From Neglect to Limelight: Issues, Methods and Approaches in Enhancing Sustainable Conservation and Use of Andean Grains in Bolivia and Peru

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Abstract

Quinoa (*Chenopodium quinoa* Willd.), cañihua (*C. pallidicaule* Aellen) and amaranth (*Amaranthus caudatus* L.) are staple crops for millions of people in the Andes (National Research Council 1989, Holle 1991, Jacobsen *et al.* 2003). Their nutritional content (high quality proteins and good micronutrient profile), hardiness, good adaptability to environmental stresses, versatility in use, and rich associated food culture and traditions are among the reasons for their widespread use by the native civilizations of the Andes over millennia. The role of these species as a staple food has however dramatically changed in the last fifteen years due to their poor economic competitiveness with commodity cereal crops, lack of improved varieties or enhanced cultivation practices, drudgery in processing and value addition, disorganized or non-existent market chains as well as a negative image as "food of the poor" (Querol 1988, Tapia *et al.* 1992, Padulosi *et al.* 2003). Less nutritious, but more practical and trendier products made of wheat, maize and rice have been replacing Andean grains in the diets of millions of people across Bolivia, Peru and Ecuador, countries whose history has been intimately linked to the domestication and use of these ancient crops (Pearsall 1992).

The reduced use of Andean grains has been accompanied by the loss of their genetic diversity with important, albeit less obvious, repercussions for the livelihoods of Andean communities in terms of reduced sustainability and resilience of local agricultural systems, wasted opportunities for improving food and nutrition security, impoverishment of local cultures resulting in reduced self esteem and identity of people (Bressani, 1993, Kraljevic 2006). As with minor millets in South Asia or leafy vegetables in sub-Saharan Africa (Oniang'o *et al.*, 2006), the case

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of Andean grains is representative of the limits of the Green Revolution approach, which concentrated its efforts on global commodity crops, missing out hundreds of other valuable species of regional or local importance and of great value to people's livelihoods (PADULOSI 2008).

The recognition that agricultural biodiversity is a strategic asset in people's lives has promoted over the last fifteen years or so, the rediscovery of those so-called neglected and underutilized species (NUS) crops which, as in the case of Andean grains, have for too long faced marginalization from the Research and Development sector, which has not supported their continued and effective use (PADULOSI and HOESCHLE-ZELEDON 2008). Several projects and collaborative research frameworks at national and international level have been launched in support of NUS, contributing to a re-focussing of needed and deserved attention on these 'forgotten crops'. To that end, an important role in demonstrating the value of NUS and the development of best practices, methodologies and tools for their use enhancement is being played by the 'IFAD-NUS Project', the first UN-supported global effort dedicated solely to the use enhancement of NUS, including quinoa, cañihua and amaranth, tackled through international participatory, multi-stakeholder and multi-disciplinary efforts.

This article reports on the work implemented by the project in Bolivia and Peru over the last seven years, highlighting significant approaches, experiences and outputs as well as challenges and experiences during the implementation of the project, which could be valuable lessons for other similar endeavors in support of NUS.

Key words:
Andean grains, genetic resources, conservation and use.

Introduction: NUS Definitions and Justification of Project

The definition of NUS has engaged scholars for some time now and we believe that the best way of sharing the common understanding of what NUS are is to indicate those traits that make these species (for better or for worse) distinct from other crops (Fig 1).

The conceptual framework for the promotion of NUS was developed by Bioversity International building on the results of more than ten years of work carried out around the world on these species (IPGRI, 2002). More recently a further elaboration of this framework was achieved through a number of conferences held with experts from Asia and Africa (JAENICKE and HOESCHLE-ZELEDON, 2006). Working on NUS entails a very different approach than working with well established crops. The use enhancement of NUS is challenged by many constraints, of which the following can be singled out as most recurrent: lack of information and scientific literature, lack of available germplasm and/or improved varieties, poor cultivation practices, poor value addition and marketing, lack of technical expertise and capacities in national programmes, and poor supportive policies (PADULOSI et al, 2002).

