDN of the cactus pear fields can be considered as extra forage that contributes to weight maintenance (prevention of negative growth). Data on seasonal forage uptake on degraded pastureland in relation to cattle growth are not available. Therefore, cattle maintenance must be estimated by the extra uptake of cactus pear forage.
The energy requirement for maintenance of one animal in the dry season is between 3500 and 4500 (3765) kg for a five-year period. This was calculated by a yearly increasing Em (28-32 g TDN per kg) and a weight gain of about 50 kg per year. When the total quantity of TDN required for cattle growth is included, 625 kg TDN (250 kg growth * 2.5 kg TDN on average per kg growth), the total energy requirement for the production of one cow does not exceed 5 tons TDN per cow.
The yearly TDN production of 75 ha cactus pear (138 tons of cladodes and natural vegetation) can therefore feed at least 25 cows until fit for slaughter.

8.2 People involved

One of the most important constraints in the production of cochineal has to do with the economic welfare level of the rural inhabitants. Successful cochineal production needs the supply of cheap labour. At present, cochineal is definitely not "red gold" as it was in pre-Columbian times and during Spanish colonisation. Today, cochineal is produced in marginal regions, where other opportunities for agricultural production or other income generating activities are lacking.

Cochineal insect production requires high labour input. Especially harvesting is a laborious job, as mature insects have to be collected one by one. During the rainy summer cochineal reproduction is low and cochineal is generally not harvested between January and March. In the dry season cochineal is harvested at least once a month. The major harvests take place in April, July-August and November.

In Bolivia, women farmers are traditionally responsible for cactus pear fruit production and sale. The marketing of cactus pear fruit and exchange for other agricultural produce sustain the household from December to March. Another traditional task for women is the care of sheep and goats and thus, the management of the forage stock. Management of cochineal harvest and sale in the project area will be the responsibility of women as it has always been in traditional production zones in Peru. The women organise the harvest and include children in peak times.

Cochineal production may have an impact on the labour availability for traditional agriculture as well as on the division of labour between men and women. The success of cochineal production depends on the availability of women. Therefore, cochineal (Who must be trained?), as well as production and sale (Who will work?) are gender sensitive issues.

The cactus pear and cochineal research project (PITC) and the NGO TUKUYPAJ decided to study the compatibility of cochineal introduction with traditional labour by women (Rodriguez and Schoute 1992). Two communities were compared: one that had recently introduced the production of cactus pear and another that was a traditional cactus pear fruit production zone where the fruit was grown for the market. Cochineal was introduced in both communities.

Men dominated the infestation activity of the LRP as training for growing the new crop was highly directed at them. Women were not adequately informed about the new crop. However, in the new cactus pear production zone women farmers showed their curiosity. After four years, the women organised production, harvested cochineal and sold it in the provincial town. In contrast, the women from traditional cactus pear fruit production zones were opposed to cochineal production, because it competed with their traditional fruit sale and forage management.
When the men did not take care of their cochineal harvest, cactus pear plantation "suffered" from the "plague", while the women began to show an interest in the crop, mostly in order to protect traditional fruit production. The women emphasised the need for new cactus pear fields in order to avoid competition between fruit and cochineal production.

The buying up of cochineal should be organised as close to the homestead as possible, i.e. preferably at a nearby weekly market. It was concluded that women should be further activated to participate in training, production and selling and that specific attention should be given to any restrictions to women participation. Since women make longer working days than men, have children, look after their family and carry out daily livestock husbandry tasks, it was unlikely that they would be able to take care of cochineal production at a scale of more than 0,5 ha per family.

Labour requirements
The integrated cactus pear and cochineal production requires labour for planting, replanting drop out, maintenance and protection of the field, harvest of fruits, management of cladodes, cochineal infestation and harvest, and once every four years a severe cactus pear pruning. Maintenance practices in the field consist of cutting spiny brush, weeding some root propagated weeds, repair of field protection, digging plant infiltration basins and plant protection activities. Management of cladodes consists of pruning plants for stimulation of upward growth and for harvesting forage. As already discussed earlier in this section (plant and insect productivity), production is rotated and activities are realised in part of the field. Table 8.1 shows a summary of the activities in a 13-year period.

TABLE 8.1 Production activities in one hectare of cactus pear and cochineal production for a 13-year period. The section of the field that needs to be worked is indicated with percentage of planted area.

(%)

Years	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Installation	100												
Planting fall out		100											
Maintenance		100	100	100	100	100	100	100	100	100	100	100	100
Fruit harvest		100	100	100	100	100	67	33	67	67	67	33	67
Cladode production			100	100	100	100	67	33	67	67	67	33	67
Cochineal infestation					33	33	33		33	33	33		33
Cochineal harvest					33	67	100	67	67	67	100	67	67
Severe pruning							33	33	33		33	33	33

Cactus pear production does not require high labour input, except for planting. The LRP calculated that 80 working days per hectare are required for the planting year. These and the following data were obtained from case study measurements in five experimental fields of trained and skilled farmers. Labour in the first year includes cleaning (eight days) and protecting the field (26 days), preparation of the soil (16 days), transport of cladodes (six days), planting (ten days), soil conservation measurements, for example water infiltration basins per plant (ten days) and plant protection (four days).

In the second year labour requirement drops to 13 working days per hectare for cactus pear maintenance. This consists of weeding (seven days), plant protection i.e., pruning of infested cladodes and destroying ants (three days), field protection (one day) and replanting drop out (two days). Collection of 50 kg cactus pear fruit needs less than one working day.

From the third year onward, harvests require one working day for each 100 kg of fruit. The cladode harvest of plants for forage needs one and a half day per 1000 kg.

In year 5 cochineal infestations can be started. It was recommended to infest initially one third of the field. Infestation requires 15 working days per ha. When the cochineal harvest starts, the labour requirement increases rapidly. An average of 4.8 kg fresh cochineal can be collected per day when infestation levels are good. With adequate post-harvest management one kg dry, first quality dry cochineal is obtained from three kg fresh cochineal. In the first production year (with low infestation levels) only one kilogram of dry cochineal can be harvested per day.

After three years of cochineal production, the cactus pear plants are pruned. Pruning takes 24 working days per hectare. From pruning, a large quantity of forage is obtained. This makes pruning the essential part of forage collection.

8.3 Design of the integrated cactus pear productions

Production scenarios for an integrated cactus pear and cochineal production system were built. Some important variables were projected or assessed with formulas from literature, while others were discovered by own research of the LRP (see previous sections). Scenario building did not immediately result in the one and only "best" production system. Systems were proposed using a different technology according to the different production conditions (quality of natural resources) and because of access to capital and production technology (socio-economic welfare level of farmers).
It could not be known beforehand how production scenarios would score on pre-established evaluation parameters (farm innovation criteria). Therefore screening was needed to find the optimal production technology.
In the first place, production conditions and technology were defined. Among the most important aspects, the following should be mentioned:
- Quality of land;
- Labour availability;
- Access to capital;
- Plant density and juvenile stage of cactus pear;
- Cochineal infestation method;
- Cochineal rotation scheme;
- Level and kind of investments;
- Multipurpose use of cactus pear;
- Estimated cochineal quality, etc.

The cactus pear and cochineal research project (PITC) defined three basic scenarios for production conditions of campesino farms and three for middle and large agricultural enterprises. That resulted in large differences in technology (See Table 8.2).

TABLE 8.2 Comparison of technology packages for six scenarios of cochineal production

Definition of package	*Farmer 1 (traditional)*	*Farmer 2 (traditional)*	*Farmer 3 (PITC)*	*Enterprise 1 (meca-nized)*	*Enterprise 2 (without mech.)*	*Enterprise 3 (in shed)*
Old cactus pear garden (ha)	0	0,1 ha	0	0	0	0
Projected new plantations (ha)	0,5	0,5	1,0	30	30	14
Plant density/ha	1660	1660	2500	2500	5000	5000
% of area with cochineal	100%	100%	67%	77%	77%	93%
Plant care	Traditional	Traditional	Medium	Medium	Medium	High
Erosion control	Yes	Yes	Yes	No	Yes	No
Juvenile stage	4 years	2-4 years	4 years	3 years	3 years	2 years
Protected infestation technology	No	No	Yes	Yes	Yes	No
Integrated cactus pear use	Yes	Yes	Yes	No	No	No
Production risks	10%	10%	7%	5%	5%	3%

In relation to campesino production, traditional management (0.5 ha) and a medium technology package for cochineal growing (1 ha) was considered. Traditional management was further subdivided into a case with 1000 m^3 old cactus pear garden and an other without grown-up cactus pear gardens.

For agricultural enterprises two types were designed based on 30 ha of cochineal growing, one without mechanisation. A third scenario for "medium" enterprises was formulated with 14 ha of high-density plantations and cochineal growing on isolated cladodes in sheds.

When the technology was defined, specific production rhythms were calculated for cactus pear: forage, fruit and cochineal harvests. Productivity levels of cochineal were calculated for the six technology packages (see Table 8.3).

TABLE 8.3: Cochineal productivity compared for six technology packages of cactus pear and cochineal production systems (for definition of packages, see Table 7.2)

(in kg dry, first class cochineal per hectare)

Definition of package	*Farmer 1 (traditional)*	*Farmer 2 (traditional)*	*Farmer 3 (PITC)*	*Enterprise 1 (meca-nized)*	*Enterprise 2 (without mech.)*	*Enterprise 3 (in shed)*
Total production in 13 years	583	623	1192	1512	1503	2787
Mean production from first infestation	58	49	119	137	137	253

The next step consisted of determination of the labour requirements (and production costs) projected for the next 13 years. The following activities were included:
- Planting of cactus pear fields;
- Maintenance of the plots;
- Replantation / densification of the cactus pear plantation;
- Cochineal infestation;
- Cochineal harvest and post-harvest management;
- Fruit harvest and forage collection;
- Pruning for rejuvenation.

Total and yearly requirements of labour for each of the six production systems were calculated (see Table 8.4).

TABLE 8.4 Labour requirements compared for six technology packages of cactus pear production systems (for definition of production systems see Table 7.2) (labour days)

Definition of package *Labour requirements*	*Farmer 1* *(traditional)*	*Farmer 2* *(traditional)*	*Farmer 3* *(PITC)*	*Enterprise 1* *(mecanized)*	*Enterprise 2* *(without mech.)*	*Enterprise 3* *(in shed)*
Total 13 years	586	727	1784	53.395	58.635	44.481
Mean per year	45	56	137	4.107	4.510	3.422
Mean per year and ha	90	93	137	137	150	244
Efficiency (kg produce /day labour)	0,50	0,51	0,67	0,86	0,77	0,88

Labour investment in resource-poor farmer production systems is relatively low. These investments must be low in order to avoid competition from traditional agricultural produce for family consumption. However, labour efficiency is also low. That makes it difficult for the campesino producers to compete with agricultural enterprises. These large enterprises are faced by another problem though: how to guarantee the required cheap labour force in the area.

When labour calculations were finished and costs calculated, the income could be estimated. Table 8.5 shows some economic and financial variables calculated for the six scenarios.

Technology based on low investments presented high internal rates of return and low break even points (production costs of one kg cochineal).

TABLE 8.5 Comparison of economic and financial variables of 6 technology packages (see for descriptions table 8.2) of cactus pear ad cochineal production systems. ($ per hectare)

Definition of package	*Farmer 1* *(traditional)*	*Farmer 2* *(traditional)*	*Farmer 3* *(PITC)*	*Enterprise 1* *(mecanized)*	*Enterprise 2* *(without mech.)*	*Enterprise 3* *(in shed)*
Total system Investment (US$/ha)	2,414	2,145	8,156	146,500	82,000	156,500
Total labour 13 years (US$/ha)	586	727	1784	53.395	58.635	44.481
External capital/ha (US$/ha)	1,711	2,012	5,336	23,742	24,149	46,224
Mean Net income/ ha year (US$/ha)	634	648	1424	516	472	731
IRR (%)	41	53	60	7	9	5
Break even point for price of cochineal ($/kg)	5.86	5.38	4.48	13.72	15.51	14.97

The Huancarani scenario

The Huancarani scenario needed further adaptation to the presented technology packages. This adaptation resulted in an average labour requirement of 104 working days per year per hectare. The labour input was much higher than in other scenarios, because of the integrated production focus. The yearly labour requirements for one hectare of integrated cactus pear production in Huancarani increases rapidly when cochineal is produced. Between 130 and 160 working days are required for optimal cactus pear and cochineal production. This number is generally not available at family level. Therefore, PITC (Fundación Bolivia Exporta 1992) recommended producing cochineal to a maximum of 0.5 hectare per family.

For the Huancarani scenario, cochineal production was projected to be higher than traditional technology but lower when using PITC technology. 73 kg first class dry cochineal per hectare was projected for the case study area. However, the labour input of each of the farmer-campesino scenarios, prepared by the PITC project, remained still too high and investment levels had to be lowered for the Huancarani case.

An external investment of 1332 US $ was needed for a 13-year period of one hectare of cactus pear and cochineal production. The Huancarani production scenario is nearly 30% cheaper (less external investment) than the lowest investment of the other initial six scenarios of the PITC project. Huancarani farmers emphasised the low budget and low risk strategies. The external capital requirements will be less than 20 dollars in most of the years, except for the first year, when investments of 440 dollars for cactus pear planting, 295 and 191 dollar for cochineal infestation in year 5 and 13 respectively, and 298 dollar for building a night stable for cattle in the seventh year are required.

Income depends strongly on the market prices of cactus pear fruit, export prices of cochineal and the estimated value of cladodes for forage. The average price of cactus pear fruit was calculated at 0.05 US $ per kg (7-9 fruits). During the research period, 1991-1994, export prices of cochineal were among the lowest paid in the last 20 years i.e. 12 dollars per dry kg, first quality. In 1995, cochineal prices reached 30 dollar per kg but, according to important cochineal exporters, this situation was not likely to last long (Fundación Bolivia Exporta 1991 and a personal comment of Antonio Bustamante in November 1995). A cost/benefit analysis was, therefore carried out at the minimum price of 10 dollars. Fortunately, Bustamante was wrong. Cochineal was sold at high prices for a relatively long period making a great economic impact.

The value of cactus pear forage was calculated in relation to the average price of cattle (150 US $) in relation to the total quantity of forage consumed by cattle. On one hectare in a 7-year period (year 7 to 13) 8.35 tons of TDN of cactus pear may be produced. One cow needs five tons of TDN. For this period the total cattle production on one hectare will then be 1.67 cows. According to the low prices of cattle the value of one ton of fresh cactus pear forage should be less than one dollar.

Fruit production was included in the economic calculations from the second year, cochineal production from the fifth year and forage production from the seventh year. For a period of 13 years, the income from one hectare integrated cactus pear and cochineal production was estimated at 592 dollars for fruit production, 218 dollars for forage and 5985 dollars for cochineal. Figure 8.4 shows the yearly gross income and the total costs, which include labour at 1.56 dollars per day.

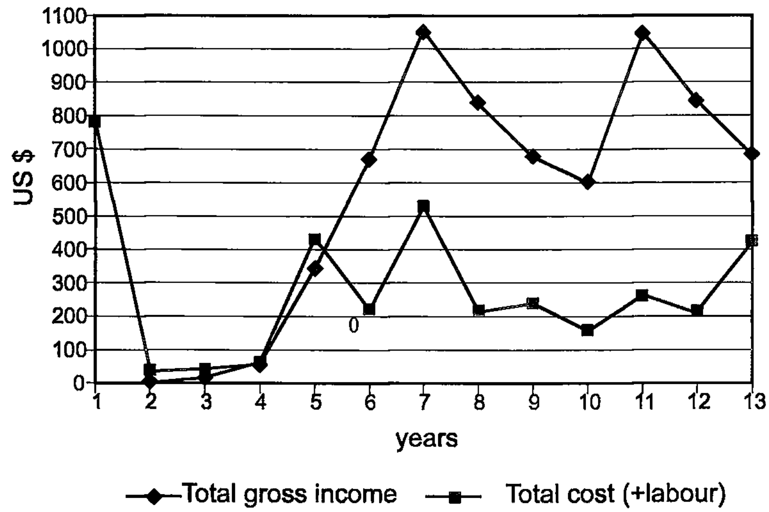


FIGURE 8.4 Gross income and total costs of integrated cactus pear and cochineal production, Huancarani, Bolivia

A cost-benefit analysis of the integrated cactus pear and cochineal production was carried out for a 13-year period and included fruit, forage and cochineal production. For the Huancarani case, cash flow turned positive from year 6, when cochineal production compensated the investments of that year. In year 7 earnings reached the level to repay the initially invested money. From year 7 the cash flow was between 434 and 779 US $ per hectare. The Internal Rate of Return (IRR) was 21 percent, the Benefit Cost Ratio 1.52 (Present Net Value 8 percent).

The cost/benefit analysis was carried out based on three main assumptions: (1) that production levels were properly estimated, (2) that the production costs of 1992-1993 would not change, and (3) that the prices of produce would remain stable. However, such assumptions are subject to market uncertainties, especially in the case of cochineal. As mentioned earlier, the cochineal price was at its lowest during the Land Rehabilitation Program (1989-1994) but increased in 1995 to the second highest level ever paid. When productivity, production costs or the export price of cochineal were to change, the Internal Rate of Return (IRR) may become lower than the rate of interest.

In order to assess the safety margins of the cochineal production, an economic sensibility analysis was carried out on the earlier mentioned three parameters. It calculated the Internal Rate of Return for each combination of parameters. Production levels with an increment and a reduction of 20 percent were analysed. In the same way, production costs were increased and reduced by 20 percent. The range of cochineal prices to be calculated was established at between 5 and 30 US $ (see Figure 8.5).
This analysis showed that cochineal production is profitable from 7 to 8 dollars per kg cochineal paid to the farmers. In the case of a 20% reduction of cochineal production, it still remains profitable (IRR = 19%) when the minimum cochineal price is 15 dollars. When the production costs are increased by 20%, an IRR of 21% is reached with a minimum price of 15 dollars per kg cochineal.

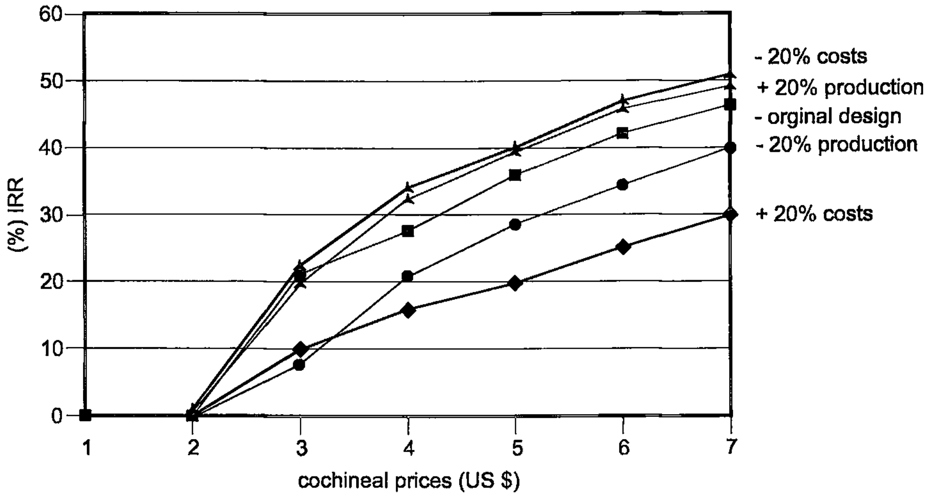


FIGURE 8.5 Economical sensibility analysis for production levels, costs and cochineal prices (IRR)

TABLE 8.6 Net nutrient flows of Nitrogen, Phosphorus and Potassium of 75 ha cactus and cochineal production

	Cactus pear Forage (1)	***Cactus pear fruit (2)***	***Cochineal (3)***	***Natural vegetation (4)***	***Manure input (5)***	***Net input flow 5-(1+2+3+4)***
*N, P and K % of Dry Weight **	N= 0.8%** P= 0.05% K= 1.2%	N=1.1%** P= 0.28% K= 3%	N= 4.5% P= 0.40% K=?	N= 1.2% P= 0.09% K= 0.8%	N=1.6% P= 0.7%(***) K=1.3%	
Kg Dry Weight	234,000	15,000	4,500	60,000	150,000	
Kg N-P-K	N= 1870 P= 117 K= 2808	N= 165 P= 42 K= 450	N= 203 P= 60 K= ?	N= 720 P= 54 K= 480	N= 2400 P= 1050 K= 1950	N= (558) **** P= 777 K= (1788)

* Sources for chemical analysis: cactus pear forage, Enserink 1978; NAS 1976; cactus pear fruit, Enserink 1978; cochineal, Ney 1967; natural vegetation, NAS 1976.
** Calculated from protein content. Proteins require nitrogen (16 % of dry weight) (Nobel 1988).
*** The values for manure were obtained from unpublished data of local NGOs. The P value is considered to be unreliably high (personal communication from E. Smaling).
**** Between quotation marks means a net substraction of nutrients.
The K content of cochineal could not be found in literature.

NPK net input-output test

The cactus pear and cochineal production scenario was evaluated for the net nutrient flows of Nitrogen, Phosphorus and Potassium (NPK). It focused on nutrient flows (at cropping system level) that were caused by farmers. Other nutrient flows, such as weathering, run-off, erosion, etc., were not known at local or regional level. The output flows consisted of fruit, forage, natural vegetation and cochineal while the only input flow was manure. Table 8.6 shows the calculations.

From the cactus pear fields 7.5 kg nitrogen per hectare and 24 kg per ha potassium are extracted every year, while 10 kg per ha phosphorus is added to the soil. If the quantity of dung were to be doubled, substraction would change into a net input of nutrients. Farmers decided to maintain the original low manure input, accepting substraction of nitrogen and potassium. Emphasis was put on fertilisation of traditional production fields in the first years. Farmers did not want to manure cactus pear plantations sufficiently, until cochineal would produce a stable net income and the manure investment would be paid back each year.

When different technologies are to be compared, calculations on one hectare are best. However, for the situation in Huancarani, a community design of the total quantity of involved hectares was also required. In the case of the Land Rehabilitation Program in Huancarani, the subtropical agroecozone aggregation level of analysis was selected in which 75 hectares of cactus pear were planned.

8.4 The layout of the production scenario

In the final design of cactus pear and cochineal production in the tropical agroecozone of Huancarani, plant production is guaranteed by the diversity of crops introduced, by multipurpose use of cactus pear and moreover by the selection of plant species with drought resistance. In comparison to the original position of exhausted and overstocked agricultural land, the total biomass production per hectare will increase.
At cactus pear level, the only important biotic factor of selection is the genotype so that it was the only designing criterion at plant level. Physiological aspects of the plant, such as the special energy metabolism, efficient water use of roots and cladodes among other characteristics of the plant were intrinsic parts of the cactus pear genotype.
Genotypes were evaluated for adaptation to the local soil conditions and the climate of Huancarani as well as for the performance in relation to specific production objectives (combined cochineal, fruit and forage production). The yellow and glabrous genotype was selected for all production purposes in the subtropical agroecozone (2000-2600 m.a.s.l.). The white (green) and glabrous genotype was selected for fruit production in the grain agroecozone (2600-2800 m.a.s.l.). A third cactus pear, the spiny yellow genotype, was planted around cactus pear fields as a living fence for protection against cattle damage in the future.

The main designing factor at crop level was plant density. Plant densities varied from 1660 to 2500 plants per ha, in relation to soil quality and production objectives. Production fields for forage were planted with a minimum of 2000 cactus pear plants per ha.

At field level (cropping system level), the cactus pear and cochineal production scenario included other plants such as weeds, shrubs, woody and fruit trees. These elements were not spread with a fixed arrangement of plants, except for cactus pear. Cactus pear was generally planted at distances of 2 to 3 meters between rows and 2 meters between plants. A special planting scheme was made for the other species in relation to growth conditions on the site (niches: with special soil, vegetation and micro-climatic conditions in parts of the field). In other words, planting of additional woody and fruit species depended on production opportunities in the fields.

Following Mollison's (1990) recommendations for farm design, each element of the cactus pear and cochineal production system contributed to its performance with many production functions (see Table 8.7).

TABLE 8.7 Production and regulation functions of the cactus pear and cochineal scenario.

Design components and agricultural practices	***Functions***
Cactus pear	- Rapid and efficient water uptake and storage when first rains occur - Soil conservation by shallow rooting and special rain roots characteristics - Multi-purpose use: fruit, forage and cochineal production - Diversified food consumption and income - Continued production in times of drought - Protection against germinating grasses and weeds
Cochineal	- Income diversifying produce
Woody trees	- Leaked nutrient transport from deeper layers - Dust, water and sediment caption from outside the field - Decreased water run-off - Increment of biodiversity - Shelter opportunities for wild fauna
Fruit trees	- Diversified production, by use of protection and specific micro climatic production conditions (optimal use of niches) - Increment of bio-diversity - Family consumption and income
Natural vegetation of grasses and weeds	- Increased soil cover - Prolonged water availability in topsoil - Improved soil life by natural mulch layer - Improved soil structure and water infiltration - Protection of shallow root system of cactus pear - Dust, water and sediment caption from outside the field - Decreased water run-off
Soil conservation measurements: Infiltration basins	- Higher water infiltration, decreased water run-off - Prolonged water availability for cactus pear and fruit trees
Protection of the field	- No uncontrolled cattle feeding of cactus pear - No soil compacting by cattle - Regeneration of the natural vegetation
Other agricultural practices: weeding	- No competition between cactus pear and grasses close to the base of cactus pear in the first years after planting

Impact of the "final" layout

The layout of the cactus pear and cochineal scenario was integrated in the traditional production of the subtropical agroecozone. Cactus pear cladodes and natural vegetation produce forage for complementary cattle feeding. Fruit for family consumption and eventually for selling is also produced. Four and a half tons of first class cochineal are produced yearly, which contribute to the family income (see Figure 8.6). The layout is constructed at agroecozone level because of the important links with natural resources and production systems outside the cactus pear fields.