- **Important in local consumption and production systems:** they are an integral part of local culture, present in traditional food preparations and are the focus of current trends to revive culinary traditions;
- **Highly adapted to agro-ecological niches and marginal areas:** they have comparative advantages over commodity crops because they have been selected to withstand stressful conditions and can be cultivated using low input and biological techniques;
- **Ignored by policy makers and excluded from research and development agendas:** special efforts are needed to improve the cultivation, management, harvesting and post-harvesting of under-utilized species and studies are needed on issues such as marketability, nutritional status and policies and legal frameworks to regulate their use;
- **Represented by ecotypes or landraces:** most under-utilized species require some degree of improvement;
- **Cultivated and utilized drawing on indigenous knowledge:** cultivation and use can be enhanced by using farmer-based knowledge and by introducing innovative cultivation practices. Unfortunately, processes such as urbanisation and changing farming methods are contributing to the rapid erosion of traditional knowledge.
- **Hardly represented in *ex situ* gene banks:** efforts are needed to rescue and conserve genetic diversity of under-utilised species. Without characterization and evaluation the useful variation of these species will remain poorly understood. It is important to combine *ex-situ* with *in-situ* (on farm) conservation efforts as large-scale conservation efforts are unlikely to be made for these species. A "conservation through use" approach therefore becomes particularly important;
- **Characterized by fragile or non-existent seed supply systems:** efforts need to be made to provide planting material to farmers in order to make the cultivation of underutilized species more feasible and sustainable over time.

Fig. 1: Description of neglected and underutilized species (NUS) (from PADULOSI and HOESCHLE-ZELEDON 2004)

The IFAD NUS Project framework was developed through a series of multi-stakeholder workshops held in 2000 in Bolivia, Peru, Ecuador, India and Nepal. The Project was launched in 2001 and completed its first phase in 2005. Based on the outcome of an independent evaluation, a second three-year new phase was granted and launched in 2007 (PADULOSI, 2007).

With regard to the Bolivian and Peruvian components of the project, 34 project sites of between 20 to 120 families have been involved between phases I and II. All in all, more than 1,170 families have been directly involved in the implementation of the project, a fact that helps underscore the truly bottom-up, community-based and participatory approach of this project.

The global coordination of the Project is carried out by the international research organization Bioversity International based in Rome (Italy), while Fundación PROINPA, and CIRNMA are the two national agencies implementing the work in Bolivia and Peru respectively and coordinating activities undertaken jointly with a wide range of over twenty stakeholders from local NGOs and private enterprises such as food processing companies to universities, other research organizations and extension workers. The reach of the stakeholders covers expertise from grain production to ecotourism, nutritional analysis, conservation, marketing and food quality standard assurance.

Relevant approaches, methodologies, outputs and outcomes of the work carried out in these countries since 2001 are presented in this article grouped in the eight main areas of intervention as established in the project. Table 1 lists these domains along with the main activities pursued by the project to tackle the challenges faced in the areas of intervention.

Table 1: Problem areas, main foci and activities of the IFAD NUS project.

Area of Focus	Expected Outputs	Project Activities
1. Problem Area: Lack of the required genetic material of the target neglected and underutilized species		
Provision of genetic material of the target species	- Improved availability of seed and other planting materials - Crop improvement programmes - Improved planting materials for traditional varieties	- Set up local germplasm supply systems among rural communities - Initiate participatory improvement programmes to obtain clean planting materials and improved varieties
2. Problem Area: Loss of germplasm and traditional knowledge		
Conservation of germplasm and associated traditional knowledge	- Resource base of selected species secured through *ex situ* and on farm conservation - Appropriate traditional knowledge documented and shared among stakeholders	- Assess distribution of species and genetic erosion threats - Sample germplasm for *ex situ* maintenance and use - Implement on farm conservation through community-based actions

		- Identify and collate traditional knowledge using participatory procedures based on informed consent (including e.g. recipes on uses)
3. Problem Area: Lack of knowledge on uses, constraints and opportunities		
Documentation of knowledge on uses, constraints and opportunities	- Enhanced information on production levels, use constraints and opportunities - Knowledge of gender and other socially significant factors obtained	- Participatory surveys on uses, constraints and opportunities with communities and other levels of the production chain. - Analyze survey data for gender and other socially significant factors
4. Problem Area: Limited income generation		
Development of community-driven actions to enhance income generation	- Strategies for adding value and increasing rural incomes using target crops - Enhanced competitiveness of selected crops	- Develop value adding strategies (through processing, marketing, commercialization). - Investigate and identify improved agronomic and production procedures
5. Problem Area: Market, commercialization and demand limitations		
Actions addressing market, commercialization and demand limitations	- Enhanced working alliances among stakeholders in market chains - Improved processing and marketing opportunities identified - Improved capacities of marketing associations and producer groups	- Strengthen operational links in the market chain between seed supply system, processing and distribution stakeholders - Develop improved low-cost processing techniques - Analyze and identify market opportunities
6. Problem Area: Lack of research and development activities and weak national capacities		
Research and development-oriented activities to strengthen national capacities	- Enhanced national capacities to work with neglected and underutilized crops - Enhanced information and knowledge on the selected neglected and underutilized crops - Methods to improve nutritional values developed and documented	- Carry out short training courses for researchers - Develop and undertake community-based participatory courses - Characterize crops for agronomic, nutritional and market related traits - Study formal and informal classification systems - Investigate methods of maintaining and enhancing nutritional value - Investigate new areas of crop production