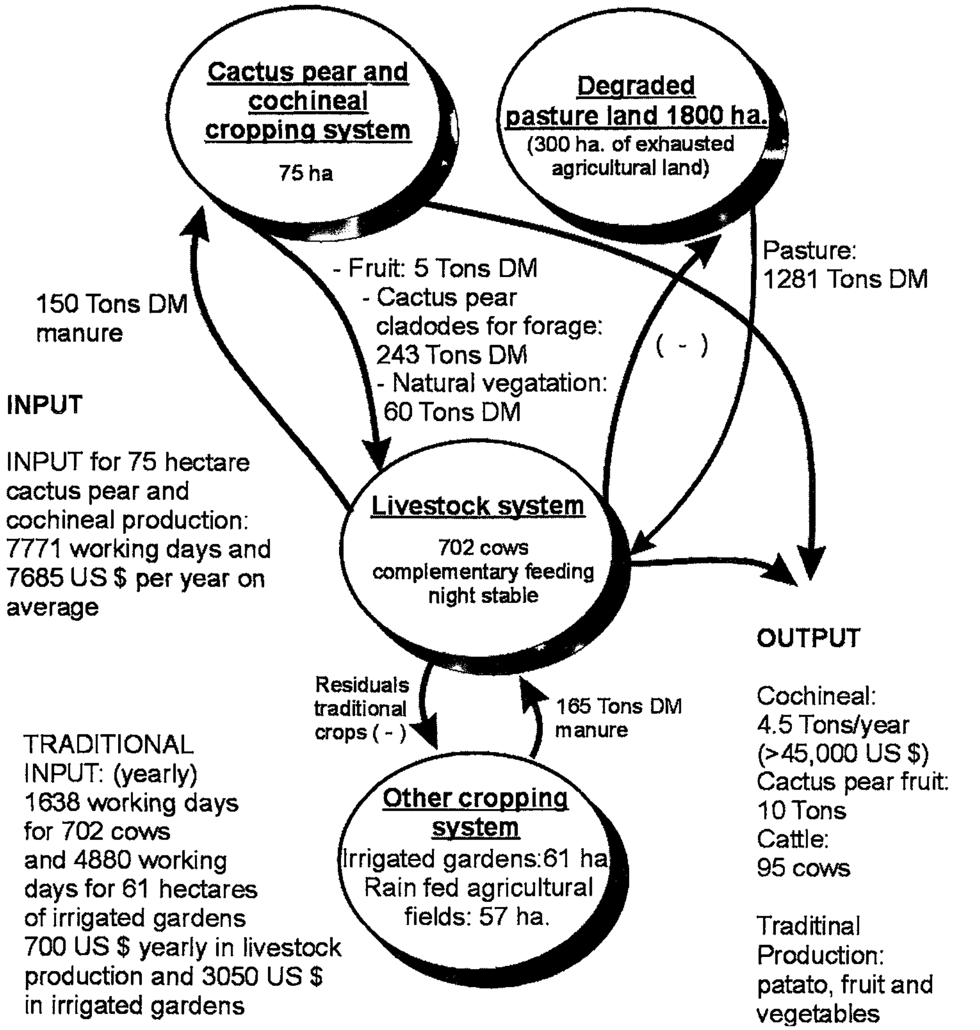


FIGURE 8.6 **Layout of the cactus pear and cochineal production scenario for Huancarani.**

Livestock production is the centre of internal redistribution between production subsystems. Cactus pear plantations deliver 300 tons of dry weight forage for cattle. Degraded pastureland produces a minimum of 1281 tons dry weight forage.

Manure is collected in night stables close to the cactus pear fields. It contributes to the soil fertility of both cactus pear production and conventionally irrigated fields. Traditional fertilisation levels are maintained for the irrigated gardens. Nutrient cycles at agroecozone level are improved, although not closed, until cochineal is produced.

The integrated cactus pear and cochineal scenario foresees increased livestock production. When maintenance of cattle weight is reached during the dry period, these animals will be fit for slaughter earlier. Per year seventy cows can be selected for sale without a complementary forage gift. The cactus pear forage results in at least a production of 0.33 cows per hectare per year. This means that the cattle production can be increased with 25 cows, i.e. from 70 to 95 cows per year due to complementary cactus pear forage feeding. The average cash income from livestock increases with 36%.
Cactus pear fruit and cochineal are new income generating crops. Up to ten tons of fruit can be sold from 75 ha of cactus pear. Per year the total cochineal production in the community will be 4.5 tons on average from the infestation year. In addition, the productivity levels of conventional crops in the irrigated gardens are expected to stabilise when these fields are fertilised with manure collected in the night stables.

The production of cactus pear and cochineal goes together with an increase in input of labour and capital. It has already been discussed earlier (presentation of the subtropical agroecozone) that labour requirements in livestock production are low (about 15 working days per family year). The convential production on irrigated fields requires a relatively high labour input: 120 working days per hectare per year for potato, other tubers and vegetables. The total labour input in the subtropical agroecozone is minimal 6500 working days and that without the implementation of the cactus pear scenario. Per year the cactus pear and cochineal production system requires 7771 (the average of 13 years of production) working days on 75 ha. It is concluded that the proposed cactus pear and cochineal production double the labour input in the subtropical agroecozone. Such a labour demand needs integrated family labour input.

Capital investment in the subtropical agroecozone is traditionally low. Vaccination, injury cure and castration are carried out by farmers. The total costs are generally less than $ 10 per cow in a life cycle. Investments on irrigated gardens is about $ 50 per ha. Therefore, the yearly capital investment at agroecozone level is traditionally below $ 3750. The cactus pear and cochineal production of 75 ha requires a yearly capital investment of $ 7685 for the first 13 years. Application of the production design makes the capital investment in the subtropical agroecozone three times higher than current investments. Since families do not have capital reserves of that order, financial support (by NGOs) was required in order to invest in cactus pear, cochineal, as well as livestock production.

8.5 Conclusions

Farmers were fascinated by discussing the several production scenarios and to build up the final layout of the integrated cactus pear and cochineal production system. For them it was like a puzzle. Bits and pieces of knowledge were brought together in production scenarios in which all kinds of components and functions received their place. The cactus pear and cochineal design was the final result of learning in practice. It showed "what" was learned. The previous two chapters did not show "how" farmers learned. This is the process side of farm innovation. We called it learning from practice. The next chapter will present the design of the learning pathway that was followed for learning in practice. The platform building and organisation of farmers will be analysed and a methodology will be reviewed that made it possible to improve decision-making.

Chapter 9

Design of a learning pathway: learning *from* practice

In this chapter a meta-study will be presented about what happened during discussions between the resource-poor farmers of Huancarani and development workers. An attempt will be made to register what can hardly be registered.

The second aim of the LRP can be translated into three strategies:
- To let farmers experience that they are capable of finding their own way towards development as long as they are skilled in communication;
- To register how farmers deal with what they have learned from their own activities and from others;
- To return the new insight to them as a tool for working with development workers and/or scientists in an interdependent way.

9.1 The scene and observation of the discussion

Discussions on the activity agenda and applied methodology of the LRP took place regularly among 10 to 25 farmers from Huancarani and sometimes with the entire assembly of the farmers union (over a hundred families present). These discussions were planned immediately after having finished an activity or a method, as a kind of evaluation of the action with the purpose to redesign planning and make decisions for further action. These sessions also worked out as events to strengthen motivation and confidence. Complementary to the discussions on a specific subject, two or three times per year, general meetings for evaluation

and planning were held, in which all relevant mid-term results were discussed and activities compared and planned again. These meetings were strategically planned i.e. before the planting season of cactus pear, during the growing season and at the end of the growing season. So, we counted on more than 25 specific methodology evaluation meetings and eleven general meetings in five years.
Eloy Vargas, the local development worker, led the discussions. He prepared the meetings with some colleagues and me beforehand. I attended most of the specific meetings and participated in the discussions by raising clarifying questions. The atmosphere and aim of the meetings changed during the realisation of the LRP. We started with five general meetings, just to let farmers feel that they were coming together for their own sake, not for that of the donor. General issues were discussed and information was given to the farmers when they asked for it. These meetings resulted in planning a working agenda on the basis of what the farmers considered relevant to them. They came up quite easily with the following issues:

- to analyse their problems;
- to know about new opportunities for farming;
- to experiment with new crops;
- to get some insight into the future impact of changes on actual farming.

While listening, I made my own observations by simple registration of who had said what. Beforehand we had taken into account that a certain percentage of the farmers would be reluctant and sceptical. They seemed to think: "Here we go again without results". But, because of the good group spirit and participatory focus of the meetings, farmers changed their attitude from scepticism to positive criticism and prudence. The farmers were eager to learn, although their enthusiasm was not the same for all kinds of activities and methods that were put forward and this was clearly expressed. Other methods were proposed and incorporated into the activity agenda. This made the subjects of the meetings concrete enough to give the farmers a feeling of "this is about *my* farm and *my* skills". After a short period none of them seemed to have any problems with acting as an unskilled farmer. They were all at about the same level and could contribute to the discussions as they could tell a little about what their family experienced on the discussed subjects. Gradually, they all experienced that the platform was an important device for creating common knowledge and solidarity. The platform had to become their school, their institution for learning about how to observe, integrate observations and design management decisions. At the same time it was the place where they felt strong enough to invite outside support and where external information could be discussed without having anything to do with power or social class.

9.2 Institutionalisation of the platform

Farmers attendance at the meetings was excellent. There was always sufficient time for the social aspects of the getting together. For the facilitator, such "free moments" were perfect for getting some insight into what lives among the farmers. Meetings were also planned in coordination with other events so that the farmers' participation became quite high. Additional unexpected events were taken up to analyse and discuss aspects of every day life of the farmers, but also to obtain insight into the farmers' worldviews and their organisations. If necessary, individual problems concerning the process were always discussed separately at other moments and outside the meetings. Especially Eloy Vargas went up to farmers and discussed any problems they might have privately.

The meetings gradually became important learning platforms for research and decision-making. Excursions, experimentation and demonstrations were highly appreciated. The on-farm experimental plots and, later on, the production fields that were planted, almost took on the function of "a laboratory for students". Finally, the farmers' meetings took on the characteristics of an institutionalised organisation. Farmers decided among others that:

- They were part of a decision-making team;
- Their joint decisions in the platform should give direction to farmers' individual management decisions inside their own farms;
- The information should be open to everybody in the community and had to be communicated;
- New activities had to be discussed in the platform at first, in order to prevent disturbing interference with other activities.

The Huancarani platform of the LRP participated actively in the regional and national organisations of cactus pear and cochineal producers. In that way Eloy Vargas, the facilitator of Huancarani and some farmer leaders were able to show their results to other platforms and received feedback from other communities. At the same time, Huancarani farmers were updated constantly about production perspectives, commercial aspects of cochineal sale, national project funding and support as well as national farmers' organisational affairs. For Huancarani, participation in the cactus pear and cochineal organisation became the most important strategy for confidence and perseverance.

The platform of the Huancarani farmers also participated in the LRP national research project on cactus pear and cochineal (PITC). In those days, many scientists came to visit Huancarani, as they were interested in the agricultural experiments and the local growing of cactus pear and cochineal. Farmers discussed the results in their own community in relation to those on other production sites. They became up to date with research and the impact of calculations. Huancarani became an important example of farmer participation in adapting the cactus pear and cochineal prototype production system to local production conditions and local *campesino* objectives. Because of its success, the farmers' representatives of the Huancarani platform were invited to participate in regional and national workshops and seminars on technology, cost benefit calculations and the impact of cactus pear and cochineal production. The PITC research project operated as a think tank based on exchange of experiences and guided research.

I considered institutionalisation of the meetings of Huancarani farmers as a good sign of the progress farmers were making in achieving the second goal of the LRP.
The platform made it possible for farmers to interact with outsiders and to learn continuously and interdependently. Several examples can be found in literature of the favourable effects of being a member of a relevant organisation.
Kabourakis (1996) found that the success of regional development on Crete in Greece must be attributed to the creation of the Farmers Support Group, a decision-making platform of organic olive growers. Da Silva (1999) reported that control of blackbird populations in rice could only be achieved due to the stringent farmers' decisions in the so-called CITE groups. Röling and Van Fliert (1998) pointed out the success of the so-called farmer field schools as tools for the introduction of biological control of insects in rice in Indonesia. Vereijken (1999) and Leewis (1999) demonstrated that implementation of an innovative farm design is not possible without a farmers' study group.

Referring to the examples mentioned above, I came to the conclusion that the learning platform of the Huancarani farmers formed the basis for the LRP's success later. Probably, for farmers learning to learn needs a basis where learning processes can take place, can be developed and can be observed. But was it all success and sunshine? There were some "useful" crises that were important to learn from. The following aspects may be considered as being negative:

- Deficient research results on cactus pear plant diseases;
- Insecurity concerning succession rights of common lands;
- Problems with the distribution of cactus pear plants;
- Failure to produce cochineal in sheds;
- High fluctuation in cochineal quality from equally treated samples.

These crises functioned as unexpected events and became the subject of debate in the group. I will describe two mechanisms that led to the solution of such crises and to improved learning by the group: knowledge integration and decision-making procedures.

9.3 Integration of knowledge

Everybody was willing to contribute to solutions and told about his own experiences with cactus pear growing or what relatives had practised. The complex problems provided several learning pathways to solutions and sufficient aspects, functions, roles and tasks were present to involve everybody actively. However, the more puzzle-resolution the subject was, the more dependent the platform members became on outside help. The quality of cochineal provides a good example.

The farmers became skilled in indicating how rural development could be improved by the production of the insect. They were willing to make their own cost-benefit analysis. With the help of the facilitators they had become skilled in joint experimental research on improved infestation (inoculation by insects) and post-harvest techniques. But they turned out to be very uncertain when the cochineal quality fluctuated without any indication of the reason for it. They did not understand the factors that influence cochineal quality and did not know how to improve the quality of the product. In other words, their autonomy in decision-making ceased at the fundamental level of problem analysis and results of basic research.

The crisis that followed after the discussions about how to improve the quality of the produce, immediately made the farmers conscious of the problem but they felt like unskilled managers. It was difficult to bring them beyond this point. We discovered that they looked at their facilitators expectantly. The evaluation unveiled indeed that from then on they expected an active role from outsiders. The Cochabamba State University carried out some basic research and the first results were promising. The farmers became agitated. They said that "normally", as soon as farmers turn out to be uncertain, the scientists or the donor come with a recipe, a solution or a tool. As this did not happen in the LRP, they became irritated, as most of the farmers wanted to apply the results of research projects immediately, without waiting for an adapted technology for their own situation. When they did so, they returned to the platform meeting later with rather sad stories such as "it does not work", "it is too difficult" or "it does not make sense". This was the moment to let them feel that the research on improvement of the quality of the produce we had done so far only said something about the relationship between the experimental results and the conditions that we created for the benefit of the experiment.

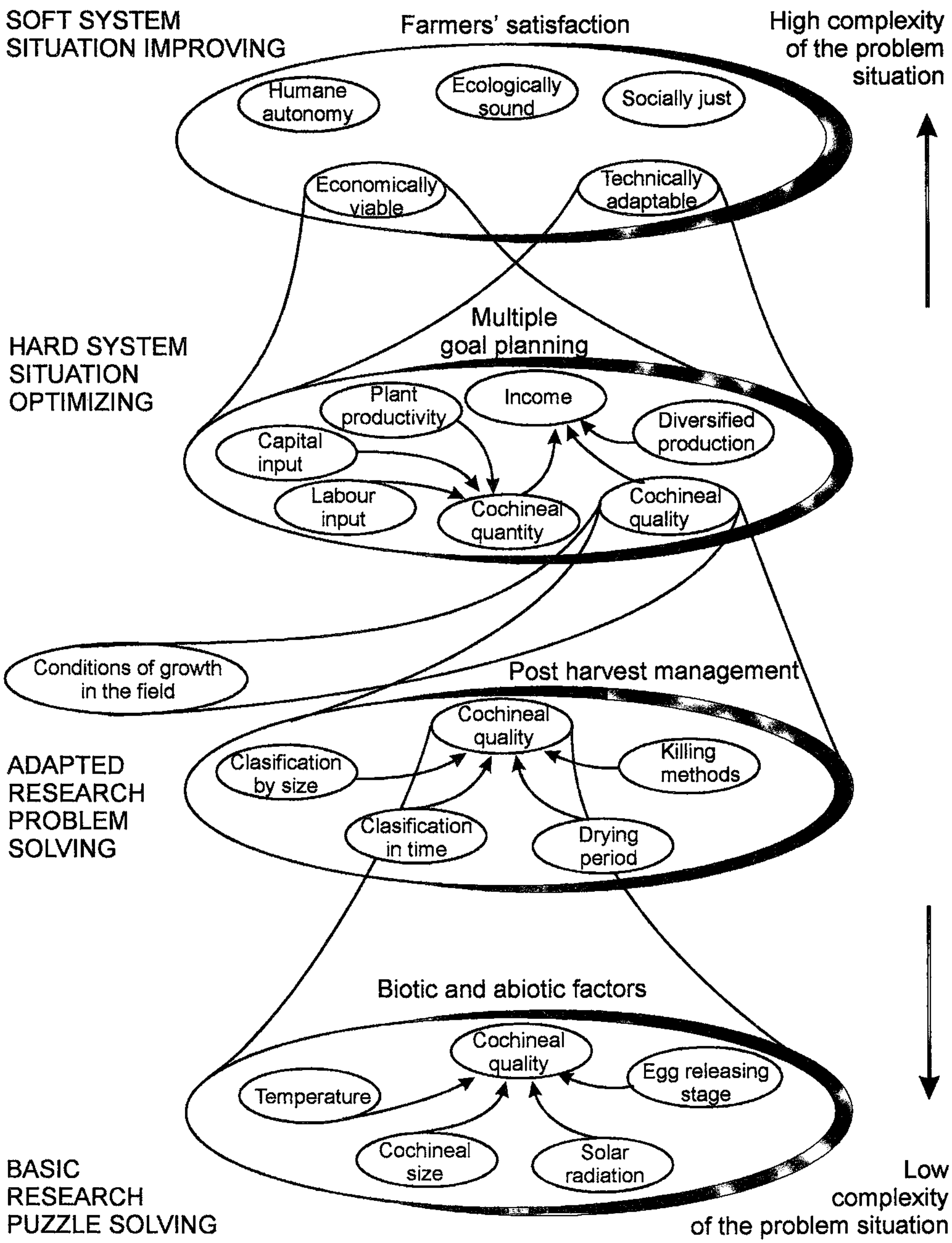


FIGURE 9.1 **The improvement of cochineal production by knowledge integration of relevant aspects: cochineal quality factors (lowest level of complexity), agricultural management techniques, productivity, economic features and criteria for development (highest level of complexity).**

In the following I will show what happened when we tried to make farmers aware of how they can integrate the results of experimental research into their own farming system, against the background of our motivation to generate rural development. The case of "Improving the quality of cochineal" will be discussed, as it is an example of the learning-in-practice pathway (see Chapters 4, 6,7 and 8). The results gave us some idea of which production factors may influence the quality of cochineal and how these results could serve the final decision-making and implementation of farm innovation. To achieve this, generated knowledge was brought together with other knowledge at different levels. The process involved is known as knowledge integration.
We tried to achieve our goal in four steps (see the four complexity levels of Bawden in Section 4.1):

- Understanding the knowledge about factors that influence cochineal quality;
- Improvement of the effectiveness of agricultural management techniques;
- Optimisation of production at cropping system levels;
- Satisfaction from the scenario as part of decision-making.

These four steps will be discussed in the following subsections (see also Figure 9.1).

9.3.1 *Factors of improving the quality of cochineal*

Harvesting and conservation of cochineal has a great effect on the quality of the dried insect as raw material for carminic acid or carmine dye production. One of the main indicators for quality of cochineal is the presence of the chemical substance: carminic acid (CA). In all their experiments scientists at the Cochabamba State University found that the length of egg release by the female insects as well as the size of the harvested insects affect the quality of cochineal. Other factors were of less importance. Farmers concluded therefore, that the exact moment of harvesting the insect had to be determined by the size of the insects. The sizes were classified according to meshes found on the market or with material found around the house. Also, they decided that the way of killing the insects should be studied as well as the moment of classification and the drying period (see for results Section 7.4). The farmers thus began to realise that so far the results only helped to explain and understand the factors that determine the quality of cochineal. They themselves brought forward that they now had to experiment on their own farms, under their own farm-specific conditions. In other words, they understood that the results of scientific efforts in getting the best cochineal quality could only be achieved by integration of this knowledge into their own every day management and farm structure: applied research on practical agricultural management techniques.

9.3.2 *Effectiveness of agricultural practices*

New applied experiments were set up, partly contracted out to the University and partly carried out on-farm and managed by the farmers themselves. The best killing methods for cochineal were determined; the farmers understood that cochineal quality has everything to do with quantity. Technology that guarantees higher cochineal quality causes, as a negative side effect, reduction of the quantity of the product.

So far, it had not been possible yet to classify exactly the quality of cochineal in the farmer community because the farmers did not have a chemistry laboratory at their disposal. To be dependent on outsiders was against their objective of taking the quality of produce and sale into their own hands. So, in a third round, the farmers in the platform decided (taking into

account the results of the two previous rounds of experimental research) to develop a local classification system for the quality of cochineal.
They created indicators based on smell, colour, humidity, firmness, size and uniformity of the harvested insects. Surprisingly, they could achieve good correspondence between the results of separately made judgements on quality. Farmers were able, to a high extent, to classify cochineal for its quality. Scientific validation showed that their score was very precise. So, a quality system was developed. Farmers could identify cochineal with an error of less than 0.5% carminic acid, in a range of 19% and 24% carminic acid. This was an unexpected result of the LRP. It gave farmers a tool to control their own cochineal quality at a generally accepted standard. That also made them skilled in negotiating about prices and in marketing.

From their experiment, the resource-poor farmers of Huancarani could reach a very good understanding of the relationship between the growing conditions of cochineal, post-harvest management and the quality of their produce. They demonstrated that they had become skilled in reaching an uniform, high quality at community level. This was a result of learning by (guided) doing. Once they had discovered how to guarantee quality of cochineal, they started to discuss the production of high quality cochineal as part of a cost-benefit calculation. Cochineal production had to be efficient and integrated into the current farming system.

9.3.3 *Optimisation of the cropping system*

The next step of knowledge integration according to the complexity levels of Bawden et al. (1985) was to make cochineal production efficient. This meant that the farmers' costs had to be fully compensated by income from the market. This had to do with knowledge of cactus pear plant productivity, the diversity of cactus pear uses, required capital input, labour availability, dimensions of cactus pear plantations and so on. The farmers had to integrate their knowledge of several components into a system level or, to be more precise, the aggregation level of the cropping system: produce, as much as possible, at high quality against the lowest costs. The platform experienced, with simple scenario building on the basis of production rhythms and cost benefit analyses, that they could achieve optimal production for local growing conditions at competitive costs. They could compare and evaluate the efficiency of different cochineal production scenarios and trade off the desired income for their family and the insect quality to strive for. They learned the effects of external capital inputs and labour. Finally, the farmers required an evaluation of the results. Two important questions remained unanswered. Were they happy about their results? Could they see that their initial problem was solved considering the various points of view as defined in the criteria for farm innovation? Next, they had to learn decision-making on how to improve the outcome of their work continually.

9.3.4 *Satisfaction from the farm innovation scenario*

The knowledge of quality factors, effectiveness of agricultural management techniques and production efficiency will result in optimal production scenarios. In order to reach final decision-making in relation to implementation, the farmer needs to feel at least happy with it. That is to say, the outcome of scenarios must be evaluated in the context of criteria that are satisfactory to the farmer. It must be remembered that the farmers were unhappy with the actual situation of farming at the start of the LRP. We raised the question about farmers' satisfaction in relation to the general results if applied to their own farms. Confrontation of farmers with their different management and farming styles could be done by making them aware of how they could compare each other's satisfaction. For example, personal differences in appreciation, margins between costs and income, acceptability of the scenario from a social point of view, technical implication, autonomy in relation to suppliers and buyers, gender focus, contributions to the improvement of the environment or biodiversity conservation have to become "measurable".

In this way, farmers learned to improve the quality of their product as they saw that so far their results had met their initial demands. Or, in other words, when there would have been shortfalls between results and final goals, the design process concerning the question of how to reach a higher cochineal quality should be repeated. This is what I called earlier learning from failures or heuristic learning. Once farmers had reached the initial complexity level by knowledge integration, final decision-making was required before implementation of the proposed solution. Farmers had to learn to improve joint decision-making. How the LRP trained farmers to do this will be shown in the following section.

9.4 Designing decision-making as a skill for better farming in Huancarani

In addition to knowledge integration between the complexity levels of production factors, effective handling and efficiency, farmers had to make choices between options. According to Bawden et al. (1985) and Simon (1969) the results from research should always be integrated into the initial complexity level of the problem situation. Land degradation and lack of income opportunities for resource-poor Quechua farmers are examples of such complex problems. Solutions had to be found at the same level. Therefore, the research in the LRP had to be integrated into the highest level of complexity of soft systems. At this level, farmers had to decide whether the followed integration had resulted in a satisfactory solution according to pre-established criteria. Therefore, soft system design turned out to be a decision-making tool.

In order to make the farmers' opinion on scenarios for farm innovation explicit, we brought together various production scenarios and compared them with the "with-without cases", SWOT and Multi Criteria Analysis (MCA) methods.

9.4.1 *Comparison of "with-without cases"*

The future impact of two production scenarios was assessed. The effects of the cactus pear and cochineal production scenario (with case) were set against the consequences of the conventional production system of the subtropical agroecozone (without case). The with-without-case analysis is a test that analyses the satisfaction degree of meeting farm development criteria between the two scenarios. The outcome was further analysed on strong and weak aspects, threats and opportunities (SWOT analysis).
Table 9.1 shows the criteria (as defined by the Huancarani farmers) and the assessed impact of the "with and without" scenarios.

9.4.2 *SWOT analysis*

Farmers were enthusiastic about the fact that the cactus pear and cochineal scenario scored positive on two thirds of the farm development criteria. However, the long list did not immediately present a final criterion (read overview) for acceptation or rejection of the proposed production scenario. Therefore, farmers were invited to subdivide the assigned impact on each attribute of development criteria between strong and weak aspects (part of SWOT analysis).

Strong aspects of the cactus pear and cochineal production scenario
Farmers evaluated that all environmental preconditions of farm development, such as protection of forests, biodiversity, soil conservation and integration of livestock and agricultural production, could be reached by the proposed production system. Economic variables, such as productivity increment, positive Internal Rate of Return (IRR), and non-existence of competition with agricultural land, were also evaluated as positive.
In addition, farmers indicated that they appreciated cactus pear and cochineal because of the regional production knowledge of Andean farmers for hundreds of years. This production fits into their culture and tradition. Moreover, a good deal of knowledge is still there, although the younger farmers felt themselves not sufficiently knowledgeable about both commodities anymore. The opportunities for cactus pear production were in the first place the traditions of the Andes, on which the Huancarani farmers rely.
Cactus pear allows several possibilities for production. These can be implemented in the future according to local necessities and markets. This may guarantee maintenance of opportunities for agricultural development. In the future decisions on starting the production of a certain use of cactus pear can be made step by step.

Weak aspects of the production scenario
The economic aspects of the scenario showed that high investments are required for cactus pear plantation and cochineal infestation. According to the farmers, they cannot raise such amounts of money themselves, although levels were below the pre-established investment criterion. So, once again the farmers changed the threshold level for investment. This meant that capital had to be found outside the community. Development institutes were asked to support these activities with a credit line or joint venture investment (policy of the national Bolivian Export Foundation).
Cactus pear requires a long juvenile growth period before fruit, forage and cochineal start to produce. That is why the economic result of the production is only positive from year 7 and the cash flow not until year 6, which are considered weak aspects.
It also became clear that not all families were able to participate in the programme, because they do not possess land in the subtropical agroecozone. Special attention should be given to group planting on communal land.

The men were very active in the LRP and have dominated the platform so far. Farmer women are not likely to have much influence on the programme until the production of cochineal starts. The harvest of cochineal and the sale of produce are traditionally women's responsibilities (Rodriguez and Schoute 1992). The lack of gender focus may be a threat for the success of the programme.

The criterion of minimal labour input could not be addressed successfully and was another weak aspect of the programme. On the one hand, one may be afraid of the possibility that farmers may not invest the required amount of labour to protect and maintain the plantation before production starts. On the other hand, when cochineal production starts, labour

TABLE 9.1 Comparison of the impact of the cactus pear and cochineal production with conventional farming, according to the development criteria (first column) and qualitative or quantitative indicator for each attribute (second column)

Farm innovation criteria	*Qualitative or quantitative indicators*	*Impact of the cactus pear and cochineal design*	*Impact of the conventional production system*
1. Maintaining Andes culture	1.1 Maintaining Andes crops	Cactus pear and cochineal are traditional Andes crops, as well as the fruit species pacay and chiremoya (National Research Council 1989).	Traditional Andes crops (vegetables and root crops) are replaced by high productive mixed food and cash crops (potato).
	1.2 Community tasks in agricultural production	High involvement of the farmers union in all phases of the land rehabilitation programme.	The farmers union will not supervise livestock keeping in the sub-tropical zone.
	1.3 Maintained possibilities for further development	Cactus pear is a multipurpose crop and other uses than fruit cochineal and forage may be developed in the future (see for other uses Figure 5.1).	Residual crops are fed to cattle, but manure is not collected. Declining soil fertility is a fact. The quantity of irrigation water in the canyons is declining. Development possibilities are decreasing.
2. No competition with food crops	2.1 No competition with agricultural land	Cactus pear is planted on exhausted agricultural land	No competition.
	2.2 Minimal labour input	Cactus pear and cochineal production on 0.5 ha requires an average of 65 to 80 working days per year when at full production.	Minimal labour input. Yearly labour input is less than the number of working days needed for 0.5 ha irrigated potato production (60-80 working days).
	2.3 Minimal capital input	The average yearly capital investment is $ 51, but the first year requires an investment of $ 220 and two more years pass the limit (148 in the fifth year and seventh year).	Minimal capital input. Yearly capital input is less than 0.5 ha irrigated potato production ($ 120-134)
3 Economic efficiency	3.1 Increased agricultural productivity of the land	Forage production is increased to maintain the weight of cattle in the dry period. Fruit and cochineal are produced (see Section 7.2). Agricultural production on irrigated fields is maintained by organic fertilisation.	Productivity will decrease.
	3.2 Internal rate of re turn is higher than rate of interest (8%)	Internal Rate of Return (IRR) = 21 %, at minimum prices of 10 $ per kg dry and first class cochineal.	Was not calculated for annual cash crops.

Farm innovation criteria	*Qualitative or quantitative indicators*	*Impact of the cactus pear and cochineal design*	*Impact of the conventional production system*
	3.3 Yearly economic result and cash flow are > 0	The economic result is positive when cochineal production starts (year 7). The cash flow is positive from year 6 onwards.	Potato, peanuts, and some fruits yearly show positive economic results and cash flows.
4 Socially just	4 Active participation of the peasant families in the programme	60% of the families may plant cactus pear on their own (exhausted) agricultural land. All families have access to plantations on communal land.	39 % of the families own irrigated gardens in the subtropical agroecozone; 60 % use the zone for grazing.
5 Gender focus	5 Increased role for women in agricultural production and sale	It is expected that, in future, fruit, forage and cochineal production will be managed and sold by Huancarani women, as occurs in traditional production zones (Rodriguez & Schoute 1992). At this stage, the program is dominated by men.	No changes in roles are expected.
6 Protection of ecosystems	6 Protection of vulnerable and rare ecosystems	Forests and permanent pasture land are not cleared.	Land of high fertility is needed in order to maintain productivity in the future.
7 Rehabilitation of degraded land	7.1 Construction of biodiversity of plant species.	Cactus pear, fruit and woody trees are introduced.	The number of plant species declines on degraded pasture land and exhausted agricultural land by overgrazing.
	7.2 Soil conservation, minimum of water and soil losses.	Soil conservation and soil regeneration is reached by the vegetation cover of recovered natural vegetation and cactus pear plantation. A mulch layer arises. Additional soil conservation measurements are carried out.	Land is overgrazed and the scarce vegetation cannot prevent ongoing soil erosion and water run-off.
	7.3 Integration of agricultural and livestock production	Forage production is expected to maintain the weight of cattle in the dry period. Manure distribution on agricultural land will at least result in a lower net output of nutrients.	Improved cattle productivity nor manure caption is expected.

competition between peak-time cochineal harvesting and sowing of traditional food and cash crops in the period of mid-October to mid-November may be a problem. Additional labour force from outside the community may be needed to harvest cochineal before the rainy season starts.

Conclusion
Notwithstanding the weak aspects (capital investment, labour availability and gender focus), farmers decided to implement the production of cactus pear and cochineal. The results of the evaluation confirmed their initial choice. But, at this stage they became aware of some production risks. The original scenario was not changed on details by SWOT or with-without case analysis, but certain constraint lifting activities were added, such as financial support for cactus pear planting and cochineal infestation and further minimisation of labour input.

We noticed that farmers accepted the analysis of strong and weak aspects and that they were enthusiastic about the result of each aspect. However, they did not show much interest in the total scores of strong and weak aspects. Strong and weak aspects were not exchangeable or negotiable. In contrast, this technique was used to obtain an overview of the many aspects and effects. It was also used for comparing the impact of the design with pre-established criteria for farm development and was therefore useful for making explicit personal or group positions, so that it could be discussed, proved or invalidated.

9.4.3 Multi Criteria Analysis (MCA)

With the help of the Multi Criteria Analysis (MCA, Van Pelt 1993) the LRP compared several production scenarios. The analysis was based on the list of development criteria, which was quite comprehensive with respect to the farmers' development objectives; the performance was assessed (impact matrix) and compared. The result of such an exercise is ranking of alternatives.

MCA is a decision-making tool and does not validate decisions made afterwards. It can be seen as a mirror: it answers the question of which alternative or scenario would suit the criteria (goals and restrictions), set for farm development, best.

The integrated cactus pear scenario was subjected to MCA together with two other development scenarios: potato production and a forestation programme. The impact matrix was therefore constructed with three production alternatives (scenarios). The scenarios were evaluated for the criteria defined by the farmers themselves (see Table 9.1 of the with-without-case analysis). The scores of each criterion (and attribute) were determined by simple calculations of the percentage a goal had reached or by a threshold level that had not been passed. For qualitative indicators, farmers started a discussion in the platform until consensus was reached (farmers' opinions at their meetings). In other words, farmers sometimes required qualitative analysis, but most of the indicators were calculated quantitatively, with the help of scientists, by assessment of future impact.

The MCA was carried out using the weighted summation technique. The Land Rehabilitation Programme chose, in view of the knowledge exchange between farmers, local facilitators and scientists for the application of a simple technique and procedure, which could be done by hand. The standardisation technique of data consisted of transformation to values between 1 and 0. The highest (positive) score received value 1, the other two received the relative part. Table 9.2 shows the standardised scores of the development alternatives and the final ranking.

TABLE 9.2 Standardised scores and ranking (last row) of three development alternatives for farm innovation according to development criteria set by Huancarani farmers.

Development criteria	*Cactus pear and cochineal production*	*Potato production*	*Forestation*
1. Andes culture maintained (max. 15%)	14.2	2.2	7.5
2. No competition with traditional food crops (max. 15%)	11.3	0.8	15.0
3. Economic efficiency (max.:30%)	25.9	25.0	0
4. Socially just (max. 6%)	3.6	1.8	6.0
5. Gender (max. 4%)	4.0	2.0	0
6. Protection of vulne rable natural ecosys tems (max. 10%)	10.0	0	10.0
7. Rehabilitation of degraded land (max. 20%)	20.0	0	6.5
Total score (max. 100%)	89%	32%	45%

The cactus pear and cochineal scenario obtained a first rank because of simultaneous high scores on cultural, economic as well as ecological criteria. In contrast, potato production scored only well on the economic criterion, while forestation scored well on food security and ecological criteria.

It was concluded that the cactus pear and cochineal production scenario may have a positive impact on a wide range of development criteria, which was to be expected from this multipurpose crop. Even if the relative priority of farmers' criteria were to change (a changed weight set), for example an inclination to views based on purely economical or ecological criteria, the cactus and cochineal scenario would still score high. In other words, the sensibility to other ranking of alternatives, by changed weighting of farm development criteria, is expected to be low.

9.4.4 *Risk and uncertainty analysis*

The cactus pear and cochineal scenario scored well and passed all comparative evaluations: comparison of with-without cases, strong and weak analysis and the Multi Criteria Analysis.

Farmers were able to select a new production scenario based on their own development criteria. The cactus pear and cochineal production scenario was accepted.
However, cactus pear needs at least a five-year period of growth before it can be infested with cochineal. The choice for cochineal production could wait until more information would be available from research and experimental implementation in the field. Farmers are generally reluctant to implement a complete technology package all at once. They prefer a phased (step by step) introduction in accordance with their current opportunity gaps. With cactus pear planting, farmers opened a wide range of possibilities for farm development but, because of the phased implementation of the integrated cactus pear and cochineal design, the development workers nor the farmers could assure that the project would be implemented as was planned earlier.

The previous tests obviously concerned the entire (correct implementation of) design. But was this really so obvious? Not so for the facilitation team. The question was why farmers felt so confident about the correct implementation of the design. During platform discussions we found out that the farmers' logic behind this strong statement was that they see implementation of the programme as just an internal affair. Farmers got the impression that the platform could solve all problems and that they would not change their minds anymore now that the final design was accepted. However, external influences (opportunities and threats) such as changed market conditions (low cochineal export prices), new emigration opportunities for young Huancarani farmers, or sudden aggravation of cactus pear plant diseases, may influence the correct implementation of the project. As the farmers knew that implementation of the complete production scenario would mean mid-term planning, they should have been aware of all kinds of obstacles that could ruin the expected positive impact of the programme. A simple, changed production objective of the integrated cactus pear and cochineal scenario, caused by external influences or by unforeseen internal aspects, could lead to alteration of step by step implementation of the scenario. The LRP could not assure the correct implementation of the design as a step by step implementation (process approach) is extremely vulnerable to changes. In such a case, its future impact may change also. Therefore, the LRP offered a risk and uncertainty analysis to the farmers.

Previous analysis showed that the cactus pear and cochineal production system was not sensitive to changes in price and productivity, which made the farmers feel more confident. The effect was calculated for a situation in which cochineal prices or cochineal productivity would be affected, both with extremes of 20% maximum and minimum (see Section 8.4: the normal procedure for economic-financial analysis of project feasibility).

The risk and uncertainty analysis focused on altered implementation of the design. The following next example shows how farmers learned to assess the impact of incorrectly implemented production scenarios.

There may be many causes that change the original production objectives, but access to capital, availability of labour and the right motivation of the farmers are crucial for the large investments in the first, fifth and seventh year.
In the first year, the decision concerns cactus pear planting. At this stage no precise decision is needed for specific cactus pear uses and production levels yet. Next, in the fifth year, cochineal introduction can be chosen. Forage production in the seventh year is the third and last important decision moment. The risk that the final decision on forage production will not be made is high because of the influence of cochineal production. In the case of high cochineal prices, the cochineal production will not be sacrificed for forage production (of

lower economic impact). When cochineal prices are low, farmers may be disillusioned and neglect their plantations before they reach the forage production stage. This phenomenon is a weak side of multipurpose plant or multi-crop development projects. Because of this and in addition to the original design, the LRP designed three scenarios with altered production objectives. The first alternative consisted of reducing cochineal production by half, the second alternative was to reject cochineal production altogether. The third alternative was to analyse the impact of the design in which forage production was not implemented. Table 9.3 shows the results of this analysis.

The Multi Criteria Analysis carried out for the four scenarios (i.e. including the original design) on the basis of seven farm development criteria and showed the following ranking: (1) the original design; (2) reduce cochineal production by half; (3) no cochineal production at all; and (4) no forage production at all. It was concluded that removal of one use of the multipurpose cactus pear would result in a lower overall performance of one of the main criteria: a lower economic result or a negative ecological impact. This means that the impact of cactus pear and cochineal production is highly sensitive to a decrease in production diversity (elimination of the multi-purpose perspective).

As cochineal production obviously is important for generating family income, scenario 1 scored high on the economic criteria. On the other hand, forage production meets the environmental criterion. If cactus pear forage production is not implemented, the economic criteria will be reached anyway. But there may be competition with food production if the livestock production objective must be reached by cultivating other forage. For example, the production of Lucerne may be an interesting forage alternative but requires high-quality, irrigated agricultural land and competes with food and cash crop production. Without forage production and hence, manure collection, agricultural land cannot be fertilised, so that the decline in fertility is expected to continue in the irrigated plots in the subtropical agroecozone. In order to meet both economic and ecological farm development criteria, the production system should consist of the multipurpose use of cactus pear. The team of the Land Rehabilitation Programme was conscious of the high probability that the farmers would not implement forage production.

The analysis with MCA showed again that farmers were not interested in a final score, but used the technique for analysis and discussion and to reach consensus.

TABLE 9.3 Comparison of the impact of four scenarios of cactus pear and cochineal production, according to the attributes of development criteria formulated by the Huancarani farmers

Attributes of development criteria	*Original design*	*Half of cochineal production*	*No cochineal production*	*No forage production*
1.1 Maintaining Andean crops (based on local knowledge and technology) 5%	Cactus pear and cochineal	No changes	Cactus pear	No changes
1.2 Community tasks in agricultural production 5%	Communal land, communal organisation of programme. Production by individuals and groups	No changes	No changes	No changes
1.3 Maintained possibilities for further development 10%	All cactus pear alternatives, cattle production and development of irrigated fields	No changes	No changes	No development of cattle production nor manure caption for irrigated gardens
2.1 No competition with agricultural land 10%	OK	No changes	No changes	If improvement of forage production is aimed at, agricultural land for Lucerne production will compete with agricultural production
2.2 Minimal labour input 2.5%	Total labour requirement for 0.5 ha and 13 years: 674 days	539 working days	404 working days	480 working days
2.3 Minimal capital input 2.5%	Total capital requirement for 0.5 ha and 13 years: $ 666	$ 551	$ 435	$ 524
3.1 Increased productivity (fruit, cladodes, cochineal, natural vegetation) 10%	Sum of yearly average dry weight productivity on 0.5 ha: 2040 kg	2355 kg dry weight	2720 kg dry weight	480 kg dry weight
3.2 Internal rate of return of integrated cactus pear and cochineal production is more than rate of interest 15%	*IRR* = 21%	*IRR* = 9%	*IRR* = < 8%	*IRR* = 25%

Attributes of development criteria	***Original design***	***Half of cochineal production***	***No cochineal production***	***No forage production***
3.3 Yearly economic result and cash flow are > 0 5%	Economic result: year 7; Cash flow: year 6	Economic result: year 10; Cash flow: year 6	Positive economic result and cash flow cannot be reached	Economic result: year 7; Cash flow: year 6
4 Active participation of the families in the programme 6%	60% of the families	No changes	No changes	No changes
5 Increased role for women in agricultural production and sale 4%	An increment is expected as in Peru cactus pear and cochineal are traditionally managed by women (50%)	Less cochineal production may increase women role in the crop (75%)	No expectations of new incomes of women (0%)	No changes (50%)
6 Protection of forests and permanent grassland 10%	OK	No changes	No changes	No changes
7.1 Construction of biodiversity 5%	Pasture, cactus pear, cochineal, woody species, other fruit species	No changes	All species are present except cochineal.	No changes
7.2 Soil conservation 5%	Vegetation cover, individual water infiltration basins per cactus pear plant Protection belt around the field with a living hedge	No changes	No changes	No changes
7.3 Integration of agricultural and livestock production 5%	Cactus pear forage, manure collection and distribution on irrigated agricultural fields	No changes	No changes	No integration between livestock and agricultural production

9.5 Discussion

Farmers were tacitly unskilled when they started the LRP. After problem analysis they became conscious of their real problems and the underlying causes. So, when they started research and design in order to find solutions for their problems, they were, consciously, unskilled.
The question then was how to become skilled? We found that two pathways had structured this phase of the farmers' learning process: knowledge integration and decision-making. These were not present in the four complexity levels of the problem situation with the same intensity.

The example of cochineal quality showed that synthesis of part solutions into the initial complexity of the problem occurred first by knowledge integration from low to high complexity, and then by decision-making at high complexity.

At the level of puzzle resolution (the lowest complexity level), knowledge integration was most important. Examples are to:

- Integrate the limitations of cochineal production on cactus pear into the integrated cactus pear production scenario;
- Integrate the results of local production factors into the integrated cactus pear production scenario;
- Integrate (a)biotic factors in relation to cochineal quality into adapted research on post-harvest management techniques.

At the level of effective agricultural management practices (the third level of complexity i.e. applied research), 50% of outcome referred to practical actions and 50% to knowledge integration. It should be noticed that practical action can only be reached when farmers are aware of and agree on the consequences of changed agricultural techniques. This indicates that decision-making is required before implementation. Examples of practical action were:

- Improved plantation;
- Use of pruning against cactus pear diseases;
- Adequate infestation techniques;
- Adequate post harvest management.

At hard system level, knowledge integration appeared to be dominant (more than 50%). Some examples of the LRP were:

- New investment policies to change initial design objectives and development criteria;
- Formulation of the multipurpose use of cactus pear and integration into current farming;
- Data on livestock production as input for the integrated cactus pear and cochineal production system;
- NPK input/output data incorporated into the integrated production system.

At the soft system level (the highest level of complexity), decision making was frequently carried out (88%).

Knowledge integration took place by building research components into multiple objective system levels, as well as from the hard system's level to decision-making in the soft system level. "Final" decision-making generally took place at the soft system level. When farmers were not interested in knowing the impact of a specific agricultural management technique on the whole set of farm development criteria, they could still find decision-making at the level of applied research. At this level decision-making focused on direct practical action. This is often the case when a more curative than preventive solution is required for a particular problem.

The results of a particular activity were integrated at higher complexity levels, while gaps on knowledge or data in system analysis of scenario design pushed specific research at lower complexity levels, but always with the objective to reintegrate those demanded results at the level where the missing data were experienced. Therefore, integration of results follows the direction from low to high complexity. Knowledge integration is, therefore, towards increasing complexity, in contrast to problem analysis.

9.6 Conclusions

Learning from practice is platform building, knowledge integration and decision-making. Decision-making concerns implementation of a design or an agricultural practice, or has to do with the activity agenda: selection of methodologies, continuing studies, experiments and design. Learning from practice was a trial and error procedure and an on-going process of evaluating results of an activity and planning more activities.

Learning from practice is focused on methodology. 'How did we carry out the activities'? and 'Why did the methods work and how did the procedure results'? And, also, how can we learn better in practice?" I found out that farmers did not consider the methodology for decision-making very satisfactory. According to them, it could be better, even though they agreed that decision-making procedures were very important and had a great impact on the success of the LRP (see Chapter 11).

Up to this stage, it is clear that farmers have improved from being consciously unskilled to consciously skilled workers. This means that knowledge and joint decision-making is obtained with the help of applied methodology, strict procedures and debates. However, it does not happen automatically yet.

In order to make farmers skilled in a tacit way, in other words, to ensure that farmers carry out farm innovation procedures by themselves based on an internal logic, it is necessary to study the relationship between problem analysis, goal setting, research, design, knowledge integration and decision-making.

We need further abstraction in order to make the learning process of Huancarani farmers available for new practice. The next chapter will present the development of a toolkit that will show how the Huancarani farmers learned.

Chapter 10

A management tool for interactive learning: learning *for* practice

The implementation of the Land Rehabilitation Program (LRP) was not easy. It was certainly not the type of straightforward planning we are used to in experimental research. Such a procedure was not possible anyhow. Resource-poor farmers were excluded from normal knowledge networks. The LRP felt back mainly on farmers' knowledge, thinking pathways and decision-making procedures, as well as on facilitators' knowledge. Two steps forward and one step back would be a better description of the process involved, or, going in all relevant directions simultaneously. However, there definitely was some result: the farmers recognised their autonomy and became skilled in raising questions about what they wanted. Even after the LRP had ended, farmers continued to work in platforms, always being enthusiastic to use the tools they had learned in order to analyse and experiment, integrate knowledge and make decisions at farm and community level.

In this chapter the position and the role of the methods and techniques involved will be explained. They will be presented as a model, synthesising what has happened during all those years in which the LRP was carried out. The model must be considered as a "checklist" for other development-aid programs for resource-poor farmers in extremely deprived situations, but also for European farm innovation processes.
In the following five sections the phases of problem analysis, research and design, knowledge integration, goal setting and, finally, the decision-making will be discussed.

10.1 Structuring the problem analysis phase

In the Land Rehabilitation Program, problem analysis focused on the decline of land quality, unsustainable production systems and income problems. Many aspects were analysed at the level of community and farming systems, such as geographical location, quality of natural resources, climatic conditions, social relationship between families and the market, *campesino* economy, production diversity, etc. All these aspects represent the following dimensions of development: productivity, profitability, accessibility, sustainability and autonomy.

Next, at the second level of complexity (hard systems), the analysis will focus on systems that showed potential for providing solutions to the general problem. Simulation models were assembled of specific production systems at field or agroecozone level, in which production and monetary relationships were distinguished. These, selected from the hard systems, provided an overview, insight in and understanding of system structure and behaviour.

Two components required further analysis:

- Agricultural management practices (for example cochineal infestation methods or post-harvest management techniques) in order to determine the most effective practices adapted to local production conditions;
- Factor responses that influence cactus pear and cochineal growing.

The problem analysis therefore covered four levels of complexity and systems, as shown in Figure 10.1.