7. Problem Area: Lack of links across conservation and production to consumption value chains		
Establishment of effective links between conservation and crops value chains	- Market chains established or strengthened - Participatory networking procedures established	- Hold planning workshops for all stakeholders - Establish and strengthen operational links between stakeholders
8. Problem Area: Inappropriate or inadequate policy and legal frameworks		
Development of policy and legal frameworks and public awareness	- Raised awareness among policy-makers of issues and options for improved policy and legal frameworks - Links to existing rural and economic development projects enhanced	- Identify inappropriate policy/legal elements - Undertake public awareness actions among policy-makers - Establish close partnerships with extension workers and others involved in agricultural development

Material, Methods and Results

Area 1: Provision of genetic material to users

The lack of suitable varieties, or predominance of low yielding and /or pest and disease susceptible varieties is very often a major bottleneck hampering the promotion of NUS. With regard to Andean grains, earlier efforts made by PROINPA and CIRNMA on surveying, characterizing, assessing and selecting local material (INIA, 2002 and 2004; SOTO and PINTO, 2003; SOTO *et al.* , 2004) represented for the IFAD NUS project an important basis for launching its germplasm improvement efforts. Building on available local material and breeding lines, the project organized a number of participatory selection activities involving the three species. A total of 42 evaluation trials were carried out between 2001 and 2008 in both countries (20 in Bolivia and 22 in Peru). Criteria for selection used in these participatory trials included the identification of most useful market traits and indigenous knowledge on traditional uses reflecting also gender related criteria. Following are the results and observations emerging from these approaches.

Quinoa

An good example of the participatory work carried out with farmers in Bolivia was undertaken in the Regions of North and Central Altiplano during the 2002 season. In these trials, ten varieties originating from Bolivia were grown in eight demonstration plots. The results indicated that farmers preferred varieties mainly on the basis of yield, colour and seed size. However, the highest score assigned by farmers refered to yield rather than to the size of the grain. The varieties Chucapaca, Patacamaya, and Line 26 were selected as being the most attractive. Such a finding is somehow in contrast with the fact that the most popular variety in Bolivia and Peru today is "Quinoa Real", which is characterized by large, white grains. Because of the important role of Quinoa Real today in sustaining the incomes of farmers in Bolivia and Peru, the project directed some research efforts to also understand better the variation within the variety with the objective of broadening the number of ecotypes that could be used by farmers in the cultivation of this type of quinoa. Trials to assess the agro-morphological characteristics and yield of six Quinoa Real ecotypes (Achachino, Lipeña, Toledo, Pandela, Kellu and Pisankalla) were carried out in Chacala in the Southern Altiplano region of Bolivia in the summer of 2002-2003. The trials revealed that all ecotypes were characterized by branching, short branches, and great variation with regard to plant colour, physiological maturity dates and colour of grain before threshing (Table 2). For all grains with the exception of Pisankalla the colour after saponin removal is white. The average height of the plants ranged from 70.2 cm (Kellu) to 87.0 cm (Toledo); the length of the panicle ranged from 20.3 cm (Pandela) to 28.1 cm (Lipeña); and the yield ranged from 644 kg/ha (Pandela) to 915 kg/ha (Kellu) (Table 2). The low yields obtained in these trials were greatly influenced by drought during this growing season in Bolivia.

In Peru, the participatory selections on quinoa made in three districts of Puno led to the identification of nine promising ecotypes. Resistance was seen as a fundamental trait by farmers; the "Koitu" variety was selected for its resistance to cold and frosts and its resistance to the main pest *Eurysacca quinoae* ("k'ona k'ona" in Quechua language) and the variety group "Witullas" is characterized by resistance to cold (particularly the "Orqo Witulla" ecotype), drought and pests. Farmers believe that white seed quinoa varieties are more susceptible to abiotic stresses than those of other seed colours (although characterized by good grain yield, which might explain the preference in Bolivia for white grains). In the end, these evaluations resulted in the identification of the early maturing ecotypes of Witullas, Sajama, Quello Juira, Janco-quello and Yoqello and the late maturing ecotypes of Kuchiwila, Chullpi and Pasankalla. The Chullpi ecotype showed the highest yield (3,600 kg/ha) followed by white grain quinoa (3,000 kg/ha), and pinkish grain quinoa Witullas (2,200 kg/ha).

Table 2: Agro-morphological traits and production traits in Quinoa Real ecotypes characterized in Chacala, Bolivia in the summer of 2002-2003.