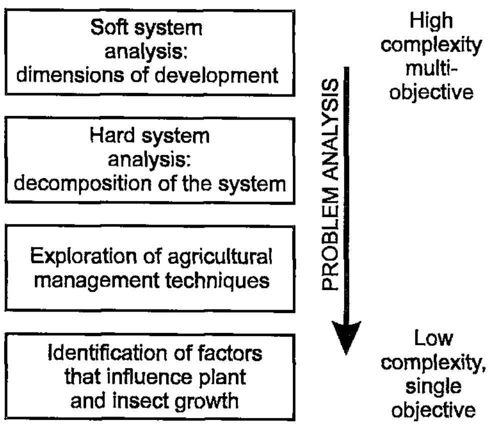


FIGURE 10.1 The problem analysis phase subdivided into four levels of complexity of the problem situation.

In the figure, the arrow indicates that the analysis needed a reductionist way of reasoning. The outcome of the problem analysis is identification of the components (and or subsystems) at four levels of complexity that require further study for problem solving. The lowest levels of complexity should result in setting a research agenda. The problem situation is translated into terms of essential variables that are subjected to experimental research. The highest levels of complexity are preparatory for setting a design agenda. The problem situation is translated in terms of required alternative production systems.

10.2 Structuring the research and design phase

Two kinds of experimental research were distinguished in the LRP: basic and applied research. Basic research focuses on explanations of phenomena. The knowledge involved raises a better understanding about what happens on the field. Applied research addresses the improvement of the effectiveness of an agricultural management practice. Applied research focuses on what must be done. Many experiments were set up in the Land Rehabilitation Program (see Chapter 7). In addition to research at component level, design was applied at subsystem levels. This concerned the creation of production scenarios at cropping and agroecosystem levels. At the cropping system level of aggregation, integrated cactus pear and cochineal production scenarios were designed and the optimal scenario was selected. At agroecosystem level the selected cactus pear and cochineal design was inserted adequately into the present agricultural production.
Figure 10.2 shows the experimental research and design phases in a diagram.

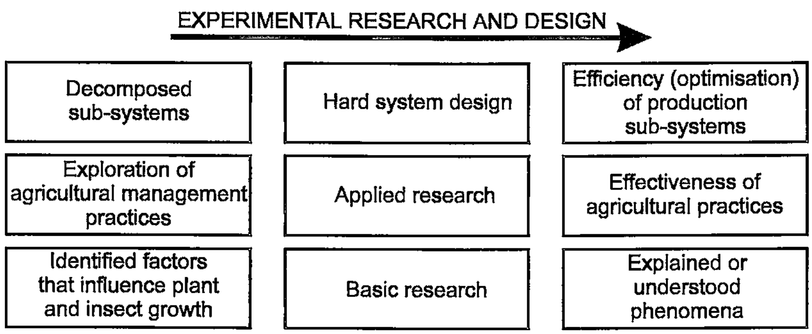


FIGURE 10.2 The research and design phases of the LRP in order to solve problems identified at three levels of complexity.

10.3 Structuring the knowledge integration phase

The knowledge integration pathway consisted of the creation of new production systems. The results of research at the lowest level of complexity (factor responses) became inputs for and contributed to applied research. The results of both basic and applied research were taken up and incorporated into hard-system scenarios. Finally, the results of design of (hard) cropping and agroecosystems were integrated into soft-system scenarios, based on client satisfaction and decision-making. Therefore, the synthesis towards complex solutions cannot be considered as a specific scientific methodology, but consists of knowledge integration between complexity levels.
Figure 10.3 shows the knowledge integration pathway between results of research and design.

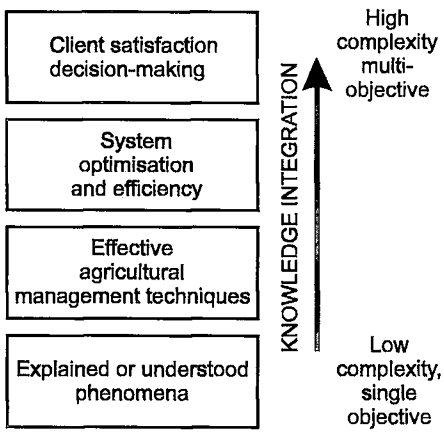


FIGURE 10.3 The knowledge integration phase from low to high complexity

10.4 Conditioning of possible solutions

The three phases as discussed above (Figures 10.1, 10.2 and 10.3) can be merged into a "U" shaped form, visualising the place and links between problem analysis, experimental research and design and knowledge integration (see Figure 10.4). In this diagram, knowledge integration must be equally important as problem analysis, as shown by the LRP. The question is, therefore, why knowledge integration became unnoticed in literature.

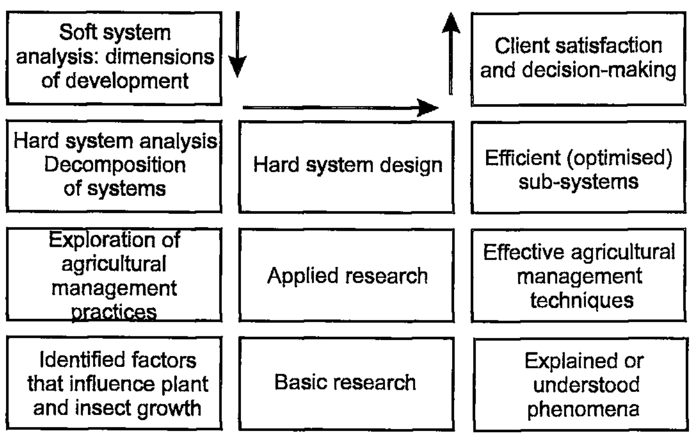


Figure 10.4 Presentation of joint problem analysis - research, design, knowledge integration of the LRP

The answer lies in the following:
- Problem analysis with a system perspective is often kept hidden in a continuing improvement of system analysis;
- Research at component level (formulated from problem analysis) is generally followed up by more in-depth experiments in the same way, rather than by translation of partial results into solutions at levels of the initial problem situation.

Knowledge integration, being a synthesis pathway to problem solving after experimental research, is linked with problem analysis and further research with feedback from the scientific world, more than from the farmers' world (initial problem situation).

The LRP concluded that problem analysis, research, hard design and knowledge integration are not sufficient. A solution, once integrated at community level, will not be maintained if the context of the invention is not sustained by coherence with the farmers' worldview, in the context of adequate actions such as laws, credit systems or retaliations in case somebody does not act as was agreed. The Land Rehabilitation Program could not be completed, according to the farmers themselves, if the community did not embed their platform decisions into a learning-process point of view. The white area in the center of the U-shaped form (Figure 10.4) shows that a design of structures and procedures inside the community, for conditioning solutions, is missing. We therefore proposed to mention this part of our tool "a design for the soft aspects of farm innovation". It refers to goal setting at the highest complexity levels (see Figure 10.5) and to soft designing (see Figure 10.6).

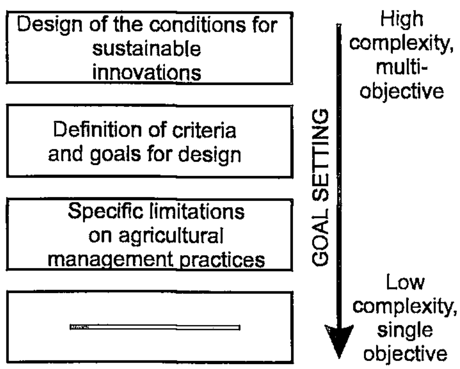


FIGURE 10.5 The solution conditioning stage by goal setting at three levels of complexity

Goal setting could be found at three levels of complexity. At soft system level, the conditions for sustainable farm innovation processes were defined. At the hard system level, general objectives were translated into precise goals and limitations to farm development. Some specific limitations were formulated at the level of agricultural management techniques.

The soft design phase

In the soft design phase, farmers practised and learned to improve their decision-making procedures. Most important, as part of soft design, was the creation and functioning of the platform. It served for discussion, exchange of experience and communication between farmers and outside stakeholders. The platform was especially structured for decision-making by all actors involved. With the help of certain instruments such as SWOT, Multi Criteria

Analysis and with-without comparison, farmers could make their points of view more explicit and could in addition, discuss their own impressions of ranking of scenarios and compare (trade-offs) between the assessed impact on development goals. Farmers selected between options and were decision-making oriented. They took decisions in order to re-structure, add or take away components or functions of the actual farming system and they did not put emphasis on any small changes on certain components. It was satisfaction-oriented.

In Figure 10.6 the design pathway and the specific methodology at the highest complexity level of the problem situation are shown.

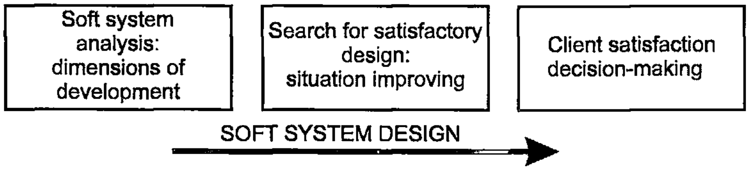


FIGURE 10.6 The soft design phase of the LRP at the highest complexity level of the problem situation

10.5 Presentation of a management tool for designing interactive learning pathways

Conditioning of the solution had to be added to the joint system analysis, research and design as well as knowledge integration. The white area of the "U"-shaped pathway is completed by designing societal structures, needed as "conditions" of solutions found by the platform. Now the model for learning in farm innovation processes has become complete.
Figure 10.7 shows the management tool for designing interactive learning pathways.

The framework clearly shows that in a complex problem situation two phases are required in order to define a design and research agenda. These phases are problem analysis and goal setting. When these phases are carried out well, the framework offers four entries to start problem solution, according to the four complexity levels of the problem situation. Design can be chosen at soft system as well as hard system levels, but can also be used as applied and basic research at component levels, for agricultural management practices and factor responses respectively. The farm innovation team may select one or, simultaneously, several levels to take action. When research and design are completed, these must be integrated into the knowledge integration phase. Results of research at low complexity levels are no longer integrated (with force) into models of problem analysis, but can now be inserted into design scenarios prepared at higher levels of complexity. Knowledge integration at system level is therefore the mix of "vertical" integration of research results with "horizontal" design of system scenarios (options).

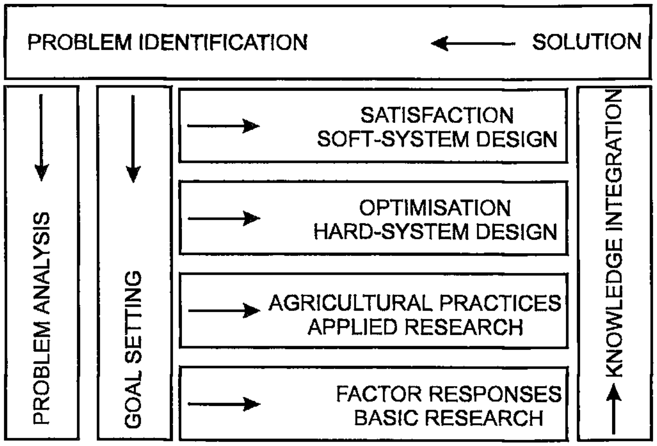


FIGURE 10.7 The management toolkit for designing interactive learning processes. After problem identification, two pathways must be worked out: problem analysis and goal setting. Then, four types of actions (research and design) can be chosen at four levels of complexity. The results of these actions must be integrated as a solution towards the initial problem. Cycles can be drawn iteratively.

10.6 Conclusions

The management toolkit offers the user many pathways to solve complex problems. This flexibility may cause problems for those who are used to count on strict procedures for research. One may ask: 'How is it possible for me as a researcher to include all phases of the management tool?' Of course, most people are restricted in their actions by time and space, but also by their voluntary restriction on specific subjects of their interest. They may become experts in farming system research, production optimisation or experimental research, others become specialists in a specific crop or study a specific discipline of plant science: plant protection, ecophysiology or soil-fertility management.

But the answer is simple. Look at the farmer. He (she) is, at the same time, a family member, agricultural producer, livestock keeper, farm manager, salesman, administrator of vulnerable rare ecosystems and so on. Farmers necessarily look at their farms with a broad, integrated and interdisciplinary view. Farmers had to learn from their own experience and that of others around them, in order to tackle all kinds of problems and seize opportunities. And they did it well, albeit, not alone. Farmers did not win their survival struggle for centuries by working their piece of land and taking care of their family. They organised themselves in all kinds of groups in order to face their hostile environment together. They even organised themselves into the platform for the Land Rehabilitation Program, because they understood that they could not make it alone referring to the design of sustainable production systems.

This is also true for the use of the management tool for designing interactive learning processes. In the case of complex problems at system level, researchers do not work alone. The tool does not pretend to be a personal management instrument in the sense that one scientist alone has to work out all phases of the tool. The tool has been made with the experience of teamwork and can be picked up by another team in order to tackle its complex problems between a group of scientists as well as together with other relevant (groups of) stakeholders.

Personally, I use the toolkit to determine the learning pathway, as a scientist that means in accordance with my specialisation and personal interest. I can also compare and make my pathway complementary to the preferred learning pathways of other members of the platform in which I participate. Maybe some white spots will show up in phases that cannot be worked out by the actual team. Then, specialists can be contracted. Each problem in relation to a specific platform of relevant stakeholders can lead to the pathways and actions of preference. It depends on the problem, whether all phases of the toolkit are needed. It depends on the stakeholders in the platform whether one or several pathways are worked out simultaneously.

But in all cases, there is a need for a person who manages the learning process as a whole, and who facilitates the chosen pathways for interactive learning. In the LRP, farmers showed enthusiasm for goal setting more than for problem analysis. The scientists preferred reductionistic problem analysis. The facilitator of the learning process had to ensure interactive strategies among stakeholders, a stimulating environment for integration of knowledge and a real balanced participation of all stakeholders in decision-making procedures. In the following chapter the applicability of the design of learning processes for the farmers in Huancarani will be shown. This will be done with the help of the toolkit.

Chapter 11

The applicability of designing pathways for learning processes: the opinions of Huancarani farmers

We found three learning pathways for resource-poor farmers in Huancarani. Together, they created a "management toolkit for designing interactive learning pathways". This device is very helpful to process managers and development facilitators in new complex situations such as farm innovation. Project leaders can use the toolkit as a checklist or as an instrument for planning and evaluation of an activity agenda. But is it really fundamental? What are its strong and weak aspects? This question can only be answered by making an inventory of the farmers' appreciation of working in a participatory project. Relevant questions were: Did the farmers really participate and how happy were they about their own roles? What did they think of the methodology they had followed in terms of importance and impact? In other words: Was the success of the LRP the result of an interactive learning process?

These questions will be discussed in this chapter. First, the present method of testing farmers' opinions will be tested. Next, the farmers' appreciation of their participation as well as their interaction during the realisation of the methodology will be discussed. Finally, the farmers' preferences for learning pathways in relation to the same indicators, as visualised in the management toolkit, will be presented.

11.1 Method for testing the farmers' appreciation of their participation in the LRP

The farmers in this program had a low level of education. It was out of the question that they would adequately indicate in questionnaires or other written sophisticated and individual procedures what they felt or what their opinions were. We had to find other approaches. So, we decided to evaluate the farmers' appreciation in the same way as we had always done: create a shared picture about the question from the activity agenda, exchange judgements, opinions or ideas and take a shared decision. Once we noticed that all members of the platform had the same activity, moment and context in view, we continued by asking about their appreciation of participating in the LRP: was their participation sufficient, effective, useful, etc.?
Either Eloy Vargas or myself guided the discussion. When we saw that everybody had said what he or she wanted to say, we continued by asking what mark they would like to give to their participatory grade. They could give one joint value between bad and very good. We assigned numbers for evaluation: one for bad and five for very good. The decisions in question concerned farmers' appreciation for certain activities. However, not only farmers participated, other relevant stakeholders became involved as well and gave their opinions freely. The meeting kept on discussing their valuation until all farmers agreed. We only accepted one shared opinion. So, when the group gave "sufficient" (3), everybody had to agree.

Problems showed up. Sometimes it happened that one farmer could not agree. For instance, when the group evaluated that the participation rate of farmers was good, only one farmer insisted on his opinion that it was not good, simply because he himself had not participated because of his absence at a particular moment or because he simply refused to participate. Such an opinion could not considered as being relevant. It was to the group (or finally to Eloy Vargas) to judge which opinion had to be included or not. Our experience was that in this way, the farmers could evaluate and express their appreciation of most activities quite clearly and with common sense. Finally, a specific score on an activity was frequently compared to other already evaluated activities. We asked the farmers questions like: 'Was this activity more participatory than was practised in the fieldtrip?' or 'Was this method of the same importance to the success of the LRP as the on-farm applied experimental research activities?' We found that scores were seldom changed after comparison. This implies that farmers were able to assign a value quite well and did not change their opinion easily. That gave us the impression that the figures presented here are reliable.

It was not difficult to get farmers in line. The road to consensus became easier the more farmers became used to it. All figures presented in the following section were produced in this way. They are only meaningful in their mutual connection for one specific group of people at one specific moment.

There were three questions:
- What did the farmers think of their contribution to the success of the LRP for each specific activity considering the importance of the activity, addition of valuable information or insight in order to solve the initial problem?
- What were the farmers' feelings about their participation in the program (happy or not happy)?
- Did the farmers really interact? Was there sufficient interaction between farmers?

The reactions to these questions were clustered considering three aspects of the LRP: methodological phases, complexity levels and the management toolkit.

11.2 Farmers' appreciation of applied methodology

Mainstream researchers accept that abstraction and complexity in development questions are hard to manage by people with little education. However, clustering was needed in order to get an overview of and insight into the design of learning processes. For the farmers this resulted in a big step towards abstraction.

The LRP subdivided all farm-innovation activities into seven different groups of methods:

- Problem identification and problem analysis;
- Goal setting for getting the present, unsatisfying situation changed;
- Soft designing (e.g. structuring the society, company or organisation and decision-making procedures);
- Hard design (e.g. structuring the farm, crop rotation or integrated production of a cropping system);
- Applied research;
- Basic research;
- Knowledge integration from low to higher levels of complexity.

The farmers' appreciation was also clustered into four different levels of complexity:

- Soft systems: organisation, decision-making at farm and community level;
- Hard systems: farm management production (sub)systems;
- Agricultural management techniques;
- Level of growing factors (water, nutrients or climate for production quantity and quality).

The next subsections compare the three evaluation criteria with the methodological phases and complexity levels.

11.2.1 *Farmers' opinions on the contribution of each methodology to the success of the LRP*

The farmers considered the importance of methodology to the success of farm innovation quite flexible. Table 11.1 shows that soft designing got the highest appreciation and basic research the lowest.

TABLE 11.1 Farmers' opinions on the contribution of methodological phases to the success of the farm innovation process (farmers' opinion is the average score of clustered activities). The score of each methodology ranged from poor (1), unsatisfactory (2), satisfactory (3), good (4), to very good (5).

Methodological phase	*Score*
Problem analysis	2.7
Goal setting	3.1
Soft design	4.5
Hard design	3.6
Adapted research	3.1
Basic research	1.8
Knowledge integration	3.0

A similar result was found when the activities of the Land Rehabilitation Program were evaluated by classification at complexity level (see Table 11.2). On average, the score of system levels of high complexity was satisfactory. Activities carried out at low complexity such as agricultural practices and factor responses of plant and insect growth were considered unsatisfactory.
The table indicates that farmers assigned more importance to work on complex questions related to their community or their own farm. Questions related to research were valued as being less important.

TABLE 11.2 **Farmers' opinions on the contribution of methodology to the success of farm innovation per complexity level of the problem situation. (Farmers' opinions are the average score of clustered activities.) The score of each methodology ranged from poor (1), unsatisfactory (2), satisfactory (3), good (4), to very good (5).**

Complexity level of the problem situation	*Score*
Soft systems of dimensions of development	3.6
Hard systems of cropping and farming production	3.4
Agricultural management practices	2.6
Factor responses	2.1

11.2.2 *Farmers' appreciation of their participation in the LRP*

To start with, farmers' participation will be presented according to the subdivision of methodological phases (see Table 11.3)

TABLE 11.3 **Farmers' opinions on the levels of participation versus methodological phases. (Farmers' opinions are the average score of relevant evaluated activities. The score of each methodology ranged from poor (1), unsatisfactory (2), satisfactory (3), good (4), to very good (5).**

Stage	*Average farmer participatory score*
Problem analysis	2.7
Goal setting	3.9
Soft design	3.3
Hard design	2.3
Applied research	2.4
Basic research	1.0
Knowledge integration	2.9
Total farm innovation process	2.7

Table 11.3 shows that almost all methodologies were moderately appreciated as activities in which farmers were able to participate. Only goal setting reached a higher score, which indicates that farmers were able to participate in discussions on their future, and develop their own goals and criteria for farm innovation. The score for participation in experimental research was low. This may mean that the farmers need much more training and facilitation support for this activity or, that farmers just prefer to leave research in the hands of specialised teams. It may be that the appreciation will change according to the kind of subject. A wide range between scores could be found in nearly every phase.

Farmers' participation should be carefully watched during hard, exact designing activities, as the figures show that they feel themselves not sufficiently involved. The LRP appeared not to be as participatory as it would like to be.

TABLE 11.4 Farmers' opinions on participation versus complexity level. (Farmers' opinions are the average score of clustered activities). The score of each methodology ranged from poor (1), unsatisfactory (2), satisfactory (3), good (4), to very good (5).

Complexity level of the problem situation	*Average farmer participatory score*
Soft system of dimensions of development	3.2
Hard system of cropping and farm production	2.4
Agricultural management practices	3.2
Factor responses	1.4
Total farm innovation process	2.7

Table 11.4 shows that participation was higher when problems at high complexity levels were discussed. Also, activities at the level of farm management practices guaranteed satisfactory participation by farmers. We accepted that the soft system level of complexity in question is more suitable for participatory strategies. Further, when a participation strategy is required for a learning process as a whole, extra attention should be paid to participation of farmers in hard system questions and basic research. If the farmers do not appreciate this, the platform in which they are the essential stakeholders should at least focus on the farmers' participation in the knowledge integration phase between complexity levels.

11.2.3 *Did farmers really interact?*

Many projects in Bolivia applied participatory approaches without looking too seriously at the quality or "interactiveness" of participation. These projects frequently saw participation as a means for reaching development goals. For such projects, participation was not a goal in itself. In other words, when a project emphasises consultative and collaborative (contractual) participation between farmers and development workers, farmers do not reach self-confidence, nor gain power or become autonomous. In contrast, the LRP considered these aspects of development as most important, referring directly to the second goal.

The quality of participation is not guaranteed when farmer participation is a fact. We need to value grades of interaction in terms of classification of interaction types. With the help of research carried out by Hamilton (1995) nine types were identified:

0 No participation;
1 Physical participation;
2 Consultative participation;
3 Collaborative participation;
4 Feedback loop interaction;
5 Interaction based on knowledge generating;
6 Self-directed and contrast-based interaction;
7 Coalition building interaction;
8 Concept building interaction.

Some of these kinds of interaction had a common feature in relation to interactive learning. We clustered these types of interaction into four interactive learning approaches. The classification of interactive learning approaches was more relevant in the LRP than the differences between types of interactiveness. The four interactive learning approaches were:

- Non-interactive learning type: observations of the interactive types 0, 1, 2, and 3;
- Dependent learning approach: observations of type 4;
- Interdependent learning approaches: observations of types 5, 6 and 7;
- Concept-building learning approach: observations of type 8.

Neither an average interactive score nor an average interactive learning approach, calculated from a set of activities, have an intrinsic meaning. The interactive approach is a scale for different ways of interacting that has to be understood by multiple variables instead of a simple increasing level of one indicator of "interactiveness". Therefore, rather than assigning an average "numeric score", interactiveness will be described in terms of ranges and frequencies.

With the help of the farmers in the platform, we scored their interaction types for all relevant activities of the LRP. These were grouped for interactive learning approaches and methodological phases (see Table 11.5).

TABLE 11.5 Interactive learning approaches versus methodological phases of the Land Rehabilitation Program.

	Frequencies of interactive learning approaches			
Methodological phases	***Non-interactive learning***	***Dependent learning***	***Interdependent learning***	***Concept building learning***
Problem analysis	11	9	6	0
Goal setting	0	0	5	2
Experimental research	7	2	2	1
Design	3	2	3	2
Knowledge integration	9	7	5	1
Methodology of the LRP	30	20	21	6

Table 11.5 shows that farmers hardly interact in research activities. Interaction concerning the problem analysis activities was not high either. Knowledge integration occurred with various types of interaction, except for structuring the concept. Goal setting and designing appeared to be primarily interactive actions.

From Table 11.5 it may also be concluded that the methodology of the LRP and the learning process involved was not always interactive. Almost 40% of the actions were of the non-interaction type. Dependent and interdependent interactive learning approaches were found in more than 25% of the applied activities of the LRP.

Table 11.6 shows the interactiveness scores for actions at the four levels of complexity.

TABLE 11.6 Interactive learning approaches versus complexity levels.

	Frequencies of interactive approaches			
Levels of complexity	***Non-interactive learning***	***Dependent learning***	***Interdependent learning***	***Concept building***
Soft system	8	6	8	3
Hard system	8	5	7	1
Agricultural management practices	6	6	6	2
Factor responses	8	3	0	0
Methodology of the LRP	30	20	21	6

The lowest level of complexity (puzzle resolution) can be characterised by low interactive approaches. The other three levels of complexity showed a similar picture: a highly diversified use of participatory and interactive approaches except for concept building. Closer observation shows a tendency (without statistical proof) towards relatively more concept building interaction at the soft system level (highest complexity).