Ecotypes	Growth habit	Seed colour at maturity	Panicle shape	Seed colour after saponin removal	Size of grain (mm)	Cultivated area (m2)	Height of plant (cm)	Length of panicle (cm)	Yield (Kg/ha)
Kellu	Branching	Orange-like	Amaranth-like	White	2.57	1005	70.2	21.3	915
Lipeña	Branching	Light cream	Amaranth	White	2.35	3680	72.6	28.1	750
Toledo	Branching	Orange-reddish	Amaranth	White	2.45	1780	87.0	25.6	775
Achachino	Branching	Red	Amaranth	White	2.17	3200	77.7	23.4	862
Pandela	Branching	Pinkish	Amaranth	White	2.2	5500	73.3	20.3	644
Pisankalla	Branching	Purple	Glomerule-like	Coffee colour	2.4	5280	76.7	26.0	736

Cañihua

Based on a preliminary evaluation of cañihua germplasm carried out in Bolivia in 2002 by PROINPA, the most promising varieties with interesting grain and yield traits were used in the 2002-2006 seasons for a participatory evaluation involving thirteen communities from the departments of La Paz, Oruro and Cochabamba in the regions of the Altiplano Norte, Altiplano Centro and Zona Alta respectively.

The results of these trials were used for the selection of accessions No. 081 and 472, appreciated by farmers for their precocity, homogeneity and high yield, whitish colour of the flower bracts and large brown grains. These accessions were deployed by the National Seed Programme of Bolivia for the selection of two commercial varieties successfully released in 2007 with the names of “Illimani” and “Kullaca” (Fig 2), which represented the very first cañihua varieties to have been released in this country.

Fig. 2: Characteristics of "Illimani" and "Kullaca" cañihua varieties released in Bolivia in 2007.

ILLIMANI

Plant colour: green at flowering and pinkish-orange at maturity
Colour of inflorescence: whitish
Plant height: 54 cm (average)
Days to maturity: 160
Potential grain yield: 1500 to 2000 kg/ha
Yield average: 800 kg/ha
Grain colour (with perigonium): greyish-white
Grain colour (without perigonium): dark coffee
Grain diameter: 1.20 mm

KULLACA

Plant colour: Green at flowering and purple at maturity
Colour of inflorescence: whitish
Plant height: 50 cm (average)
Days to maturity: 150
Potential yield: 1000 to 1200 kg/ha
Yield average: 700 kg/ha
Grain colour (with perigonium): greyish-white (see left, top)
Grain colour (without perigonium): dark coffee (see left, bottom)
Diameter: 1.22 mm

In Peru, cañihua is cultivated with good yields at lower altitudes on black soils. The crop is resistant to cold temperatures and hail (TAPIA *et al.*, 1979). It has a much shorter habit than quinoa, fewer ramifications, pinkish stems and green leaves. In this country the participatory selection trials were carried out during the 2002-2003 and 2003-2004 seasons at Illpa, Chullunquiani and Camacani (located in the Puno region of the country). Sixteen lines obtained from the INIA gene bank in Puno were used for the trials. The results of the trials indicated that accession. 419 had the highest performance at all the three sites (421.39 g/4m^2), followed by accession 100 (413.90 g/4m^2). Six accessions had a good response to favourable environments (accessions 100, 181, 354, 419, 422 and M2), whereas accessions 212 and 405 were found important for acceptable performance in unfavourable environments (or those characterized by low technology and in general used for self-consumption farming systems). In order to make the use of gene bank material more efficient and cost effective, a study was also conducted on the cañihua germplasm maintained at the UNA Puno gene bank in Peru aimed at the identification of duplicate accessions: 96 duplicates (out of 374 accessions of cañihua collected in 2002) were identified through these investigations.

Amaranth

In Bolivia, during the 2002-2003 seasons, some 100 amaranth accessions were evaluated in the communities of Sauces (Gerardo Pozo District), Chirimolle Pampa (Alberto Montaño District), Tipa K'asa (Félix Rosas District) and Molleaguada Alta (Leandro Sejas District). The agro-morphological traits used in these evaluations included early flowering, height of plant at flowering stage, dehiscence of seed, grain yield per plant, lodging at plant maturity, position of panicles within the plant and percentage of expansion of seeds (for the production of popped grains – a top priority market trait). The results indicated that white and semi-white seeds had greatest performance with regard to this important market quality trait (and were characterized at the same time also by early maturing trait). Accessions of amaranth with crystal endosperms, on the other hand, were characterized by the highest plant growth and dehiscence in the panicles.

In Peru, the participatory selection of amaranth focused on Calca Province and was carried out at the experimental fields of INIA in collaboration with the local "Amaranth Producers Association" involving many farmer workshops organized to identify the best criteria for the selection of germplasm. Interesting differences emerged between male and female farmers (Fig 3).

Table 3: Selection criteria for amaranth in participatory evaluation carried out in Cuzco, Peru.

Priority traits selected by men	Priority traits selected by women	Common traits to both groups
• Erect panicle • Panicle with large size • Early maturing • Resistant to diseases • Easy harvest • White grain • Not dehiscent • Good production	• Erect panicle • Panicle with large size • White grain • Thick stalks • Early maturing • Resistant to disease and / or pests • Easy harvest • Tall plants • Large leaves	• Plants with large, erect panicle • White grains • Early maturing (for cultivation in • rainfall cultivations) • Resistant to disease and / or pests • Good production

The result of these participatory evaluations led to the selection of six most promising ecotypes out of which Taray 412, was successfully released by INIA in 2008 (Fig 4).

Table 4: Agronomic characteristics of the amaranth variety Taray 412 released by INIA in 2007 in Peru.

Growing habit	Erect
Plant height at flowering	150 cm
Thorns at the base of the petiole	absent
Apical inflorescence shape	Ear-shaped
Apical inflorescence position	Erect
Inflorescence density index	Dense
Inflorescence colour	Red
Grain colour	Light yellow
Grain shape	Round
Days to flowering	120
Grain loss in the field	Medium (20%)
Seed yield per plant	300 - 700 g
Thousand seed weight	1.10 g
Potential yield	3500 kg/ha
Farmer's yield (average)	2500 kg/ha
Lodging at maturity	Low
Seed emergence rate	97%
Days to maturity	170

The data gathered during the participatory selection trials was very useful for identifying varieties with traits of interest for farmers in Bolivia and Peru. As a whole, some six varieties of quinoa, amaranth and cañihua were selected and distributed to farmers by the project. However, more selection work is needed to meet local farmers' emerging needs including selection of varieties to address climate change phenomena. During the implementation of the project in fact, both in Bolivia and Peru, farmers reported increased occurrence of droughts, changes in temperature (more instances of cold spells and/or higher temperatures) during the planting season which led them to shift the planting dates of the target crops considerably as an impact mitigating measure. The selection of germplasm better adapted to these changes, and investigation into the potential impact of new material in the use of Andean grains in the coming years are thus important fields for further research. The multiplication of the accessions and varieties selected during the trials was done as a collaboration between the PROINPA Foundation, the Fito-ecogenetics Research Centre (CIFP), and the Faculty of Agronomy of The Major University of San Andres (UMSA) (Bolivia), three producers' associations of quinoa and cañihua (Cabana and Lampa) and one amaranth association (Curahuasi in Cusco) in Peru. More than six tonnes of seed were obtained by these efforts from twelve varieties in Bolivia and six in Peru. More than twenty demonstration plots were established to promote the use of the selected material by farmers at the pilot sites of the project in Bolivia and Peru from 2001 till 2008.

Another important activity was the assessment of the genetic diversity of target crops in farmers' fields. The area chosen for these studies was Lake Titicaca (one of the largest and highest lakes in the world located at 3,835 masl), whose surroundings are considered to be the most important centre of diversity for quinoa and cañihua (TAPIA, 1992). During the Inca Empire, these crops were very popular, particularly during the Tiahuanaco Period, but following Spanish colonization they were gradually displaced and substituted with maize and wheat, a process that has continued until today to the extent that their genetic diversity has been severely eroded (ROJAS, 2003). In order to gain a better understanding of the current status of both genetic diversity and genetic erosion the project carried out a survey in this area involving more than 467 families across five provinces of the department of La Paz. The results of the survey indicated that the diversity of quinoa and cañihua is affected by severe genetic erosion, thus confirming earlier reports (ROJAS *et al.* 2003, and 2004). It is interesting to note that whenever the farmers interviewed were asked about crop preferences, they always indicated quinoa and cañihua among their top choices (usually following potato, faba bean and/or oca *Oxalis tuberosa*). The survey revealed that only 40 local varieties of quinoa and 20 of cañihua were being cultivated today out of at least 200 estimated to be have been cultivated there in the past and that the average family was growing only one to four varieties of these crops in its fields (85% cultivated only a single variety). The most preferred variety of quinoa (var. 'Janko Jupa') was cultivated by 32% of the families. In order to contribute to halting this dramatic genetic erosion and in view of the important role that this area plays in the *in situ* conservation of Andean grains and their associated traditions, the project intervened with some targeted efforts: most threatened varieties were identified, multiplied and their seed distributed among local communities around Lake Titicaca for reintroduction. As a whole, some 120 kg of 40 varieties obtained from the *ex situ* gene bank of PROINPA and CIRNMA were provided by the project from 2001 to 2008. The restitution of lost varieties to their original areas of cultivation demonstrated the important role that *ex* *situ* conservation plays in the safeguarding of agricultural biodiversity. In view of the very limited representation of NUS crops in the 1,300 gene banks around the world, the role of farmers as custodians of NUS diversity and the need for greater support for their work cannot be over emphasized (PADULOSI *et al.*, 2002).