The tables above showed that some methodological phases of the LRP were more interactive than others. Therefore, the overall methodology cannot be classified as being interactive, especially when all methodological phases were included for analysis. Since these stages were all part of one activity agenda and overall farm innovation methodology, the interactive success depended on high interaction at each stage. However, the result on interactivity may be explained "better" if specific learning pathways (parts of the LRP) are considered. If methodology of a particular phase, evaluated as a non-interactive approach, were to be complemented and/or compensated by instruments of another phase or pathway, with an interactive (interdependent learning or concept building) approach, the overall result may well be satisfactory. Therefore, the management toolkit is needed for visualising learning pathways so that each phase can be identified and the relationship between phases become clear.
In the following sections the results of the same three evaluation criteria, but now visualised in the toolkit, will be presented.

11.3 Farmers' preferred learning pathways visualised in the management toolkit

The preceding paragraph showed interesting results with respect to the overall scores of the Land Rehabilitation Program as well as specific scores on methodological phases or complexity levels. Because so far no model had been developed to structure the relationship between the methodological phases and the complexity levels, the farming innovation process of the LRP (the learning pathways) could not be evaluated. The toolkit made clear that based on the experience of the LRP, many learning pathways may be selected. With the help of this toolkit, it is now also possible to "interpret" the appreciation of LRP interactive learning by the platform's members. Using the same criteria (for contribution of the methodology to the success of the LRP, farmer participatory levels and interactive approaches), strong and weak aspects of the learning process in the LRP can be found, and the use of the toolkit be evaluated.

11.3.1 *Farmers' preference for farm innovation methodology*

The participants of the platform in Huancarani attributed a score of 3 (satisfactory) on a scale of 1 to 5 to the overall methodology of the LRP. However, their appreciation of parts of the farm innovation methodology varied a great deal, (see Figure 11.1). Methodological cycles can be drawn according to the stakeholders' interest. Farmers were conscious of the fact that the initially offered methodology was not sufficient to solve identified problems. It indicated a methodological opportunity. The methodology as such could be improved on the basis of selecting the most successful activities carried out so far, or by adding new methodology. Goal setting and soft system design improved the farmers' appreciation of the overall methodology. Farmers said that the methodological cycles of related methodology at the highest complexity level of farm innovation and rural development contributed best to the success of the LRP. Design methodology received the highest score. Goal setting also scored high at system complexity levels, because of its future outlook and direct link with design approaches. This part of the LRP was considered crucial for the success of the program.

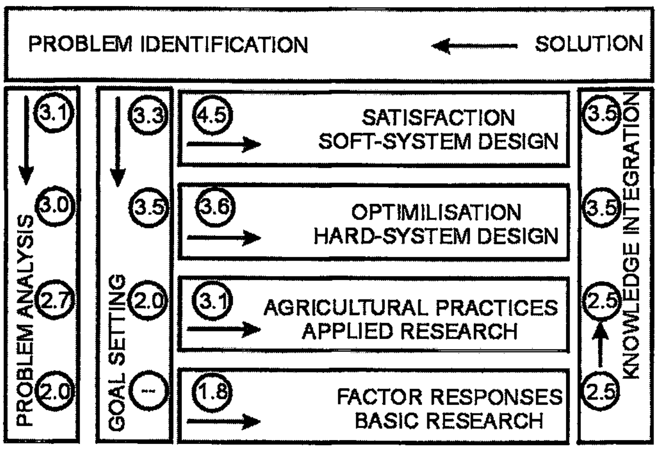


FIGURE 11.1 Farmers' opinions on the contribution of the methodology to the success of farm innovation.

The conclusion is that the LRP's success can be attributed to the participants' appreciation of learning by designing rather than that of research at lower complexity levels. Or, in other words, the participants think that research does not contribute sufficiently to learning. If knowledge integration does not take place from results of research into decision-making at high complexity levels, final problem solution integration cannot take place. But farm innovation without applied and basic research was not possible either. The same is true for problem analysis in relation to goal setting. Farmers constructed their own preferred pathway, however without rejecting other learning pathways to be implemented by other members of the platform.

The framework indicates that in order to obtain a successful farm innovation process, methodology must include hard and soft system design as well as research, problem analysis and goal setting. If a reductionist problem analysis is followed from high to low complexity, and research is carried out at the low levels, special attention should be given to knowledge integrating methodology in which research results are integrated into the initial level of complexity.

11.3.2 *Farmers' participatory pathways*

Farmers said that their contribution to the overall methodology of the LRP was sufficient and satisfactory. This is visualised with the toolkit as shown in Figure 11.2. Farmers attributed a score of on average 2.7 (satisfactory) out of a scale of 1 to 5. We could understand this score. Farmers must have difficulties with a continuously high participation in all kinds of methods and activities, especially as the LRP consisted of a very large number of diversified activities over a long period of time. Moreover, the farmers' interest in participating in questions close to their own everyday problems reduced their time for active participation on abstract, very specific complex research questions that were very remote from their own experience.

So, farmers selected a "preferred" methodology for active participation. Therefore, following their line of thinking on the importance of methodology, we saw that participation by farmers was high in activities at high levels of complexity (soft system level) such as goal-setting activities and knowledge integration, which were greatly appreciated. It is obvious that the farmers' contribution to experimental research may, in practice, only be expected when sufficient compensation from goal setting and knowledge integration is involved.

Because of limited funds, it was not possible to contract professionals for all research. Therefore, farmers were asked to carry out research. Their enthusiasm and their feelings for doing research were therefore important for completion of the research plans of the platform. Figure 11.2 shows that farmers were more involved in applied research and highly involved in the knowledge integration phase after the applied research activities had been completed. This does not mean that farmers themselves should always be involved in research activities. It is quite possible that the applied research and certainly basic research is done by professionals and elsewhere. However, farmers must understand the results in terms of consequences for their own way of farming and experimenting, thus for their own learning process.

The same phenomenon can be found at higher system levels. Results of hard system design (characterised by low farmer participation) require integration into soft system design. Farmer participation in knowledge integration is more important than farmer participation in the design of "hard systems". Therefore, the hard system level and basic research do not necessarily require high farmer participation for getting a good final score for the overall methodology.

More important than the implementation of a specific research or design activity is that farmers themselves have control over the definition of the overall research agenda: their learning pathway. Evaluation of the obtained results and further planning is more important than restriction on research activities in the sense that these must be carried out by farmers. Therefore, farm innovation methodology should focus on the availability of information and decision-making procedures for farmers themselves (or several social actors in a platform for farm development). Facilitators and scientists should strongly support this process.

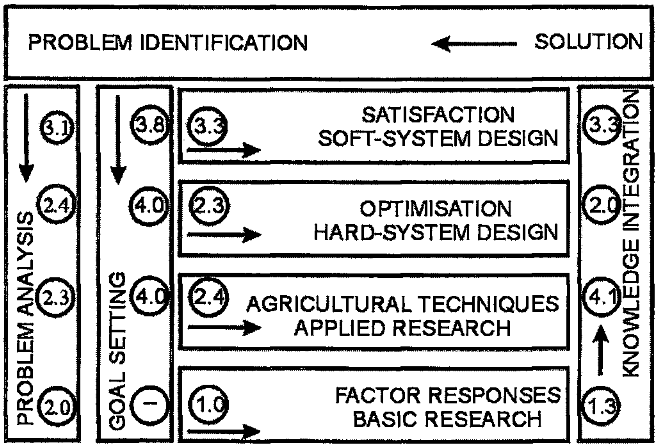


FIGURE 11.2 Farmers' opinions on their participation in the LRP farm innovation methodology on a scale ranging from 1 to 5: poor (1), satisfactory (3) and very good (5).

As we want to have farmers' participation in a development-aid project we may now conclude from Figure 11.2 that we need to create the following work plan:
- Start simultaneously with the problem identification and the goal setting phases and care for the interaction between the two, especially when farmers do not show much interest in problem analysis;
- Continue with a soft system design, because this is the farmers' preference and also because this decision-making phase includes and overrules all other methodology and activities.

On the basis of this procedure, a methodological cycle was drawn in the top of the toolkit. In other words, a leaning process is started with reference to farm innovation and rural development. It is decision-making oriented, identifies and/or formulates the learning process and prepares further inside examination of the problem. This pathway however, always requires data from research as without these there is nothing that can be synthesised into a new production system. This means that another pathway needs to be drawn up:
- Continue problem analysis at lower complexity levels; decompose into sub-systems and components;
- Start basic or applied research;
- Integrate knowledge (results of research) into models to optimise production systems;
- Integrate the results of hard system design into soft societal and decision-making design.

11.3.3 *The design of an interactive pathway for learning*

Interactive approaches say something about the quality of farmer participation. In Section 11.2.3 the types of interactive approaches for the various methodological phases and four complexity levels were shown. It was clear that no important differences were obtained between the complexity levels except for basic research (a non-interactive methodology). The other levels showed different types of interactive approaches: dependent learning processes and interdependent learning processes. So, complex questions can provide opportunities for becoming interactive although this was not always the case.

Problem analysis and experimental research were classified as being non-interactive. Goal setting was characterised by interdependent learning processes and concept building interaction (see Figure 11.3). Design and knowledge integration were more interactive than problem analysis and experimental research. However, these phases presented a wide range of interactive types. Experimental research, basic research and the hard system design are non-interactive. The interactiveness may be improved when basic research is followed by applied research and especially with on-farm and farmers' experimenting.

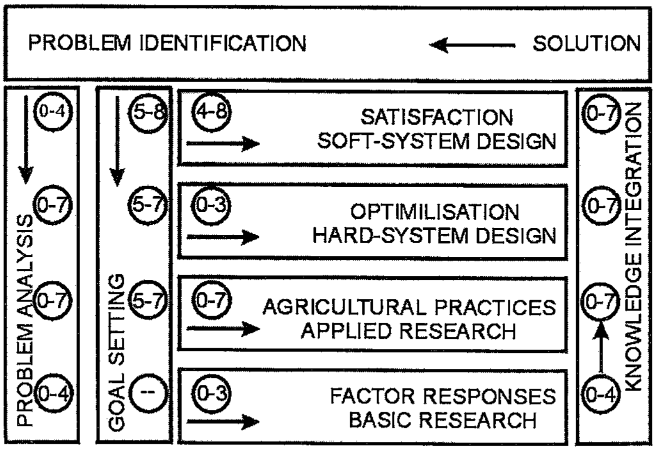


FIGURE 11.3 The range of interactive types found in the LRP farm innovation methodology.

Interactivity is improved when interactive-poor and hard designing activities are integrated with activities for the creation of decision-making models at the soft system level. In this respect, all methodology stages seem to be essential for farm innovation, although not all phases can be interdependent interactive approaches.

From the framework it can be concluded that the safest way to obtain highly interactive approaches is to follow the pathway from goal setting, soft system design and knowledge integration. A second option is: goal setting, adapted research and knowledge integration. In the second pathway, special attention must be paid to the selection of specific on-farm activities for experimental research, because not all kinds of applied research showed to be interactive (see Annex 2).

11.4 Conclusions

Farm innovations for the benefit of rural development demand a context in which they can be maintained. Such a context may be a law, a set of agreements, creation of institutions, decision-makers at community levels in a platform of relevant stakeholders, or even sanctions when accepted rules for sustaining innovations are not followed. The LRP found out that the platform with active participation of farmers is pivotal to the success of farm innovation processes. And it is the platform that is the place where the conditioning of the societal context of farm innovation takes place.

The management toolkit for the design of learning pathways is the result of a case: resource-poor farmers with extremely complex problems and a low budget and therefore poor research conditions, working together for the benefit of their own community. To a certain extent the toolkit is not new, for there is literature available on problem analysis, hard and soft systems, agronomic design, and knowledge integration. However, the toolkit shows the diversity of learning pathways for farmers who interact with other stakeholders in a platform for farm innovation.

The methodological phases that received the highest score for their impact on the success of the LRP also received the highest farmer contributions. The quality of the farmers' participation showed a similar pattern. The conclusion can be drawn that farmers participate more actively, based on interdependent interactive learning, when they evaluate the methods and techniques as highly important for the LRP.

If farmers evaluate an activity as less important, this does not mean that the activity should not be carried out. Such a farmers' opinion tells us more about their mood, preference and capacity to participate in a certain activity, than about the real importance of the activity. The LRP showed that farmers do not necessarily have to participate in all activities or methodological phases that comprise the "best" ways of interactive learning. It is more important that farmers remain knowledge integrators and are consulted to make decisions about results of activities that were not carried out by them. This study also makes clear that farmers' participation and interaction is not necessarily reached in farm innovation processes but that it is essential in the development of the farmers' autonomy and learning processes.

Chapter 12

Concluding remarks

Development-aid projects often deal with problems that are basic to the lives of resource-poor people. Food security, health, family income and community development are familiar subjects. Impact objectives of development-aid projects are therefore difficult to reach. Their context is problematic or complex and a network of reliable knowledge is usually lacking. Some other characteristics of development-aid projects are: little funding, lack of infrastructure, no executives, and projects always located at remote places. Yet, donors expect a good deal from their investments. They want large returns for little money in a short time.

Successful development-aid work also very much depends on knowledge. Normally, science provides such knowledge networks. But in the case of development-aid work, the scientific contribution is not sufficient. Scientists usually expect facts and figures based on hard experiments and modelling, but development-aid cannot provide funds for such experiments. Our case even shows that local people are not really interested in basic research, probably because they cannot see the relationship between optimised research conditions and the, sometimes chaotic, everyday reality of their farms. Scientific approaches to development-aid work do not develop either, because most scientific journals are not keen to accept results from development-aid projects such as the LRP case. The development-aid worker therefore has to do his work under marginal conditions, fieldwork as well as research.

Our experience was that working on a project like the LRP would have been much easier if the team had had something like a manual on farm innovation procedures at its disposal. However, we did not have such an instrument. Our own enthusiasm, creativity and persistence were crucial to make the LRP successful. Thanks to our careful registration of everything that happened during the LRP, we could recognise a pattern in the activities we carried out.

This pattern can be used as the required manual. This thesis will make the manual, presented as a "management toolkit for the design of interactive learning pathways", available to other development-aid projects under extreme conditions, facilitators of farm innovation in developed countries, and process managers of development policies from regional or national governments.

12.1 Design of learning processes

The purpose of this thesis is to learn from problem solving processes for complex problems by focusing on a specific case and its accompanying, also complex, methodology. It addresses the generation of a management toolkit for interactive learning for the development of sustainable farming systems. It is an attempt to learn from practice, to link practice with theory (state of the art) of interactive design, to learn from it through naming, framing and in-depth reflection and to make it advantageous to other development processes.

The LRP did not pretend to develop new methodology as existing methodology was used or adapted. So, what does the framework do if it is not considered to be a new methodology? The framework is a simple and powerful tool for managing complex problem issues such as farm innovation. It can be considered as a discovery of how methodology is organised and how instruments and methods are linked. Therefore, it is a system in itself, of methodological components and relations. It is limited by the identification of a problem issue. Inputs are: involved people, knowledge, funds and specific conditions at the site, while outputs may be the solution or part-solutions for the problem situation, as well as improved countervailing power of the involved people.

One of the main characteristics of the toolkit is that it is iterative and cyclic, by which missed methodological opportunities can be taken up again, in-depth studies may be suggested later on in the time table, methods can be carried out simultaneously, and even the identified problem can be adjusted. Another essential factor is the flexibility of the toolkit. Different activities or procedures can be selected in order to reach an objective, according to the favourite methodology of a certain stakeholder. But, it is more. On the one hand, several methodological components may contribute to the same result. For example, there were many instruments that contributed to the analysis of the problem. The farmers' way of analysis was different from the scientific way, but both contributed to a better understanding of the problem. On the other hand, one methodological component may contribute to more than one objective. The creation of and comparison between the production scenarios of cochineal contributed to the knowledge integration of soft system decision-making in the first place. But they contributed also to the identification of key actors that influence productivity and utility of cochineal (elements for in-depth experimental research), as well as to the more precise definition of development criteria (as part of goal setting).

The management tool looks complicated but it is not. It was even applicable for the local facilitators of Huancarani who have had little education. The tool facilitates any rural development procedure. With the toolkit, the project leader (project facilitator) is able to apply design methodologies in complex agreements at different levels of complexity of the problem situation. This is to say that he/she is able to:

- Describe the different phases of a design process for agricultural problems. He/she can also describe related objectives and integrated activities, such as the integration of various disciplines, information, methods and techniques;

- Design specific learning pathways, according to the capacities and interests of the stakeholders;
- Improve a learning process by adding adequate methods and techniques on four complexity levels of the problem situation and seven phases of a general farm innovation methodology;
- Recognise the phase of each stakeholders' learning pathway in the actual design process.

The essential idea behind a learning pathway is not so much the short-term technical output nor the sum of its methodological components, but the procedure, how the pathway works. The relationship between components is of high importance. A learning pathway is cyclic, flexible and iterative. Several loops can be part of a learning pathway. If a first design loop at high complexity level (in the top of the framework) lacks precise information about some essential components or relationship between components, further problem analysis and experimental research may be required to improve the scenario (new soft or hard systems). The learning pathway then, is the sum of several design loops as well as experimental research cycles, according to the need of the designer. Hence, problem analysis and experimental research can also be seen as essential parts of the design pathway.

The question arises whether the management toolkit represents a general design approach or a very complete experimental research procedure. In other words, which phase (design or experimental research) is dominant in complex problem solution? Conclusions of experimental research cannot be integrated directly into solutions of the problem. Results of experimental research must pass through knowledge integration into soft design (the initial white spot; see Figure 10.4). Design therefore, dominates experimental research if complex (hard or soft system) problem situations are considered, whereas the toolkit represents a design approach.

12.2 The role of the platform facilitator

Working under the extreme development-aid conditions of poor and devastated regions also demands that the facilitator and farmers (or other stakeholders) involved are well positioned. The project leader or platform facilitator of a development-aid project must make stakeholders aware of the fact that changing their unacceptable present situation is a matter of designing, rather than scientific research. Designing consists of technical design on the one hand and interactive-learning design on the other. Designing demands attitudes such as skilled communication, presentation, working with uncertainties, working under poor, imperfect conditions, creativity, respecting norms and values of others, and project formulation.

The platform facilitator must also be skilled in making explicit what stakeholders want to learn and change, what they are good at, and in evaluating in how far their objectives have been achieved.

It was our experience that the more the design skills were improved, the better stakeholders communicated. A project leader must, therefore, be skilled in timely recognition of jammed working and thinking patterns. The management toolkit can only be applied successfully when facilitators and stakeholders are willing to become creative. Pure knowledge is important, but it is not necessary that this also belongs to the mental properties of the facilitator. Knowledge may be obtained by contracting specialists, but the stakeholder himself must produce creativity and decision-making power.

12.3 The role of the stakeholder

Working in the LRP showed us that farmers became quickly interested in the case: farm innovation (first objective) as well as the methodology and learning issue (second objective). The reason for this is that they could easily see the relationship between the two objectives. So, in the project identification of both hard and soft design learning pathways appeared to be very important. Success in farm innovation can be attained when the stakeholders involved feel their responsibility for the whole project and not only their own private problem. Therefore, it is important that stakeholders also learn how to make agreements, to determine delegations, and find the right person for certain questions as well as care for quality. In the LRP farmers learned to make decisions systematically. Also, they can now understand that the art of decision-making is nothing else but making a choice between possibilities. Other aspects of importance were to:

- Take responsibility;
- Play a role when decisions are made in groups;
- Accept choices of the whole group;
- Develop one's own vision;
- Be skilled in negotiation between having right and getting right;
- Discover somebody's strong and weaker sides;
- Improve the capacity of analysing data, observation and experimentation;
- Improve the weaker sides of a group member;
- Dare to make norms and values explicit during discussions.

12.4 The interactive strategy

Design, and especially interactive design, creates new roles for the actors. Who is the designer: the scientist, the farmer or the platform based on the interaction among the social actors involved? Without any doubt, farmers are the ultimate implementers of the proposed changes in the conventional production system. They are the ones who have to decide whether to take action or not and require an adequate decision-making procedure. Farmers are therefore designers, based on their pivotal role in goal setting, their support in formulating proposals for production alternatives or nature resource management and selection among scenarios. They also play a dominant role in the determination of the activity agenda. The analysis of the LRP showed that farmers have their own style of planning and decision-making (the procedure from doing to thinking). These are characterised by a pragmatic, step by step pathway and consist of cycles in the upper part of the management toolkit: goal setting and soft design. The initially proposed activity agenda (to a large extent influenced by the outsider facilitator) could not be maintained. Moreover, each step (action) by the farmers was highly influenced by the results of the previous activity, but also by their motivation and creativity at the moment. In addition, they were influenced by the organisational level of the farmers union, seasonal pressure of work in agricultural production and cultural activities.

Knowledge of the local situation, practical experience, intuition, imagination, a contemplative attitude as well as rites are important elements in farm innovation. Farmers can also be considered capable of analysing and incorporating external information and influences.

Farmers have to combine all these elements and must be seen as managers who make choices for farm innovation on the basis of different sources of (sometimes-contradictory) information. A farmer is therefore a designer (creator of agroecosystems), decision-maker, producer, and administrator of natural resources. But farmers do not stand alone. They have to contrast their vision and opinion with that of other relevant stakeholders.

Interaction is based on communication between farmers and scientists. Communication may be very difficult when the farmers and scientists depart from a different cosmovision, logic and reasoning. In the case of the LRP, the team and farmers showed multi-perspective thinking. The farmers showed enthusiasm for reflection in action (from doing to thinking) whereas the facilitators and scientists focused on analysis before implementation (from thinking to doing). These different ways of thinking explain the different learning pathways that were selected, including specific and favourite activities and instruments. In the Land Rehabilitation Program, farmers showed more interest in:

- Studying the negative trends in farming in the past;
- Describing the desired future farming and the definition of farm development criteria (goal setting);
- On-farm experiments with a problem focus on agricultural handling;
- Direct observation and counting;
- Platform development;
- Scenario designing.

Scientists give priority to system analysis (farming system analysis), basic and applied research, multiple goal planning and scenario testing. These individual and favoured pathways must be respected and promoted. But also, the results of each activity need to be compared and integrated so that they can contribute to knowledge exchange and joint decision-making by all relevant stakeholders involved. Interaction strategies are then:

- Improving the quality of farmers' involvement in as many stages and activities of farm innovation as possible;
- Preventing omitting the knowledge integration and soft system decision-making phases;
- Avoiding a dominant relationship of one stakeholder group over others and allowing continuous renegotiations of the activity agenda.

The essence of the interactive strategy is therefore respect for and complementary use of contributions from different worldviews or contrasting learning pathways necessary for farm innovation. Interactive design intends to improve the joint human performance in development processes.

The framework for research methodology shows integration of farmers' and scientists' contributions to the overall methodology. Most activities are carried out with a dominant contribution by one of the two. The experience of the Land Rehabilitation Program is that the research agenda is generally not a joint action with equal contributions from the people involved in all its activities. Interaction is more a question of discussion, comparison and linking of outcomes of activities, which were carried out by one of the social actors (with his or her specific worldview and favourite pathway of design). The LRP showed that it is not necessary, efficient or possible that farmers or scientists carry out all activities together.

It is of greater importance that farmers control (and are supported in) the definition of the (flexibly arranged) activity agenda and become capable decision makers for further study and implementation. It makes more sense to promote basic research in the exclusive hands of specialised research centres, than putting restrictions on the methodology for those activities that cannot be carried out by or together with farmers. Interactive design must be rooted in a broad spectrum of methodology.

The analysis of the LRP methodology with the help of the management toolkit showed that the types of interactive learning approaches varied according to the methodological phase, complexity level, as well as the specific instrument (activity) applied. Interaction varied between extremes: from farmers participating as workers on experimental plots that were prepared by scientific research institutes (non-interactive), to interdependent learning processes and concept building interaction. The essence of interaction in this concept is not so much transfer of knowledge or technology, but facilitation of a constant learning process in the hands of, and guided by, the target group themselves. This requires special procedures.

12.5 The role of science

The underlying dialectic relationship of the construction of the toolkit is between practice and theory. In other words: which intellectual framework would make this particular action (the LRP) meaningful (Checkland 1985 in Hamilton 1995)? The contradiction between theory and practice can be translated into tension between conclusions of generated (scientific) knowledge by analysis and experimental research prepared by the scientists on the one hand, and practical experience, goal-setting and decision-making (applied management knowledge) in design approaches by the farmers on the other.

This tension also generates options for people's action. If the tension is translated into either practice or theory, in the long run farmers' learning may fail. If the tension is transformed into the link of "complementary" contributions of these apparently extreme poles, interaction between scientists and farmers is the logical outcome for farm innovation. Both knowledge carriers are required and the tension between them must be managed in a positive way. This also means that respect must be demonstrated between stakeholders and scientists and that both specific activity agendas must be accepted.

Science can contribute in making these interactive development processes of complex problem situations more effective. On the one hand, soft system design can be improved, especially the procedure for platform building, as well as decision-making in the group. On the other hand, it is of great importance that soft system design is linked with hard technical design. Integration of beta and gamma sciences then becomes a challenge, because it has to deal with contrasting points of view on how to structure, realise and finally interpret the results of the activity agenda. How can interactive designing, based on a constructivist paradigm, be made more acceptable and practicable?