Area 2: Conservation of germplasm and associated traditional knowledge

According to a preliminary calculation, we can estimate that the genetic diversity of Andean grains has been collected in Bolivia for 70% and in Peru for 45% of the estimated area of their total distribution. In its efforts to sample the genetic diversity of these species, the IFAD NUS project adopted a gap filling approach, strategically sampling only those areas where genetic diversity was considered to be highest and/or areas where genetic erosion were also registered. Fig 5 shows the sites of cultivation and collection of cañihua in Peru carried out by the project since 2002.

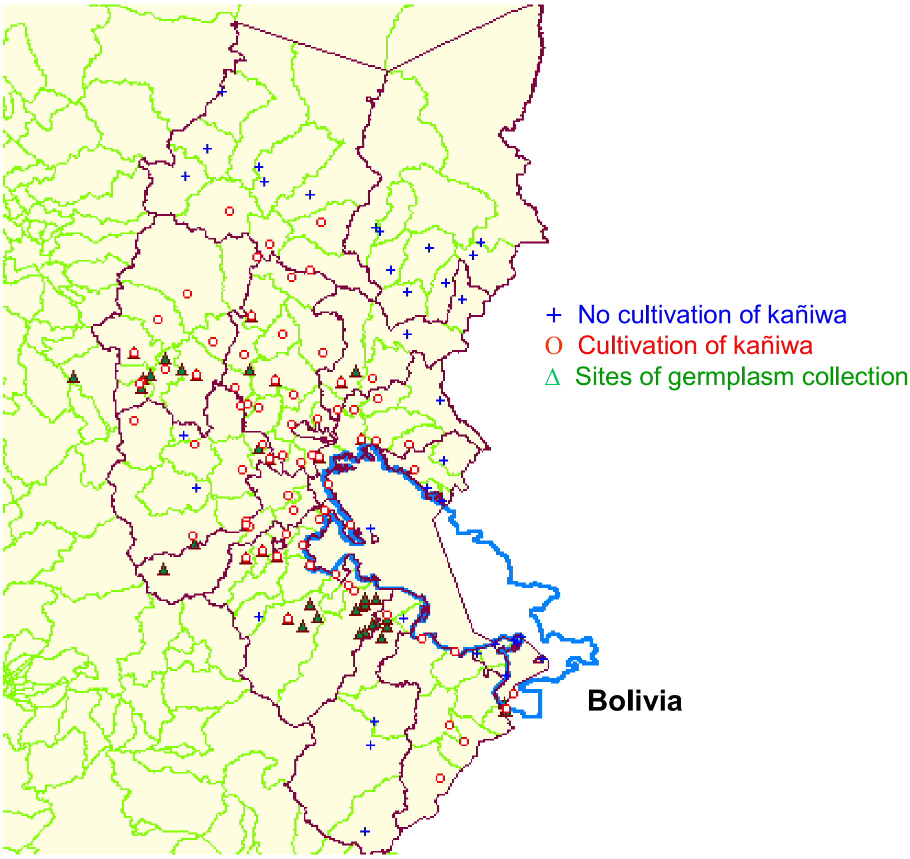

Fig. 5: Areas of distribution and collecting sites of cañihua in Peru (CATACORA 2002).

Nine missions (six in Bolivia and three in Peru) were launched as a whole from 2001 to 2004 and 1492 samples of Andean grains were gathered (Table 3).

Table 3: Andean grain germplasm collected in Bolivia and Peru from 2002 to 2004 in the framework of the IFAD-NUS project.

Country	Quinoa	Canihua	Amaranth	Total
Bolivia	144	406	136	686
Peru	145	586	65	796
Total	289	992	201	1492

In addition to the collection of new germplasm, the project also supported the recovery of many accessions in gene banks, through viability tests and regeneration activities. In Bolivia alone, these efforts contributed to an ultimate increase of quinoa, cañihua and amaranth germplasm in gene banks estimated at between 30 and 100% (ROJAS *et al.*, 2003).

In order to assist researchers and other workers in their studies aimed at assessing and enhancing the use of the genetic diversity of quinoa maintained in gene banks, a germplasm catalogue for quinoa about the accessions at the PROINPA gene bank in La Paz, Bolivia was developed and widely disseminated in hard and soft copies (ROJAS *et al.*, 2001). A catalogue on the material of quinoa, cañihua and amaranth collected in Peru along with passport data was also developed (CIRNMA, 2007). The first cañihua descriptor list was produced and published within the Bioversity series of Crop Descriptors (IPGRI, 2005). Visits by farmers to gene banks were also organized to promote the much needed linkages between conservationists and user communities, often indicated as a major obstacle in promoting the use of agrobiodiversity (FAO 1996).

During the amaranth collecting missions carried out by INIA-Cusco and AEDES in Cusco, Arequipa and Apurimac in Peru, a low presence of genetic diversity was observed and most worry some more than 80% of the area cultivated with amaranth was observed to be cultivated with only one variety (Oscar Blanco).

The data gathered during the multiplication of the germplasm collected in Peru by the project and carried out at the UNA and INIA gene banks, showed that among the quinoa germplasm, green, pinkish and purple seeds were the most common types The most common inflorescence type is the glomerule-like one, 21 accessions had amaranth-like inflorescences, and 135 were of the intermediate type. The study revealed also the presence of 91 accessions tolerant to frost.

The project decided to upgrade important collections of Andean grains which needed urgent attention. The infrastructure and conservation capacities of a number of gene banks were therefore improved: the National Andean Grains Gene Bank at the PROINPA Foundation in La Paz (Bolivia), The Fito-ecogenetics Research Centre (CIFP) Gene Bank of Pairumani (Bolivia), the Gene Bank of the National Altiplano University of Camacani (Peru) and the Gene Bank of the Experimental Station of the National Institute of Agricultural Research and Extension (INIEA) of Illpa (Peru). The interventions benefitted more than 7,000 accessions maintained in these collections. The multiplication of 536 accessions of quinoa maintained at the Illpa gene bank was also supported, which allowed the regeneration, and characterization of valuable material along with their characterization for agronomic traits.

In order to assist Andean grain breeders and their user community at large, the IFAD NUS project carried out *ad hoc* studies for the establishment of core collections for quinoa, cañihua and amaranth, (HODGKIN *et al.* 1995). These core collections, particularly of quinoa, have contributed to an increase in the use of genetic material from the crop genetic improvement programme, where researchers are working on the identification and selection of promising varieties of quinoa to address abiotic stresses such as frost and drought but also to search for specific economically important market traits. The quinoa core collection was developed based on a matrix of data on 2,514 germplasm accessions and 18 quantitative variables, using correlation coefficient and multivariate analysis methods (DILLON and GOLDSTEIN, 1984; PLA, 1986; HAIR *et al.*, 1992). This study led to the identification of six different groups (Fig 6) from which 267 representative accessions were selected to form the core collection: 200 accessions originated from Bolivia (the major contribution of material originated in La Paz, Oruro and Potosí), 48 accessions from Peru (significant contribution from Puno), 6 accessions from North Argentina, 1 accession from Ecuador and 1 accession from Europe (introduced material). For eleven accessions passport data were not available. The 267 accessions selected represent 10.6% of the whole germplasm collection characterized by PROINPA.

Similar studies carried out for cañihua (499 accessions and 20 variables) led to the identification of 4 main groups of accessions (Fig. 7) from which 57 accessions were selected to form the core collection (39 from Bolivia (all but one accession from La Paz), 1 from Peru (Puno) and 17 of unknown origin), representing 11.4% of the characterized PROINPA collection of cañihua. The development of the amaranth core collection based on 221 accessions and 12 quantitative variables led to the identification of 2 groups (16 accessions in group 1 and 7 accessions in group 2) and the development of a core collection of 23 accessions (10.4% of the total collection of characterized amaranth available at CIFP).