The management toolkit does not provide the user, apart from the very important overview of the learning process, with any instruments to analyse the level of learning processes of one or more stakeholder groups. One could think in terms of diagnostic instruments to identify the "quality" of the farmers' learning process. In the line of learning from tacitly to consciously unskilled or skilled, knowledge is needed to know how and at what level farmers learn. This is needed to understand how farmers' learning processes function, in addition to the self-chosen learning pathway visualised in the toolkit.

12.6 Conclusions

The decision-making platform was a helpful instrument as the farmers of Huancarani still continued to work without facilitators following the proposed learning pathways. They implemented cactus pear and cochineal production and enhanced their income while rehabilitating the soil quality of exhausted land. This shows that the farmers of Huancarani have learned to learn.

And how did they learn? They selected adequate methodology and procedures. A selection of methodology is only of interest to those who have a problem and want to find a solution methodically. The toolkit presented a broad overview of farm innovation phases, instruments and methods. It also offered different learning pathways (procedures) to farm innovation (situation improving). The toolkit may help to select a methodology that makes the points of departure more explicit to the stakeholders and improves understanding and respect between stakeholders.

Because of the rich overview of the methodology and the different (but clear) design pathways, the toolkit is, in the first place, a help for communication among the people (several stakeholder groups) that are involved in a farm innovation process. The kit may be used as an instrument for emancipation of farmers in the planning and evaluation of the activity agenda, as well as for discussing knowledge increments, knowledge integration and decision-making. It can also be used for re-planning the farm innovation procedure, or for taking concrete action in the field. In this respect the toolkit can be taken up by people who are effectively designing, who are involved in activities that include the stages: problem analysis, goal setting, experimental research, design and knowledge integration.

The toolkit is also a powerful tool for managers of farm innovation processes. It rapidly presents process-facilitators with an in-depth insight into:

- Possible (complementarily or contrasting) learning pathways;
- Specific motivations for or opinions of the stakeholders involved (scientists, politicians, pressure groups and farmers for example);
- Planning of the role of each member of the platform;
- Identification of trade-offs and conflicts of interests.

With the toolkit, integration of results of activities can be structured and joint decision-making facilitated. Besides the use of the framework to plan and implement farm innovation processes, the diagram presents the manager (and the team as a whole) with the opportunity of looking back to what had been done. It turns out to be a participatory feedback instrument but can also be used for systemisation of the experience (or self-monitoring and evaluation) scheme.

The toolkit can also be used by anyone who wants to study farm innovation processes (or general complex problem situations) from the outside. In such cases it becomes a diagnostic or evaluation instrument for the organisation and procedures of farm innovation and of other complex problem situations. It may give insight into and understanding of the following issues:

- Which stakeholder groups are present in the process and what is their influence, involvement, role or contribution?
- Which dominant pathway or different learning pathways to farm innovation have been chosen by the group as a whole or by specific stakeholders?

- Which development or process policy of a development organisation (research centres, NGOs or first-line farmer organisations) has been implemented?

Other uses are:

- Identification of a possible conflict of interest among stakeholders;
- The outlook to restructure the activity agenda;
- Identification of new learning pathways or additional pathways to fortify development processes;
- Evaluation of interactive design and "beta-gamma" integration.

The toolkit provides the opportunity to integrate experts of several academic disciplines into interactive interdisciplinary teams. It is therefore a useful window for analysis and for the organisation (design) of teams for development processes.

Annex 1

Methodology of the Land Rehabilitation Program

TABLE ANNEX 1.1: Methods and instruments of the problem analysis at four complexity levels and the actors involved

Complexity levels	*Methods and instruments*	*Actors*
Soft systems	- Secondary literature review on relevant aspects	Scientists
	- Participatory rural appraisal:	Together
	- Community walk	Together
	- Workshop and community meetings	Together
	- Starter activities and unexpected events	Farmers
	- Key informant testimonies (history of near past: persistent negative changes), ex large landowner and	Farmers
	a typical working day of a farmer woman	Farmers
	- Social drama	Farmers
	- Ranking problems	Together
	- Transect map	Together
	- Flow diagram of environmental problems	Together
	- Study tours: exchange on decision making procedures	Scientists
	- Farmers union meeting to analyse data	Together
Hard systems	- Structured questionnaire: population count, agricultural census and out-migration	Together
	- Secondary literature review	Scientists
	- Community walk	Together
	- Workshop and community meetings	Together
	- Semi-structured interviews and key informants	Farmers
	- Energy-flow diagram at agroecozone level	Scientists
	- Cost-benefit analysis	Scientists
	- Farmers union, meetings to analyse data	Together
Agricultural management techniques	- Secondary literature review	Scientists
	- Semi-structured interviews and key informants	Farmers
	- Study tours	Together
	- Farmers union meetings to analyse data	Together
Production factors	- Secondary literature review	Scientists
	- Study tours	Together
	- Farmers union meetings to analyse data	Together

TABLE ANNEX 1.2 Methods and instruments for goal setting and actors involved

Complexity levels	*Methods and instruments*	*Actors*
Soft systems	- Definition of the concept of development - Formulation of premises for sustainable development - Definition of package of demands - Design objectives	Farmers Farmers Together Together
Hard systems	- Design objectives (increased family income and no competition with traditional food production for example) - Map design of desired future farm	Together Together
Agricultural management practices	- Design objectives (forage production and adequate use of local resources before external inputs are applied)	Together
Production factors	—	—

TABLE ANNEX 1.3 Activities of basic and applied research and actors involved

Complexity levels	*Methods and instruments*	*Actors*
Soft systems	—	—
Hard systems	—	—
Agricultural management practices	- Cactus pear plantation schemes and densities - Cactus pear pruning techniques - Cactus pear disease management - Cochineal infestation techniques - Cochineal production management in sheds (study tour) - Protection of cochineal infestation at field level - Effect of post-harvest management techniques on cochineal quality (classification by size and classification moments, killing methods, and drying period) - Determination of cochineal quality by perceptual modalities (colour, smell, hardness, humidity, size)	Together Together Scientists Together Scientists Scientists Scientists Farmers
Production factors	- Identification of cactus pear diseases and plagues - Cochineal production factors: temperature, humidity, cactus pear variety and light - First instar infestation levels on cochineal productivity/kg cladode (study tour) - Effects of biotic and abiotic factors on cochineal quality (temperature, egg releasing stage, solar radiation and cochineal size)	Scientists Scientists Scientists Scientists

TABLE ANNEX 1.4 Design activities and actors involved and actors involved

Complexity levels	*Methods and instruments*	*Actors*
Soft systems	- Social organisation of cactus pear and cochineal producers	Together
	- With-without cases compared (bottleneck and SWOT analysis)	Together
	- Three development alternatives compared (MCA)	Together
	- Risk and uncertainty analysis by scenarios with changed production objectives	Scientists
Hard systems	- Cochineal production and income optimisation (cost benefit analysis)	Scientists
	- Multipurpose use of cactus pear at field level	Farmers
	- Integrated cactus pear production system at family level	Together
	- 75 ha. Integrated cactus pear and cochineal production system	Together
	- Livestock production sub-system	Scientists
	- NPK plant nutrients input output flow diagram	Scientists
Agricultural management practices	—	—
Production factors	—	—

TABLE ANNEX 1.5 Activities of knowledge integration and decision making

Complexity levels	*Results*	*Knowledge integration and decision-making*	*Actors involved*
Soft systems	The selection of cactus pear production among development alternatives	- Organisation of producers at local, regional and national levels - Organisation of cochineal sale - Discussions and final acceptance of new organisation by traditional farmers union	Together
	The design of Integrated cactus pear and cochineal accepted.	- Continuation of cactus pear plantations - Search for funds for research and design - Organisation of national congresses	Together
	The design of Integrated cactus pear and cochineal accepted.	- Promotion in other communities	Farmers
	Impact calculated of scenarios with changed production objectives	- Extra attention on the promotion of the livestock component	Scientists
Hard systems	Calculations of nutrient balance of cactus pear fields	- Integration of NPK flow diagram in the integrated cactus pear and cochineal design at agroecozone level - Delineation of cactus pear integration in the conventional farming system	Together
	The cactus and cochineal integrated production design	- Data for integration at agroecozone level	Together
	Livestock production calculations	- Improved decision-making in relation to the integrated cactus pear and cochineal design	Scientists
	Design at agroecozone level	- Acceptance of the design and planning of plantations on communal land	Together

Complexity levels	***Results***	***Knowledge integration and decision-making***	***Actors involved***
	Integration of the cactus pear and cochineal design in conventional farming	- Knowledge integration for decision-making at soft system level	Together
	Calculations of labour and capital requirements for the design	- Changed design objectives and development criteria - Search for external development (production investment) supports cactus pear plantations	Together
Agricultural Practices	Optimal planting, pruning and disease control	- Improved plantation schemes with disease "free" cladodes - Cactus pear pruning of old and diseased orchards - No further use of chemical fungicides	Farmers
	Successful cochineal infestations and first harvests	- Integration of cochineal productivity in economic as well as decision-making design - Reduction of cochineal infestation investment - Changed cost-benefit model of cochineal production	Together
	Cochineal production in sheds	- No further research nor investments for cochineal production in sheds	Together
	Optimal post harvest techniques and identification of quality indicators (to be managed autonomously by farmers on-farm or at the market place)	- Further farmer research in the field on cochineal quality indicators - Important justification for final decision-making on the integrated cactus pear and cochineal scenario - Better negotiation conditions with cochineal buyers - Lowered risk and uncertainty of cochineal productivity and profit calculations	Farmers Farmers Farmers Scientists
Production factors	Identification of cactus pear diseases	- To stop basic research, and start adapted research with practical outlook for disease control	Scientist
	Positive productivity indicators of cactus pear	- Continued promotion of cactus pear and definition of applied research on cactus pear production	Scientists
	Real indicators for cochineal production	- Continued promotion of cochineal production (but not with focus of "unlimited red gold mine") - Definition of agenda for applied research on cochineal - Inputs for economic cost benefit analysis	Together
	Identification of principal biotic and abiotic factors for post harvest management techniques	- Definition of applied research agenda - Farmer research on local classification system for cochineal quality	Together

Annex 2

Farmers participatory levels and interactive approaches

TABLE ANNEX 2.1 Farmers participatory levels and interactive approaches for problem analysis

Complexity level	*Methods and instruments*	*Farmer participatory level*	*Interactive approach**
Soft systems	Secondary literature study	No participation Low impact No precise data available	0
	Participatory Rural Appraisal: Description of the actual situation at farm and community level	Low participation Low capacity No analysis or projection	2
	Historical review	Low participation Enthusiasm and commitment Confirmation and acceptation	4
	Persistent negative changes in the near past	High participation High capacity Understanding Formulation and projection	5
	Workshop and community meetings	Regular participation (dominant farmer leader input) Open reflective atmosphere	4
	Starter activities	High participation High motivation No direct connection with LRP goals and activities	6
	Unexpected events	Low participation High connection with LRP problem analysis	4
	Key informant testimonies	Low participation Important information	2
	Social drama	High participation Low additional information for the LRP	3
	Transect map	Regular participation Lack of understanding of figures	2
	Flow diagram of environmental problems	Very participatory High reflective No agreement on conclusion	4
	Study tours	No participation	0
	Ranking problems	High participation No consensus	6
Hard systems	Secondary literature review	No participation Regular impact because few relevant information available	0
	Structured questionnaire	High cooperation Regular participation in analysis (only special cross check team) High enthusiasm when results were presented	4
	Energy (NPK) flow diagram	No participation	2
	Cost benefit analysis	Low participation Data were commented Limited understanding	2

Complexity level	*Methods and instruments*	*Farmer participatory level*	*Interactive approach*
	Cropping system comparison	Regular participation Discovery Projection inducing	5
	Agroecozone modelling	Regular participation Confirmation of data Conclusion inducing	7
	Farmers union meetings to analyse data	High participation Regular economic interest or understanding	4
Agricultural management techniques	Secondary literature review	No participation No decision making	0
	Study tours	Few people participated High impact of farmer to farmer information and opinion exchange Effective for decision making	7
	Farmers union meetings to analyse data	High participation Discussion and conclusion oriented	4
Production factors	Secondary literature review	No participation No conclusions or decision making	0
	Study tours	Few people participated Highly impressive but low understanding Not adequate decision-making	4
	Farmers union meetings to analyse data	Confusion Little understanding	4

* = With the help of research carried out by Hamilton (1995) nine types were identified:

0 No participation;
1 Physical participation;
2 Consultative participation;
3 Collaborative participation;
4 Feedback loop interaction;
5 Interaction based on knowledge generating;
6 Self-directed and contrast-based interaction;
7 Coalition building interaction;
8 Concept building interaction.

TABLE ANNEX 2.2 Farmer participatory levels and interactive approaches for goal setting

Complexity level	***Methods and instruments***	***Farmer participatory level***	***Interactive approach****
Soft systems	Definition of development	High participation Very interesting discussions and high capacity of formulation	8
	Formulation of premises for sustainable development	Chaotic discussions but rich opinions Very active participation by the farmers Well defined future vision, forward looking attitude in combination with realism	8
	Definition of package of demands	Not very easy to define criteria with precision beforehand Flexible interpretation of criteria Discussion and comprehensiveness of weighting hardly accepted Difficulties with the ecological criterion	5
	Design objectives	High participation Low capacity for precise formulation	5
Hard systems	Design objectives (increased family income for example)	High participation Low capacity for precise formulation	5
	Map design of future farming	High participation High capacity and enthusiasm Planning oriented	6
Agricultural management techniques	Design objectives (forage production)	High participation Low capacity for precise formulation	5
Production factors	—	—	—

* = With the help of research carried out by Hamilton (1995) nine types were identified:

0 No participation;
1 Physical participation;
2 Consultative participation;
3 Collaborative participation;
4 Feedback loop interaction;
5 Interaction based on knowledge generating;
6 Self-directed and contrast-based interaction;
7 Coalition building interaction;
8 Concept building interaction.

TABLE ANNEX 2.3 Farmers' participation and interactive approaches in research

Complexity level	*Methods and instruments*	*Participatory level of farmers*	*Interactive approach**
Soft systems	—	—	—
Hard systems	—	—	—
Agricultural management techniques	Cactus pear plantation schemes and densities	High participation High diversity of opinion and practice Local (individual) decision-making and application New techniques proposed	5
	Cactus pear pruning techniques	Regular participation Low initial confidence	4
	Cactus pear disease management	Low participation, high concern Observations in the field only High complexity of problem No practical solution oriented	2
	Cochineal infestation techniques	Regular participation Curiosity and farmer data recording Adjustment of production technology Direct application of results	1
	Cochineal production management in sheds (study tour)	Low participation Highly motivating and eye opener Decision-making oriented	4
	Protection of cochineal infestation at field level	Low participation Observation only Low interest	0
	Effect of post-harvest management techniques on cochineal quality (classification by size and classification moments, killing methods, and drying period)	Low participation High complexity Direct application of results	6
	Determination of cochineal quality by perceptual modalities (colour, smell, hardness, humidity, size)	High participation Direct application Proud and security Strong negotiation oriented	8
Production factors	Identification of cactus pear diseases and plagues	Low participation No practical solutions	2
	Cochineal production factors: temperature, humidity, cactus pear variety and light (study tour)	No participation No question of interest	0
	First instar infestation levels on cochineal productivity/kg cladode	No participation Too complex	0
	Biotic and abiotic factors on cochineal quality (temperature, egg releasing stage, solar radiation and cochineal size)	No participation High concern and interest of farmers Decision making on applied research agenda	0

*** = See table before**

TABLE ANNEX 2.4 Farmers participation and interactive approaches in design

Complexity level	*Methods and instruments*	*Participatory level of farmers*	*Interactive approach**
Soft systems	Social organisation of cactus pear and cochineal producers	High participation Class consciousness improving, Very difficult New concepts about organisation and quality control	8
	With - without cases compared (bottleneck and SWOT analysis)	High participation Most suitable for farmers Decision making oriented	7
	Three development alternatives compared (MCA)	Regular participation No farmer calculations, Culturally not accepted that several criteria are transformed to one score, Decision-making oriented	6
	Three production scenarios compared based on changed production objectives (MCA)	No farmer participation in design Risk analysis and risk-avoiding attitude, Postponement of decision-making, Good for facilitation development processes New insight campesino economy thinking	4
Hard systems	Cochineal production and income optimisation (cost benefit analysis)	Low participation, Improved definition of economic criteria Limited understanding of calculations,	2
	Multipurpose use of cactus pear at field level	High participation Integration into actual farming system, Integrated approach	8
	Integrated cactus pear production system at family level	Low participation, No decision-making High complexity, Integration and adaptation to local conditions	2
	75 ha. Integrated cactus pear and cochineal production system in the agroecozone	Regular participation, Consolidation and decision making New production (livestock feeding) practices Stimulation of communal activities Confirmation and action oriented	6
	Livestock production sub-system	No participation in design Just farmers' opinion inventory before design, Input for the agroecozone design	2
	NPK plant nutrients input output flow diagram	No participation in design Validation and decision-making oriented after design Sustainability focus	4

* = With the help of research carried out by Hamilton (1995) nine types were identified:

0 No participation;
1 Physical participation;
2 Consultative participation;
3 Collaborative participation;
4 Feedback loop interaction;
5 Interaction based on knowledge generating;
6 Self-directed and contrast-based interaction;
7 Coalition building interaction;
8 Concept building interaction.

TABLE ANNEX 2.5 **Farmer participation and interactive approaches in knowledge integration, organisation and decision-making**

Complexity Levels	*Results*	*Knowledge integration, organisation and decision-making*	*Participatory levels of farmers*	*Interactive approach**
Soft systems	Selection of cactus pear production among development alternatives	Organisation of producers at local, regional and national levels Organisation of cochineal sale Discussions and final acceptance of new organisation by traditional farmers union	High participation Initial confusion about the place of the farmer union Doubts about working together with large agricultural enterprises Knowledge generation and decision-making	7
	The design of Integrated cactus pear and cochineal accepted.	Continuation of cactus pear plantations Search for funds for research and design Organisation of national congresses	Regular participation Enthusiasm and planning oriented	4
	The design of Integrated cactus pear and cochineal accepted.	Promotion in other communities	Regular participation Farmer to farmer promotion of cochineal production	3
	Impact calculated of scenarios with changed production objectives	Extra attention regarding the promotion of the livestock component	No participation Low farmer interest in future problems of implementation of design	2
Hard systems	Calculations of nutrient balance of cactus pear fields	Integration of NPK flow diagram into the integrated cactus pear and cochineal design at agroecozone level Delineation of cactus pear integration into the conventional farming system	Low participation Too complex for decision-making	4
	The cactus and cochineal integrated production design	Data for integration at agroecozone level	Low participation Little interest of design at family (farm) level	3
	Livestock production calculations	Improved decision-making in relation to the integrated cactus pear and cochineal design	Low participation No decision-making	2
	Design at agroecozone level	Acceptance of the design and planning of plantations on communal land	High participation Understanding of the need for communal solutions	7
	Integration of cactus pear and cochineal design in conventional farming	Knowledge integration for decision-making at soft system level	Regular participation Good for motivation Local research experiments planned	6
	Calculations of labour and capital requirements for the design	Changed design objectives and development criteria Search for external development (production investment) support cactus pear plantations	Low participation Knowledge generation Precision of farmers' (economic) development concepts	4 + 8

Comple xity Levels	*Results*	*Knowledge integration, organisation and decision-making*	*Participatory levels of farmers*	*Interactive approach**
Agricul tural Prac-tices	Optimal planting, pruning and disease control	Improved plantation schemes with disease "free" cladodes Cactus pear pruning of old and diseased orchards No further use of chemical fungicides	High participation Increasing confidence Farmer individual experimenting and comparison	3 + 3 + 4
	Successful cochineal infestations and first harvests	Integration of cochineal productivity in economic as well as decision-making design Reduction of cochineal infestation investment Changed cost-benefit model of cochineal production	High participation Motivation Local research opportunities Training facility	4 + 6
	Cochineal production in sheds	No further research nor investments for cochineal production in sheds	Regular participation Frequently direct farmers' observations and discussions	6
	Optimal post harvest techniques and identification of quality indicators (to be managed autonomously by farmers on-farm or on the market place)	Further farmer research in the field on cochineal quality indicators Important justification for final decision-making on the integrated cactus pear and cochineal scenario Better negotiation conditions with cochineal buyers Lowered risk and uncertainty of cochineal productivity and profit calculations	High participation Motivation increasing High confidence Decisive for further action (action oriented)	7 + 8
Produc-tion factors	Identification of cactus pear diseases	To stop basic research, and start adapted research with practical outlook for disease control	Low participation High concern remained	0
	Positive productivity indicators of cactus pear	Continued promotion of cactus pear and definition of applied research on cactus pear production	Low participation Confirmation what already was observed in the field No new knowledge	1
	Real indicators for cochineal production	Continued promotion of cochineal production (but not with the focus of the "unlimited red gold mine") Definition of agenda for applied research on cochineal Inputs for economic cost benefit analysis	Low participation Very complex but with focus on realism Necessary for blending farmers' initial enthusiasm and economic realism	1
	Identification of principal biotic and abiotic factors for post harvest management techniques	Definition of applied research agenda Farmer research on local classification system of cochineal quality	Low participation Promotion of adapted research Curiosity	4

* = See table before

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Samenvatting

Verafgelegen in het Andes-gebergte van het departement Cochabamba, Bolivia, ligt een dorpje op een steile helling genaamd Huancarani. De bewoners zijn hoofdzakelijk kleinschalige boeren die leven van gemengde landbouw/veeteelt. De mogelijkheden tot het opbouwen van een bestaan zijn de laatste decennia afgenomen. Dat komt door niet-duurzaam landgebruik. Door rechtstreekse toepassing van landbouwmethoden, geadviseerd door de landbouwvoorlichtingsdienst alsmede landbouwprojecten, die de landbouwpraktijk van de vruchtbare valleien rond de stad Cochabamba overnamen, daalde de toch al zorgwekkende bodemkwaliteit in korte tijd. De steeds stijgende prijzen van chemische landbouwinputs werden niet gecompenseerd door hogere inkomsten van productie. De boer zag zich 'gedwongen' natuurlijke hulpbronnen aan te spreken. Hij moest de grond nog intensiever bewerken, alsmede bossen en grasland op steile hellingen ontginnen. Een andere overlevingsstrategie was het verlaten van de streek.

Deze vorm van landbouw heeft ernstige gevolgen gehad voor de streek. De bodems zijn sterk geërodeerd. Er is sprake van vorming van alsmaar dieper wordende ravijnen die landbouwgronden laten verzakken en wegspoelen, en die zelfs huizen aantasten. Het gebied is volledig verpauperd, jonge mensen migreren naar de steden of starten cocateelt in het tropische laagland.

Diverse ontwikkelingsprojecten van overheidsinstellingen en Niet-Gouvernementele Organisaties (NGOs) hielden zich bezig met het zoeken naar antwoorden op deze zeer complexe problematiek. Hoewel de oplossingen die aangedragen werden verschillend van aard waren, bleven het onderzoek en het voorlichtingstraject van zulke voorstellen over het algemeen hetzelfde. Boeren werden nauwelijks betrokken bij de ontwikkeling van die oplossingen, wel bij de promotie van technologische pakketten en caritashulp.

Enkele NGOs draaiden de zaak om na uitvoering van uitgebreid en participatief onderzoek naar oorzaak en gevolg van de huidige situatie van het boerenbedrijf. Zij lieten de boeren zelf studeren en beslissingen nemen over wat er gebeuren moest. De vraag was hoe de boeren een bestaan konden opbouwen op basis van de huidige kwaliteit van de natuurlijke hulpbronnen. Er werden twee duidelijke doelstellingen geformuleerd:

1 het innoveren van de landbouw met behulp van duurzame landbouwsystemen met inachtneming van de lage kwaliteit van de natuurlijke hulpbronnen. Het plan moest uiteindelijk leiden tot de introductie van teelten waarmee gemarginaliseerde ex-landbouwgrond zou kunnen worden gerehabiliteerd;
2 de organisatie en scholing van de boeren wat moest leiden tot verbetering van het vermogen van de boeren om het management van ontwikkelingsprocessen zelf ter hand te nemen en verder te sturen in een steeds veranderende context.

Steeds meer boerengemeenschappen raakten enthousiast over dit concept en maakten, of via de NGO werkzaam in hun gebied of zelfstandig, deel uit van het Land Rehabilitatie Programma (LRP; een samenwerkingsverband tussen NGOs, onderzoeksinstellingen, boerenorganisaties en een onderzoekproject). De eerste boerengroepen kwamen na analyse van het probleem en visualisering van de oplossing uit op de ontwikkeling van de geïntegreerde teelt van tuna (de cactusvijg, *Opuntia ficus-indica* Mill.) en de cochenille (schildluis voor de productie van rode kleurstof, *Dactylopius coccus* Costa). Deze 'ontwerproute' werd daarna overgenomen door andere boerenorganisaties. De Wereldbank

besloot een onderzoekproject (PITC) te financieren om antwoorden te vinden op technische en economische vraagstukken van de tuna- en cochenille-teelt.

Eén van de gebieden waarin het LRP functioneerde was de rurale gemeenschap Huancarani, gekozen tot casus van dit onderzoek. In nauwe samenwerking met de boeren en hun organisaties werd een discussieplatform opgericht, dat permanent moest functioneren als coördinatiecentrum voor alle activiteiten op het gebied van rurale ontwikkeling. De activiteiten bestonden ondermeer uit een scala van veldwerk, promotie- en besluitvormingsactiviteiten, historisch onderzoek, probleemanalyse, on-farm experimenten en het ontwerpen van alternatieve productiesystemen. De activiteiten werden in twee leerfasen ingedeeld:

- boeren leren van onderzoek en ontwerpen in de praktijk uitgevoerd door henzelf of door anderen en
- boeren leren over de leerprocessen die zich tijdens de LRP voltrokken. Op die manier ontwierpen en verbeterden boeren hun eigen leertrajecten om zelfstandig en zelfbewust de ontwikkeling van hun gebied ter hand te nemen.

Daarnaast beseften zowel de boeren, als de wetenschappers en de facilitator van het LRP landbouwinnovatie-leerproces dat de werkwijze gebruikt kon worden voor de aansturing van nieuwe leerprocessen van (andere) boeren. Dit kan gezien worden als de derde leerfase.

Hoofdstuk 1 brengt de lezer op het spoor van interactieve leerprocessen voor landbouwinnovatie. Het laat het doel en de reikwijdte van het onderzoek zien. De beperkingen en mogelijkheden van het Land Rehabilitatie Programma worden gepresenteerd aan de hand van een voorbeeld over de complexiteit van de activiteitenagenda tijdens de probleemanalyse.

Hoofdstuk 2 gaat dieper in op het ontstaan en de uitvoering van het Land Rehabilitatie Programma. Daartoe wordt eerst een analyse gemaakt van de relatie tussen het gebrek aan goede landbouwgrond en emigratie. Verder wordt uit de veelheid van rurale gemeenschappen die deelnamen aan het LRP, een casus geselecteerd voor verdere analyse. De keuze van Huancarani als casus voor onderzoek wordt beargumenteerd aan de hand van de eigenschappen van het gebied en de motivatie van de boeren. Zij wilden zowel technisch-landbouwkundig innoveren als procesmatig interactief leren.

Hoofdstuk 3 beschrijft het gebied in termen van zijn biotische en abiotische kwaliteiten. De geschiedenis van het landgebruik en landeigendom wordt geanalyseerd met als doel de negatieve tendensen met betrekking tot de kwaliteit van de grond te verklaren. De huidige productiewijzen en problemen rond de bedrijfseconomie worden beschreven in termen van natuurlijke hulpbronnen (land), kapitaal en arbeid. Gender-gevoelige aspecten worden in het perspectief van landbouwinnovatie geplaatst. Uit de beschrijving van de culturele context van het LRP blijkt dat de boeren in Huancarani reeds op diverse wijze waren georganiseerd om de belangen van de boeren op de één of andere wijze te behartigen: type Inca-organisaties, boerenvakbonden, alsmede commissies en besturen van activiteiten van NGOs. Ook werd duidelijk dat de boeren er, in vergelijking met wetenschappers, een geheel eigen karakteristieke visie op na houden wat betreft het concept ontwikkeling, en ook contrasterende besluitvormingsprocedures volgen.

Hoofdstuk 4 toont hoe het werkproces met de Huancarani-boeren werd aangepakt. Eerst wordt de complexiteit van de problemen van Huancarani-boeren vastgesteld. Aan de hand daarvan worden voorstellen gedaan om die complexiteit beheersbaar te krijgen door middel van keuzen voor methodologie, procedures en activiteiten, gegroepeerd volgens vier complexiteitsniveaus van het probleem. Op basis daarvan wordt een theorie geponeerd over de wijze waarop de problemen van het gebied zouden kunnen worden aangepakt. Dit heeft alles te maken met het doel van permanent kunnen leren door en samen met boeren. Ten slotte valt de theorie uiteen in drie niveaus van leren door boeren: leren in de praktijk, leren van de praktijk en leren voor de praktijk. Daarmee is het werkproces voor de uitvoering van het LRP vastgelegd.

Hoofdstuk 5 beschrijft hoe identificatie van de problemen van de boeren wordt aangepakt. De lange lijst van problemen wordt vervolgens op drie manieren geanalyseerd:

- het bepalen van negatieve trends tussen het boerenbedrijf, de markt en de natuurlijke hulpbronnen,
- de ecologische impact van de ene agro-ecozone op de andere en
- de prioriteitsstelling in de problemen bekeken vanuit een duurzaamheidperspectief.

Clustering maakt duidelijk wat de samenhang is tussen problemen en bevestigt de noodzaak om te werken aan de autonomie van boeren tijdens ontwikkelingsprocessen.

Hoofdstuk 6 beschrijft hoe het platform met beslissingsbevoegdheid ontstaat. Uit de eerste platformdiscussies wordt duidelijk welke doelen de boeren hadden. Met behulp van een toekomstvisie en analyse van de problemen (zie Hoofdstuk 5) worden maatstaven geformuleerd voor de oplossing van hun problemen. Dat leidt uiteindelijk tot ontwerpdoelen op de drie leerniveaus zoals die gedefinieerd zijn in hoofdstuk 4. Leren *in* de praktijk heeft tot doel het ontwerpen van duurzame landbouwproductiesystemen met nadruk op de teelt van tuna en cochenille. Leren *van* de praktijk beoogt boeren weerbaar te maken zodat zij het ontwikkelingstraject zelf ter hand konden nemen. Dit doel wordt geoperationaliseerd door middel van de uitgevoerde activiteiten, procedures en processen te systematiseren, onderkennen en te verbeteren. Vervolgens wordt gezocht naar patronen van toegepaste methodologie die het mogelijk maken nieuwe leerprocessen te ontwerpen. Dit is het doel van leren *voor* de praktijk.

Hoofdstukken 7 en 8 bespreken de leerroute van boeren in de praktijk. Na introducties over de tuna-teelt en de cochenille-productie worden in hoofdstuk 7 de aanpak en resultaten beschreven van uitgevoerd onderzoek als onderdeel van het LRP. Hoofdstuk 8 gaat daarop door en stelt het ontwerpen van de geïntegreerde teelt van tuna en cochenille centraal. Er worden diverse scenario's ontwikkeld en het uiteindelijke ontwerp, een optimaal productiesysteem, wordt geïntegreerd in het huidige productiesysteem van de subtropische agro-ecozone in Huancarani.

Hoofdstuk 9 neemt dan afstand van het leren in de praktijk en start een analyse over hoe het leren van boeren tot stand kwam. Op zich is de creatie van het platform de eerste strategie om te kunnen leren. Het platform staat er niet alleen voor en wordt ondersteund door twee overkoepelende organisaties van het LRP: de één gericht op onderzoek en promotie van de teelt, de ander op boerenorganisatie en export van cochenille.
Het wordt duidelijk dat leren na experimenteel onderzoek en ontwerpen zich voornamelijk voltrekt langs drie lijnen: integratie van kennis van lage naar hoge complexiteitsniveaus, het ontwerp van een platform voor discussie en besluitvorming, en het instellen van besluitvormingsprocedures met betrekking tot de selectie van ontworpen scenario's die het beste passen en de meeste voldoening geven. De stap-voor-stap integratie verloopt via resultaten van basisonderzoek (productiefactoren) naar toegepast onderzoek (technische

teelthandelingen) en het ontwerpen van harde (exacte en rekenkundige) systemen om uiteindelijk onderdeel te worden van 'zachte' besluitvormingssystemen. Een voorbeeld van de resultaten van onderzoek met betrekking tot de kwaliteit van cochenille laat zien dat integratie van resultaten van onderzoek en ontwerp van harde en exacte productiesystemen uiteindelijk altijd opgevolgd worden door besluitvormingsprocessen van het type 'zachte', moeilijk definieerbare systemen. Drie technieken staan centraal om besluitvorming te ondersteunen: sterkte/zwakte analyse (SWOT), vergelijking met en zonder project (with-without case) en Multi Criteria Analyse (MCA) in diverse uitvoeringen.

In hoofdstuk 10 worden de methodologische resultaten, opgedaan tijdens de uitvoering van onderzoek en ontwikkelingsactiviteiten, geordend en gegroepeerd. Vervolgens worden deze stukken als een puzzel in elkaar geplaatst. Dan blijkt dat na probleemanalyse, onderzoek, ontwerpen en kennisintegratie een methodologisch gat ontstaat waardoor aangedragen oplossingen niet terugvertaald kunnen worden naar de complexiteit van het probleem in de beginsituatie. Daarom is naast probleemanalyse een fase nodig die wij doeldefiniëring hebben genoemd, en naast het harde systeem-ontwerpen is het ontwerpen van zachte besluitvormingssystemen noodzakelijk. Dit laatste kan gedaan worden zowel door geschikte structuren en momenten te ontwerpen waar boeren van gedachten kunnen wisselen, maar ook door de sociale vaardigheden van de boeren in groepswerk te verbeteren en procedures te ontwerpen die garanderen dat boeren inspraak en beslissingskracht ontwikkelen. Het ontwerpen van leerwegen voor landbouwinnovatie kan samengevat worden als:

- twee mogelijkheden in de voorbereiding: probleemanalyse en definiëring van doelen,
- daarna geven vier ingangen (op vier complexiteitniveaus) voor een methodologisch vervolg: basisonderzoek, toegepast onderzoek, hard-systeemontwerpen en zacht-systeemontwerpen,
- vervolgens kunnen de resultaten bij elkaar komen door middel van een fase van kennisintegratie,
- uiteindelijk wordt besluitvorming aangeboden op het hoogste complexiteitniveau (zie Figuur 10.7).

Dit schema staat bekend als de 'management toolkit' voor het ontwerpen van interactieve leerprocessen.

Hoofdstuk 11 evalueert alle methodologische fasen en de management toolkit op de volgende criteria:

- tevredenheid van de boeren over de toegepaste methodologie, in andere woorden, de mate waarin een specifieke methodologie volgens de boeren heeft bijgedragen aan het succes van het LRP,
- opinie van de boeren over de mate waarin zij actief hebben geparticipeerd in het LRP,
- opinie van de boeren over de kwaliteit van de participatie: interactieve strategieën.

Over het algemeen zijn de scores voldoende (niet goed of zeer goed). Dat betekent dat de methodologie nog duidelijk verbeterd kan worden. Dezelfde methodologische fasen scoren hoog op de drie criteria: doel definiëring, ontwerp van zachte systemen en kennisintegratie. Probleemanalyse en theoretisch experimenteel onderzoek scoren minder wat betreft de bijdrage aan landbouwinnovatie, boerenparticipatie en interactieve strategieën. Sommige fasen zijn meer interactief dan andere, waardoor de totale methodologie niet direct als interactief mag worden beschouwd. De interactie verbetert wellicht wanneer specifieke leerwegen van boeren worden geëvalueerd. Dit kan echter alleen duidelijk worden gemaakt met behulp van het ontwikkelde management-instrument.

Het succes van het LRP kan eerder worden toegeschreven aan het ontwerpen op hogere complexiteitniveaus dan aan experimenteel onderzoek op lage complexiteitsniveaus. Boeren verkiezen de ontwerproute boven de onderzoekweg. Kennisintegratie is van groot belang om oplossingen te creëren op het complexiteitniveau van het oorspronkelijke probleem. Uiteindelijke besluitvormingsprocessen spelen zich af op het niveau van het zachte systeem en wordt door de boeren hogelijk gewaardeerd. In alle methodologische fasen worden voor een deel van de activiteiten interactieve strategieën gevonden. Dat betekent dat een fase niet bij voorbaat non-interactief is, maar dat vanuit de motivatie van de boeren per geval bekeken moet worden hoe interactie ingebouwd kan worden. De boeren verkrijgen kennis door middel van het uitvoeren van methodologische cirkels boven in het managementinstrument voor interactieve leerprocessen: doel definiëring, ontwerpen van zachte systemen en besluitvormingsprocessen. Zij participeren beter in methoden en technieken die zij van hoger belang achten voor het slagen van het bedrijfsinnovatieproces. Wetenschappers verkiezen de reductionistische weg langs probleemanalyse, experimenteel onderzoek en kennisintegratie. Het is niet wenselijk om boeren te forceren actief en interactief deel te laten nemen aan alle methodologische fasen van bedrijfsinnovatie. Het is beter uit te gaan van complementaire bijdragen van de wetenschappelijke leerweg en de leerroute van de boerenpraktijk.

In het concluderende hoofdstuk (12) wordt ingegaan op de vernieuwende rollen voor boeren, procesbegeleiders en wetenschappers indien interactieve leerprocessen worden nagestreefd. Boeren zullen geschoold moeten worden om samen te werken, besluiten te nemen en de verantwoordelijkheid te nemen voor het ontwikkelingsproces dat zij hebben verkozen. De rol van de platformbegeleiders is meer gericht op het bewaken en sturen van het leerproces van de betrokken actoren dan het leveren van technisch inhoudelijke kennis. De wetenschap kan een bijdrage leveren aan interactieve leerprocessen door het inzichtelijk maken van leer- en besluitvormingsprocessen, een wetenschappelijk basis te ontwerpen voor de integratie van bèta- en gamma-studies en door het ontwikkelen van analysemethoden met betrekking tot de staat van leren van betrokken actoren.

Boeren zijn en blijven de uiteindelijke uitvoerders van de ontworpen plannen. Zij zijn daarmee de ultieme ontwerpers en moeten betrokken zijn bij de uitvoering van belangrijke fasen in het ontwerpproces en op zijn minst een structurele bijdrage leveren wanneer resultaten van experimenteel onderzoek of ontwerpen van technisch-economische systemen geïntegreerd moeten worden in hogere complexiteitsniveaus. Zij staan daar echter niet alleen voor. Zij hebben te maken met een diversiteit aan relevante sociale actoren waar zij mee moeten communiceren en gezamenlijke oplossingen ontwerpen. Interactieve landbouw innovatie wil niet zeggen dat alle activiteiten door of samen met boeren moeten worden uitgevoerd. Dat is uit technisch en sociaal oogpunt, maar ook wat betreft efficiëntie, niet verantwoordelijk. Wel is het van belang dat boeren het totale leerproces controleren en besturen. Procesbegeleiders kunnen gebruik maken van het management-instrument voor het bevorderen van de communicatie tussen betrokken actoren in de eerste plaats. Ten tweede kunnen zij dat instrument gebruiken voor het vergroten van eigen overzicht tijdens het 'managen' van landbouw- bedrijfsinnovatie en ten derde, als zijnde een externe consultant, voor het evalueren van landbouwinnovatieprogramma's. Het management-instrument is bovendien bruikbaar voor de integratie van diverse disciplines en voor de organisatie van actoren en methodologie in ontwikkelingsprocessen.

Resumen

Huancarani es una comunidad rural que se encuentra en un pendiente de los Andes en el departamento de Cochabamba, Bolivia. Los habitantes son en su mayoría pequeños agricultores que viven de la agricultura mixta. Las posibilidades de garantizar la vida como agricultor han disminuido en las últimas décadas debido al uso no sostenible de la tierra. La aplicación directa de métodos agrícolas, promovidos por las agencias de extensión agrícola y proyectos "copiados" de la práctica agrícola de valles fértiles alrededor de la ciudad de Cochabamba, bajó en un corto tiempo la ya preocupante calidad del suelo. La alza de precios de insumos agrícolas, la cual continua, no fue compensada por ingresos más altos. Los agricultores (campesinos) se sintieron forzados a utilizar los recursos naturales y trabajar la tierra en forma más intensiva, además del uso productivo de bosques y pastizales en tierras con un fuerte pendiente. Otra estrategia diferente de sobrevivir, fue la emigración de la zona.

Este sistema agrícola tuvo su impacto negativo en la zona. Los suelos fueron fuertemente erosionados. Se produjeron cárcavas cada vez más profundas arrastrando las capas de suelo y destruyendo algunas casas. La región es completamente marginal y los jóvenes han decidido salir hacia las ciudades o dedicarse al cultivo de coca en zonas tropicales.

Diversas proyectos de desarrollo de Instituciones Estatales u Organizaciones No Gubernamentales (ONGs) se dedicaron a buscar respuestas a esta problemática compleja. Aunque las soluciones propuestas fueron de distinta índole, la metodología de investigación y extensión de estas propuestas fue generalmente la misma. Los agricultores casi no fueron invitados a desarrollar estas propuestas, sin embargo ayudaron en la promoción de paquetes tecnológicos y ayuda de tipo cáritas.

Algunas ONGs cambiaron su enfoque de investigación profunda sobre causa y consecuencia de la situación actual de la empresa agrícola e invitaron a los agricultores a estudiar y decidir sobre lo que se debía hacer. Para resolver el problema de como los agricultores podrían garantizar su supervivencia en base de la calidad de los recursos naturales, se formularon dos objetivos claros:

1. La Innovación Agrícola mediante sistemas agrícolas sostenibles y tomando en cuenta la baja calidad de los recursos naturales. El plan debía ser dirigido a la introducción de cultivos que podrían rehabilitar las tierras agrícolas marginadas.

2. La organización y capacitación de los agricultores hacia el mejoramiento de la capacidad de ellos para tomar en sus manos y guiar la gestión de desarrollo en un contexto cambiante.

Otras comunidades se fueron entusiasmando con este nuevo concepto y se incorporaron vía la ONG que trabajaba en la zona o por propia motivación, en el Programa de Rehabilitación de Tierra (LRP: una coordinación interinstitucional entre ONGs, instituciones de investigación, organizaciones campesinas y un proyecto de investigación). Los primeros grupos de agricultores identificaron el cultivo integral de tuna (*Opunita ficus-indica* Mill.) y cochinilla (*Dactylopius coccus* Costa; insecto que sirve como materia prima para la producción de colorante rojo). Esta nueva forma de diseño fue "copiado" por otras organizaciones campesinas. Además, el Banco Mundial decidió financiar un proyecto de investigación (PITC) en búsqueda de respuestas a preguntas técnicas y asuntos económicos del cultivo de tuna y cochinilla.

Una de las zonas donde el LRP funcionaba era la comunidad Huancarani, seleccionada como estudio de caso para esta investigación. Se creó mediante una activa cooperación de los agricultores y sus organizaciones de base, una plataforma de discusión permanente como centro de coordinación para todo tipo de actividades en el área de desarrollo rural. Las actividades incluyeron entre otras: trabajo de campo, promoción y toma de decisiones, investigación histórica, análisis de la problemática, investigación experimental en finca y diseño de sistemas de producción alternativa. Las actividades fueron clasificadas en dos fases de aprendizaje:

- Los agricultores aprenden mediante investigación y diseño en la práctica, realizado por ellos mismos o por otros y
- Los agricultores aprenden sobre los procesos, los cuales se efectuaron durante el funcionamiento del LRP. Así, los agricultores diseñaron y mejoraron su propio línea de aprendizaje con el fin de autogestionar de manera consciente e interdependiente, su camino de desarrollo en la zona.

Al mismo tiempo, los agricultores y los facilitadores del proceso de aprendizaje sobre innovación agrícola, se dieron cuenta que la forma de trabajar pude ser utilizado para la gestión de nuevos procesos de aprendizaje de otros agricultores. Esto fue entendido como la tercera fase de aprendizaje.

El capítulo 1 lleva el lector hacia la huella de procesos de aprendizaje interactivo, describe el objetivo y la amplitud de la investigación. Las limitaciones y oportunidades del LRP son presentadas mediante un ejemplo sobre la complejidad de la agenda de actividades durante el análisis del problema.

En el capítulo 2 se analiza de manera profunda la creación y realización del LRP. Primero se realiza un análisis sobre la relación entre la falta de tierra agrícola de buena calidad y la emigración de la población. Posteriormente se selecciona entre una multitud de comunidades rurales que participaron en el LRP, el estudio de caso para continuar el análisis. La selección de Huancarani como estudio de caso fue argumentada por sus características de la zona y la motivación de sus habitantes para innovar, tanto de manera técnica (en sus fincas) como en el sentido de proceso (de aprendizaje interactivo).

En el capítulo 3 se hace una descripción de la zona en términos de las características bióticas y abióticas. La historia del uso de la tierra y la tenencia de tierra es analizado con el fin de aclarar las tendencias negativas relacionadas con la calidad de la tierra. El sistema de producción actual y los problemas económicos de la finca, están descrito en términos de recursos naturales (tierra), capital y mano de obra. El enfoque de género se pone en la perspectiva de la innovación agrícola. Una descripción del contexto cultural del LRP menciona como los agricultores de Huancarani fueron organizados de distinta forma con el fin de reivindicar los diferentes intereses presentes en este sector: organizaciones de tipo Inca, sindicatos campesinos, comisiones y directivas de actividades de ONGs. Otro aspecto importante en este capítulo, es la constatación de que los agricultores en comparación con los académicos, tienen una visión característica sobre el concepto de desarrollo y siguen procedimientos de toma de decisiones contrastantes.

El capítulo 4 muestra el proceso de trabajo con los agricultores de Huancarani. Primero se determinó la complejidad de los problemas del sector para luego proponer estrategias que permitieran manejar esta situación mediante la selección de métodos, procedimientos y actividades agrupados en cuatro niveles de complejidad del problema. Sobre esta base, se propone una teoría sobre las estrategias para enfrentar los problemas de la zona. Esto está relacionado con el objetivo del aprendizaje permanente por parte de los agricultores y el aprender en conjunto con ellos. Finalmente la teoría se desglosa en tres niveles de aprendizaje: "aprender en la práctica", aprender de la práctica" y "aprender para la práctica". De esta manera queda establecido el proceso de trabajo de la ejecución del LRP.

El capítulo 5 ofrece una descripción sobre cómo se identificó los problemas de los agricultores. La larga lista de problemas fue analizada en tres etapas:

- la determinación de las tendencias negativas entre la finca, el mercado y los recursos naturales;
- el impacto negativo entre una zona agro - ecológica y otra y;
- la priorización de los problemas desde la perspectiva de la sostenibilidad.

La organización de este trabajo, implicó indicar las relaciones entre problemas y confirmó la necesidad de tocar la autonomía de los agricultores en los procesos de desarrollo.

En el capítulo 6 se describe el proceso de creación de la plataforma de toma de decisiones. Durante las primeras discusiones, los objetivos de innovación agrícola de los agricultores fueron aclarados. Con la ayuda de una visión sobre el futuro y el análisis de la problemática (véase Capitulo 5), se formuló las metas para solucionar sus problemas. Finalmente, se llegó a objetivos de diseño para los tres niveles de aprendizaje definidos en capitulo 4. "Aprender *en* la práctica" tuvo como objetivo el diseño de sistemas productivos de la agricultura sostenible con énfasis en el cultivo de tuna y cochinilla. "Aprender *de* la práctica" tuvo como objetivo reforzar la autonomía para autogestionar su propio línea de desarrollo. Este objetivo fue operacionalizado mediante la sistematización de las actividades, procedimientos y procesos. Después, se buscó patrones de metodología aplicada, lo que permite diseñar nuevos procesos de aprendizaje. Esto último resultó en el objetivo de "aprender *para* la práctica".

Los capítulos 7 y 8 tratan del proceso de aprendizaje de los agricultores en la práctica. Luego de una introducción sobre el cultivo de tuna y la producción de cochinilla, el capítulo 7 nos revela el plan y resultados de la investigación realizada como parte del LRP. El capítulo 8 continúa ubicando como eje central, el diseño del cultivo integral de tuna y cochinilla. Se desarrollaron diversos escenarios y el diseño final de un sistema productivo optimizado, fue integrado con el sistema de producción actual en la agroecozona subtropical en Huancarani.

El capítulo 9 toma distancia de aprender en la práctica y comienza con un análisis sobre el cómo se logró el aprendizaje por parte de los agricultores. La creación de una plataforma es en sí mismo, la primera estrategia para poder aprender. La plataforma no fue aislada y fue apoyada por dos coordinaciones interinstitucionales del LRP: una con el enfoque de investigación y promoción y la otra, para la organización campesina y exportación de cochinilla.

Queda en evidencia que el aprender, después de la investigación experimental y el diseño, se realiza mediante tres caminos:

- la integración de conocimientos desde niveles de baja a alta complejidad,
- el diseño de plataformas de discusión y
- la aplicación y procedimientos de toma de decisiones, mediante la selección del escenario diseñado y la opción más adecuada de acuerdo al mayor grado de satisfacción.

La integración de conocimientos, paso por paso, se obtiene por medio de resultados de investigación básica (factores de producción) vía investigación aplicada (manejo técnico), vía el diseño de "sistemas duros" (modelos exactos y matemáticos) para finalmente incorporarse en "sistemas más blandos" de toma de decisiones. Un ejemplo de los resultados de la investigación en el tema de calidad de cochinilla, nos demuestra que la integración de resultados de investigación experimental y el diseño de sistemas productivos, siempre es continuado por procesos de toma de decisiones que no siempre es fácil de definir. Tres técnicas apoyaron la toma de decisiones: FODA (Fortalezas, Oportunidades, Debilidades y Amenazas), la comparación con y sin proyecto y el Análisis de Criterios Multiples en diversas ejecuciones.

En el capítulo 10 se ordena y agrupa los resultados metodológicos de la ejecución de la investigación y las actividades de desarrollo del LRP. Se juntan estos pedazos como una rompecabezas, quedando en evidencia un "hueco metodológico" después del análisis del problema, la investigación experimental y el diseño e integración de conocimientos, por el cuál las propuestas de soluciones no pueden ser traducidas en el nivel de complejidad inicial. Por esta razón, junto con el análisis de los problemas, se necesita una fase metodológica llamada definición de objetivos.

Además, es necesario complementar el diseño de sistemas productivos con el diseño de "sistemas blandos" de toma de decisiones. Esto se obtiene no sólo mediante el diseño de estructuras de trabajo y un ambiente adecuado para que los agricultores intercambien sus opiniones, además es importante el mejoramiento de las capacidades sociales en el trabajo de grupos y el desarrollo de procedimientos que garanticen a los agricultores, un mejoramiento en su participación y un poder decisivo.

El diseño de procesos de aprendizaje para la innovación agrícola se puede resumir en:

- Dos oportunidades durante la preparación: análisis del problema y definición de objetivos;
- Una continuación metodológica con cuatro entradas de estudios (en cuatro niveles de complejidad), una investigación experimental básica, una investigación experimental aplicada y el diseño de "sistemas duros y blandos";
- En una fase de integración de conocimientos se juntan los resultados de los cuatro niveles de complejidad; y
- Finalmente una fase de toma de decisiones que se obtiene en el nivel de complejidad más alto (véase Figura 10.7).

Este esquema se llama el instrumento de gestión para el diseno de procesos de aprendizaje interactivo.

En el capítulo 11 se evalúa todas las fases metodológicos y el instrumento de gestión mediante los siguientes criterios:

- La satisfacción de los agricultores sobre la metodología aplicada, es decir, el grado en que la metodología apoyó al éxito del LRP;
- La opinión de los agricultores sobre el grado de participación activa en el LRP y;
- La opinión de los agricultores sobre la calidad de su participación: estrategias de interacción.

En general las notas fueron regular. Esto significa que la metodología puede ser mejorada todavía. Las mismas fases metodológicas tuvieron notas altas para los tres indicadores: definición de objetivos, diseño de sistemas blandos e integración de conocimientos. Análisis de problemas e investigación experimental básica, lograron niveles más bajos de contribución a innovación agraria, participación campesina y estrategias interactivas. Algunas fases fueron más interactivas que otras, por lo cual, la metodología total no puede ser determinado como interactiva. La interacción mejora posiblemente cuando son evaluados los caminos de aprendizaje de algunos campesinos específicos. Sin embargo, esta situación no se puede explicar sin la ayuda de un instrumento de gestión.

El éxito del LRP se puede asignar en mayor grado al diseño en niveles de alta complejidad, que a la investigación experimental en niveles de baja complejidad. Los agricultores preferían el diseño sobre la investigación experimental. La integración de conocimientos es muy importante para crear y sintetizar soluciones al nivel de complejidad del problema inicial. La toma de decisiones final se realiza en el nivel de sistemas blandos, la cual es altamente valorada por los campesinos. Todas las fases metodológicas contienen una o unas actividades con estrategias interactivas. Esto significa que una fase en sí mismo no se puede clasificar a priori como no-interactiva, pero sí se debe estudiar según la motivación de los agricultores, cómo incorporar la interacción en cada caso. Los agricultores incrementaron su conocimiento mediante la aplicación de círculos metodológicos en el instrumento de gestión para el diseño de procesos de aprendizaje interactivo: definición de objetivos, diseño de sistemas blandos y procesos de toma de decisiones. Ellos participaron más activamente en métodos y técnicas cuando asignaron a estas más importancia para la innovación agrícola. En general, los académicos prefieren el camino del reduccionismo a través del análisis del problema, la investigación experimental y la integración de conocimiento. No es adecuado forzar a los agricultores a participar o interactuar activamente en todas las fases de la innovación agrícola. Es mejor partir de contribuciones complementarias entre el camino de aprendizaje académico y el camino de la práctica agrícola.

En el capítulo 12 las conclusiones están dirigidas a los nuevos roles para los agricultores, facilitadores de procesos y académicos, cuando se busca procesos de aprendizaje interactivo. Los agricultores deben ser capacitados para trabajar en grupo, tomar decisiones y responsabilidades para ejecutar las alternativas seleccionadas. El papel que juega el facilitador tiene que ver más con el cuidado y seguimiento del proceso de aprendizaje que con la contribución en conocimientos técnicos. La ciencia puede contribuir a los procesos de aprendizaje interactivo mediante la visualización de los procesos de aprendizaje y toma de decisiones, en el diseño de una base científica para la integración de estudios beta-gamma y mediante el desarrollo de métodos analíticos sobre el nivel de aprendizaje de los actores involucrados.

Los agricultores son y deben seguir siendo los implementadores finales del plan diseñado. Ellos también son los diseñadores y deben estar involucrados en la ejecución de las fases importantes del proceso de diseño o mínimamente contribuir estructuralmente cuando los resultados de la investigación experimental o los diseños de sistemas técnico - económicos deben ser integrados hacia niveles de complexidad más altos. Sin embargo, los agricultores no se encuentran solos, ellos deben enfrentar una diversidad de actores sociales relevantes, con las cuales deben comunicarse y diseñar en conjunto las soluciones.

La investigación - diseño interactiva, no significa que todas las actividades deben ser ejecutadas con los agricultores. Esto no es responsable desde ángulos técnicos, sociales y de eficiencia, pero es muy importante que ellos controlen y gestionen el proceso de aprendizaje total. Los facilitadores de proceso pueden utilizar el instrumento de gestión desarrollado para mejorar en primer lugar, la comunicación entre los actores involucrados, en segundo lugar para mejorar la visión general durante el manejo de la innovación agrícola y en tercer lugar, para evaluar como consultor externo los programas de innovación agrícola. Se trata de un instrumento aplicado para la integración de disciplinas y para la organización de actores y metodología en los procesos de desarrollo.

Summary

On a remote hillside in the Andes Mountain chain in the Department of Cochabamba, Bolivia, the rural community of Huancarani is situated. The habitants are generally resource-poor small farmers, who live on mixed arable and livestock farming. During the last decades, the possibilities to build up a living have decreased. The cause is non-sustainable land use. Because of direct application of agricultural practices, promoted by the agricultural extension services and projects, which were copied from the agricultural reality of the fertile valleys around Cochabamba, the already alarming quality of the soil decreased in a very short time. The ever incrementing prices of chemical agricultural inputs were not compensated for by higher income from production. The farmer saw him(her)self "forced" to address the natural resource base. He (she) had to cultivate the land more intensively, and to reclaim forests and grass land. One of the strategies for survival was emigration.

These agricultural practices have had serious effects on the region. The soils are heavily eroded. There has been talk of formation of ever-deeper canyons, resulting in sinking and flushing away agricultural land, even affecting farmhouses. The region is completely marginalised. Young people migrate to the cities or start coca production in the tropical lowlands.

Some development projects of state institutes or Non Governmental Organisations (NGOs) worked on answers to the complex problem situation. Although the "solutions" brought in were of high diversity, the process of research and extension of such proposals remained the same. Farmers were hardly involved in the development of the solution, in contrast to their participation in the promotion of technology packages and charity aid.

After profound and participatory research on the causes and consequences of the actual state of farming some NGOs turned things upside down. They let the farmers themselves study and decide about what must be done. The question was then how farmers could earn a living on the basis of the actual quality of the natural resources. Two objectives were formulated:

- Agricultural innovation by sustainable production systems and taking into account the actual quality of the natural resources. The design should lead to the introduction of crops by which exhausted agricultural land can be rehabilitated;
- The organisation and training of farmers that should lead to the improvement of the farmers' capacity to start and guide the management of their own development process.

Farmer communities became more and more enthusiastic about this concept and became part of it, with the help of the NGO working in their area or autonomously, in the Land Rehabilitation Program (LRP: an inter-institutional cooperation among NGOs, research schools, farmers organisations and a specific research project). The first farmers groups finished with the development of the integrated production of cactus pear (prickly pear; *Opuntia ficus-indica* Mill.) and cochineal (*Dactylopius coccus* Costa; an insect that provides raw material for a red dye). This "design pathway" was taken up by other farmers' organisations. The World Bank decided to finance a research project (PITC), with the aim to find technical and economic answers to the production of cactus pear and cochineal.

One of the zones where the LRP worked, the rural community of Huancarani, was chosen as the case study area. In close cooperation with farmers and their organisations, a platform was created that would function permanently as a coordination centre for all activities related to rural development. The activities consisted, among others, of: fieldwork, promotional and

decision-making activities and also a historical review, problem analysis and the design of alternative production systems. The activities were subdivided into two phases of learning:

- farmers learn from research and design in practice, carried out by themselves or by others;
- farmers learn about the methodological processes that occur during the realisation of the LRP. In that way farmers designed their own pathways for learning in order to take the development of the region into their own hands, both autonomously and consciously.

Farmers, scientists and facilitators of learning processes of the LRP agricultural innovation realised that the working scheme could be taken up for the management of new learning processes for their farmers. That could be considered the third learning phase.

Chapter 1 brings the reader on the line of interactive learning processes for agricultural innovation. It shows the objective and amplitude of the research. The limitations and opportunities of the Land Rehabilitation Program are presented with the help of an example about the complexity of the activity agenda during the problem analysis.

Chapter 2 provides a deeper analysis of the creation and realisation of the LRP. First, the relationship between the lack of good agricultural land and emigration is analysed. A case study area is selected for further study among the many rural communities. The choice for Huancarani as case study area is justified because of the environmental "qualities" of the area and the motivation of the farmers to design innovations in both the technical-agricultural issues as well as in the process of interactive learning.

Chapter 3 describes the area in terms of its biotic and abiotic characteristics. The history of land use and land tenure is analysed with the objective to explain their negative impacts on the quality of the soil. The actual production system and economic problems are described in terms of natural resources (land), capital and labour. Gender sensitive issues are placed in an agricultural innovation perspective. From the description of the cultural context of the LRP it is evident that the Huancarani farmers were already organised in order to care for their interests: Inca type organisations, farmers unions, and also committees and boards of NGO activities.
It also became clear that farmers, in comparison to scientists, have a characteristic vision on the concept "development" and follow contrasting decision-making procedures.

Chapter 4 shows how the working process with the Huancarani farmers was organised. First, the complexity of the problems of Huancarani farmers is determined. Proposals are suggested to handle this complexity with the help of methodological choices, procedures and activities, grouped at four complexity levels of the problem situation. On that basis, a theory is proposed about the pathways that can solve the problems in the region. This has everything to do with the objective of permanent learning by farmers and with farmers. Finally, the theory is split up into three levels of farmer learning: *learning in practice*, *learning from practice* and *learning for practice*. In this way the working process for the realisation of the LRP was established.

Chapter 5 describes how identification of the farmers' problems took place. The long list of problems was further analysed in three ways:

- the negative trends that exist between the farm (household), the market place and the natural resources;
- the ecological impact form one agroecozone to the other and;
- the prioritisation of the problems according to the perspective of sustainability.

Clustering explains the coherence of problems and confirms the need to work on the farmers autonomy during development processes.

Chapter 6 describes how the platform for discussion and decision-making started. From the first platform discussions it was clear what the farmers' objectives were. With the help of a vision of the future and the analysis of the farmers' problems (see Chapter 5), standards were formulated for the solution of their problems. These were then transformed into design objectives on the three learning levels defined in Chapter 4. Learning *in* practice addressed the design of sustainable agricultural production systems with emphasis on the production of tuna and cochineal. Learning *from* practice focused on the improvement of the farmers' countervailing power in order to take their path towards development into their own hands. This objective was operationalised by the systematisation, understanding and improvement of activities, procedures and processes. Next, a pattern of applied methodology was looked for, by which new learning processes can be designed. This was the purpose of learning *for* practice.

Chapters 7 and 8 discuss the learning process in practice. After introducing the cactus pear crop and cochineal production, Chapter 7 describes the plan and results of carried out experimental research as part of the LRP. Chapter 8 continues on this line and places design of the integrated cactus pear and cochineal production at the centre. Several scenarios are developed and the "final" design (an optimal production system) is integrated in the actual production system of the tropical agroecozone of Huancarani.

At this stage, Chapter 9 leaves learning in practice and starts the analysis of how farmers' learning came into being. In itself, creation of the platform is the first strategy to learning. The platform did not just stand by itself but was supported by two interinstitutional organisations of the LRP: one focused on research and promotion of the production system, the other on farmers organisation and cochineal export.
It became clear that learning after experimental research and design takes place along three pathways:
- integration of knowledge from low to high complexity levels;
- design of platforms for discussion and decision-making;
- procedures for decision-making in order to select a scenario that is the most satisfactory.

The step by step integration occurs from the results of basic research (production factors) into applied research (agricultural management techniques), via design of hard (exact and mathematics) production systems to, finally, be part of a system of the "soft" decision-making type. An example of the results of research in relation to the quality of cochineal shows that integration of research results as well as design of hard and exact production systems will always be followed by decision-making processes of the soft system: the "difficult to define" type. Three tools are central in the support of decision-making: SWOT analysis, comparison of with-without cases and the Multi Criteria Analysis in several performances.

The methodological results obtained during the realisation of research and development activities of the LRP are put in order and are clustered in Chapter 10. These parts are put together as a puzzle. After problem analysis, research, design and knowledge integration a methodological white spot appears. Therefore, the proposed solutions cannot be translated into the initial complexity level of the problem situation. In addition to the problem situation there is a need for what we call goal-setting. Except for the hard system design there appears to be a need for soft decision-making systems. This can be reached by the design of adequate structures and moments where farmers can exchange ideas, as well as the improvement of social capacities in group work and the development of procedures that guarantee farmers participation and decision-making power. The design of learning pathways for agricultural innovation can be resumed in:

- two possibilities in a preparatory phase: problem analysis and goal setting;
- four entries (on four complexity levels) for a methodological continuation: basic research, applied research, hard system design and soft system design;
- next, results come together in a knowledge integration phase;
- and, finally, decision-making is offered at the highest complexity level (see Figure 10.7).

This framework is known as the management toolkit for the design of interactive learning processes.

Chapter 11 evaluates all methodological phases and the management toolkit on the following criteria:

- satisfaction of farmers about the applied methodology, in other words, the contribution of a specific method to the success of the LRP;
- the opinion of the farmers on the level of their participation in the LRP;
- the opinion of the farmers about the quality of their participation: interactive strategies.

Generally, scores were sufficient (not good or very good). This meant also that the methodology could clearly be improved. The same methodological phases received high scores on the three criteria: goal setting, soft system design and knowledge integration. Problem analysis and basic research received lower scores for the contribution to the success of the LRP, farmers participation and interactive strategies. Some phases were more interactive than others, so that the overall methodology cannot be evaluated as being interactive. This result may be improved when specific learning pathways of farmers are evaluated. This can only be visualised with the help of the developed management tool.

The success of the LRP must be assigned to design at high complexity levels more than to research at lower complexity. Farmers preferred the design pathway over the research pathway. Integration of knowledge is of great importance to synthesise solutions into the complexity level of the initial problem. Final decision-making takes place at the soft system level and is highly valued by the farmers. In all methodological phases one could find good interactive strategies. This means that a phase is not non-interactive before hand, but that, for each situation must be studied, how interaction can be built in according to the motivation of the farmers. Farmers improved their knowledge by making methodological cycles in the top of the management toolkit for the design of interactive learning: goal setting, soft system design and decision-making processes. They participated well when they considered the methods and techniques to be more important for the success of the process of agricultural innovation. Scientists preferred the reductionist pathway of problem analysis, experimental research and knowledge integration. It is not desirable to force the farmers to participate or interact actively in all methodological phases of farm innovation. It is better to start from complementary contributions of the scientific learning pathway and the farmers' practical learning pathway.

Chapter 12 addresses the new roles for farmers, process facilitators and science when interactive learning processes are of central concern. Farmers must be trained to work together, make decisions and take responsibility for the development pathway that they selected. The role of the platform facilitator is focused more on the care and supervision of the learning process, than on a contribution to technical knowledge. Science may contribute to interactive learning processes by visualisation of the learning and decision-making processes, by the construction of a scientific basis for the integration of beta-gamma studies and by the development of analytical methods for the level of learning from involved actors.

Farmers are and must remain the final implementers of the designed plans. Therefore they are the ultimate designers and should participate in the realisation of the most important phases in the design process or be minimally involved when results of experimental research of technical-economic design are integrated into higher complexity levels.
Farmers are not on their own. They experience a diversity of relevant stakeholders, with whom they have to communicate and design solutions together. Interactive agricultural innovation does not mean that all activities must be carried out with farmers. That is not possible from both technical, social and efficiency points of view. It is important that farmers control and manage the overall learning process. Process facilitators can use the management toolkit in the first place for the improvement of the communication between stakeholders. In the second place they can use it to increment their own overview during the management of the agricultural innovation process and in the third place to evaluate agricultural innovation processes as an external consultant.
The management toolkit is a useful instrument to enhance the integration of disciplines and to organise actors and methodology in development processes.

Abbreviations and acronyms

AGRUCO	Agroecological Institute of the State University of San Simón de Cochabamba
BEF	Bolivian Export Foundation (English abbreviation)
CA	Carminic Acid
CAM	Crassulacean Acid energy Metabolism
CBA	Cost-Benefit Analysis
CP	Crude Protein
DHV	Dutch consultant company
DGIS	Dutch Development Cooperation of the Ministry of Foreign Affairs
Em	Energy requirements for Maintenance of weigh (by cattle)
ETP	Evapotranspiration (mm)
FAO	United Nations' Food and Agriculture Organisation
FBE	Bolivian Export Foundation (Spanish abbreviation)
FLORA	Farm Household Level Optimal Resource Allocation
FSR	Farming System Research
INE	Bolivian National Institute for Statistics (Spanish abbreviation)
IRR	Internal Rate of Return (%)
LRP	Land Rehabilitation Program
MACA	Bolivian Ministry of Agriculture and small-farmers (campesino) affairs (Spanish abbreviation)
m.a.s.l.	Meters above sea level
MCA	Multi Criteria Analysis
MGLP	Multiple Goal (Linear) Programming
NGO	Non-Governmental Organisation (Private institutes for (rural) development)
NPK	Nitrogen, Phosphorus and Potassium (levels)
PITC	Cactus pear and Cochineal Research Project (Spanish abbreviation)
PRA	Participatory Rural Appraisal
PTD	Participatory Technology Development
RAAKS	Rapid Appraisal for Agricultural Knowledge Systems
RRA	Rapid Rural Appraisal
SWOT	Strong, Weak, Opportunities and Threats analysis
TDN	Total Digestible Nutrients
UMSS	The San Simon State University of Cochabamba
WAU	Wageningen Agricultural University (or WU = Wageningen University)

Glossary of technical-methodological concepts and Spanish terms

Aggregation level of analysis	Levels of space (geographical areas) or sector (subject) sub-division
Agroecosystem approach	School of Farming System Research by examination of system properties which are environmentally based
Agroecozone	Areas with a combination of climate, soils, flora and fauna in relation to specific agricultural production and livestock keeping. In the specific case of mountain areas farming systems are generally composed of more than one agroecozone.
Alpaca	Traditional livestock species of the Incas
Andes area	Mountain chain through South America from Colombia, Ecuador, Peru, Bolivia and Chile-Argentina.
Aynoka system	Traditional agricultural production planning system: distribution of the land and production plan is established by the farmers union each year (in the puna agroecozone)
Ayopaya	Province of the Department Cochabamba, Bolivia. It is also the name of a river which passes the community of Huancarani at the lowest altitude.
Blisters (black)	Bacterial cactus pear disease (*Pseudomonas* sp)
Buffer zone	Land of low quality, forests and other fragile ecosystems which were preserved for nature conservation by the Incas
Cactus pear	Prickley pear (*Opunita ficus-indica* Mill.); a long-lived perennial plant with leafless succulent stem elements that become woody (oval-racket form of the joints) of the genus Opuntioideae and sub-genus Platyopuntia
Campesino	Small (scale) and resource-poor farmer of the Andes region
Carminic acid	Chemical substance of the interior 'blood like' liquid of the female cochineal insects (larval stage) with a wide range of beautiful red colours
Charque	Salted and sun dried meat
Chuño	Frost dried potatoes
Cladode	Joint: shoot segment of the cactus pear plant that arises abruptly from an old stem areola and is clearly demarcated by a narrow base
Cochineal	The real carminic acid producing scale insect (*Dactylopius coccus* Costa)
Comunidad	Rural community, governed by a local small-farmers union and with a dispersed (plotted) pattern of farm houses in the case of the Cochabamba valleys
Cosmovision	Assumption underlying interpretation of reality
Constructivist ontology	Reality is socially constructed
Crawler	First instar migratory insect
Designing (verb)	The process of creating a desired future situation, which involves art (creativity of assembling components and relations between them as well as the art of decision-making towards the objectives formulated)
Design (noun)	Assembly of a system by concepts, materials, techniques and strategies. It is the layout of a written or drawn plan
Epistemology	The linkage between the observer and the observed

Experimental research	Research consisting of exploratory, determinative and verification types; is based on factor responses of determined variables which may influence the problem situation and may lead to a solution.
Facilitator	A person who guides a group of persons with the objective of (farm) development. He/she provides information, manages data bases, is an analysts, carries out experiments and prepares development scenarios. With these activities he/she helps decision-making procedures and participates in open discussions, but does not join the group as decision-maker him/herself.
Grain agroecozone	Centre production zone of the Huancarani community between 2600 and 3000 m.a.s.l.
Hacienda	Land tenure system by which the large-landowner has monopoly on land. Small-scale farmers carry out the work and receive a small plot of land for family food production as compensation
Hard systems	Systems characterised by easy-to-define objectives, clearly defined decision-making procedures and exact-quantitative measures of causal relations and performance
Holism	Synthesis (integration) pathway for solutions from low to high complexity levels of the problem situation in which the whole puts the parts into perspective
Huancarani	Rural community (case study area) in the Ayopaya province of the Cochabamba Department
Inca	Large Empire of Indian Kings in the Andes Mountain chain from Ecuador to the North of Chile
Independencia	Capital of the province Ayopaya, Bolivia
Infestation	Introduction of the cochineal insect on the host plant
Interactive science	A joint exercise that looks for the optimum offered by indigenous and scientific knowledge, applicable solutions and simultaneous use of different research methods and procedures for decision-making
Kermes	Insect which is bred on the Kermes oak along the shores of the Mediterranean and part of the Near East for red dye stuffs
Llama	Traditional livestock species in the Andes
Logic-in-use	The chronological presentation of the research agenda which was carried out (in the Land Rehabilitation Program) according to the step by step learning and decision-making process
Microclimate	Specific climatic conditions for a small geographical area, which shows comparative advantages for specific agricultural production
Nopal	Tuna, cactus pear, prickly pear (Mexican synonym)
Nopalito	Young sprouts (vegetable) of cactus pear cladode
Oca	Sweet root crop for human consumption
Ontology	How the nature of reality is contemplated
Oviposition	Egg releasing stage of mature female insects
Paradigm	A framework of thought and practice with a general way of seeing the world shared by members of a (scientific) community, which provides models and acceptable ways in which problems can be solved

Permaculture	Permanent Agriculture: a designing approach for the assemblage of integrated production systems that benefit life in all forms by functionality and self regulation of systems
Positivist ontology	Reality is only what is known by our senses and our ratio
Projective planning	Formulation of changes on existing components and relations of a system by which system output is improved in relation to mostly productivity and economic efficiency objectives: incrementalistic policy formulation.
Prospective planning	Restructuring, adding or taking away components or functions to the system structure by which the system output is modified according to a desired situation (of the future farm): synoptic policy formulation.
Puna agroecozone	Highest production zone of the community of Huancarani between 3000 and 3700 m.a.s.l.
Quechua	The language spoken by the Incas and which is still spoken by the rural people as their mother tongue
Quinoa	High-protein millet for human consumption
Reductionism	Research paradigm concerning analysis of components of a system in which the parts explain the whole
RAAKS	Participatory action research approach for Rapid Rural Knowledge Systems: strategic diagnosis in order to achieve agricultural innovation
Reconstructed logic	Arrangement of (clustered) research and development activities and methodologies
Rites (agricultural)	Religious acts (offering up food and drinks) especially to "Mother Earth" during sowing and harvesting time, praying for fertility, care and harvest
Scab (white or black)	Fungus causing cactus pear disease (*Phyllosticta opuntiae*)
Scenario (design)	A written or drawn plan (a model of a desired situation), created intentionally (based on specific objectives), and which is mostly offered to a decision-making platform for consideration (see design). A scenario does not predict the future, but allows people to explore technical options based on explicit assumptions given by a set of goals.
Sharecropping	Investment in agricultural production from outside the economical (family) unit of production, which is paid back with a share of the harvest
Soft systems	Systems characterised by difficult-to-define objectives, conflicts of interest between stakeholders, unpredictable human behaviour and uncertain decision-making.
Style of farming	The whole of mutually consistent ideas by which farmers plan their farms
Subtropical agroecozone	Lowest production zone of the Huancarani community between 2000 and 2600 m.a.s.l.
Survey	Data collection procedure

Sustainable Development	Development is sustainable if the present generation can meet its needs (welfare objectives) without compromising the ability of future generations to meet their own needs (WCED 1987)
System	An arrangement of components (subsystems) which process inputs into outputs: within a specific context, with well defined boundaries, components, relations between components, inputs, performance (desired output) and by-products (incidental output)
Tarwi	Lupine seeds of high protein quality for human consumption
Tuna	Cactus pear, prickly pear
Vertical land use	Simultaneous (integrated) use of agroecozones for diversified and complementary agricultural and non-agricultural production
Weight(set)	Representation of the relative priority between (sub)criteria, the scope for trade off or substitution i.e. the willingness to give up one unit of a particular factor to obtain more of another factor (Van Pelt 1993).