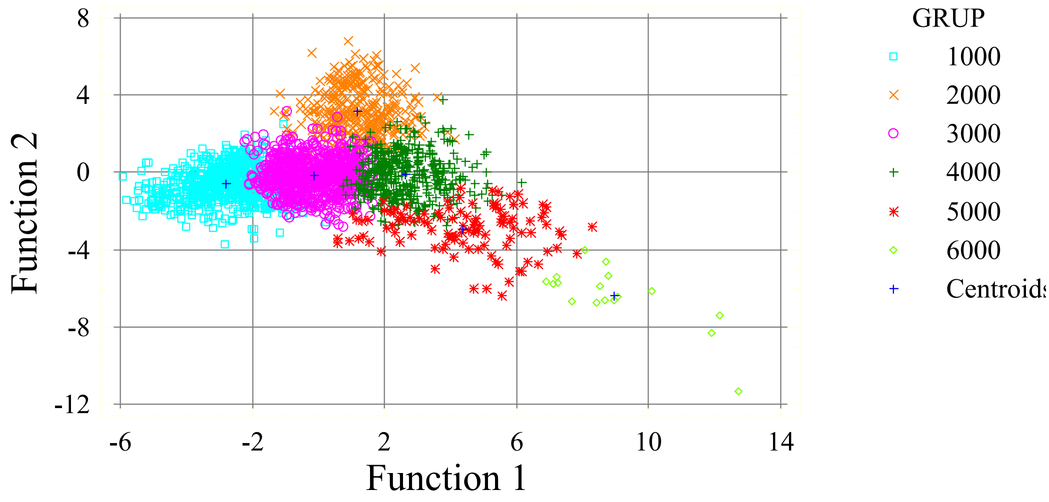

Fig. 6: **Spatial distribution of the six groups of quinoa identified in its core collection developed by PROINPA**

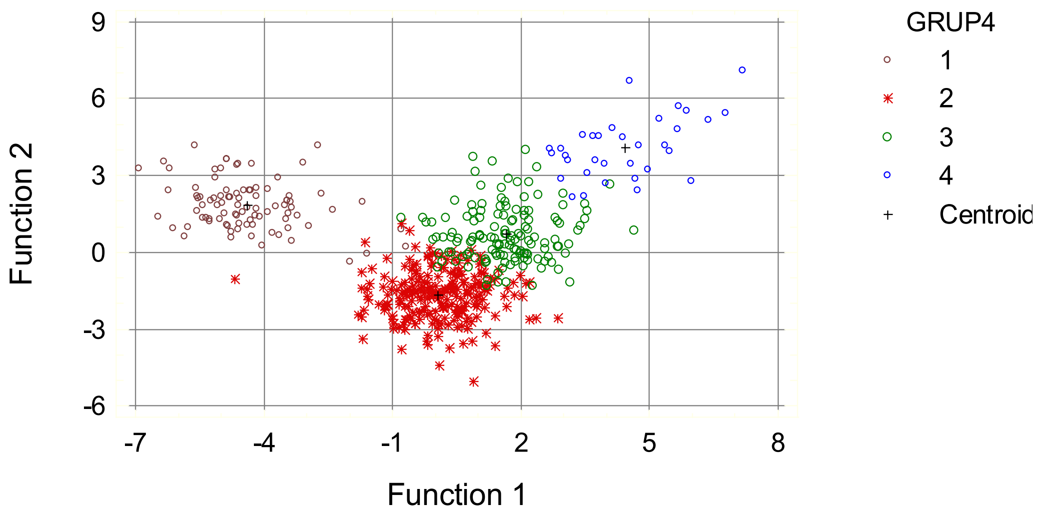

Fig. 7: **Spatial distribution of the four groups identified in the core cañihua collection developed by PROINPA**

The loss of indigenous knowledge (IK) about Andean crops is a widespread phenomenon of great concern in view of the important role that it plays in maintaining traditions of cultivation and use. The recuperation of IK was addressed by the IFAD NUS Project through a number of surveys at the community level in the project sites. During these participatory data gathering activities, detailed information was collected from local farmers with regard to traditional cultivations methods in the 'aynoqas' (community lands), 'sayañas' (lands around farmers' houses), 'kjochi irana' (lands near Lake Titicaca) and 'uyus' (corrals). Important data regarding biological indicators still used by farmers in traditional systems of cultivation land, valuable for assessing the level of conservation of quinoa, cañihua and amaranth were also gathered.

The project focused also on *in situ* conservation, in consideration of the contribution played by local communities in safeguarding genetic diversity on their farms, efforts which are highly complementary in nature to those made through *ex situ* approaches. An important contribution to the on-farm conservation of Andean grains in Bolivia and Peru is made by women. One example is the case of Ms Petronila Neyra from Puno (Peru), a farmer who safeguards on her farm more than 55 accessions of quinoa. Her contribution and that of many other custodians of genetic resources of Andean Grains were publicly recognized during more than 21 Biodiversity Fairs organized by the project in Bolivia and Peru (and Ecuador) from 2002 till 2008. Among these, noteworthy of mention were the first Fairs ever organized for quinoa and amaranth in Bolivia. These fairs represent an important instrument to promote the sharing of material and information about local crops among farmers and other users and value chain actors. Information shared during the fairs includes data on ethnobotanic uses, agronomic characteristics, commercialization and transformation, which is valuable for the promotion of agrobiodiversity, and NUS in particular (CIRNMA, 2004; FAO, 2006). Fairs play an important role in keeping alive the traditions and culture of NUS, under threat of erosion due to globalization and other social trends. They also represent a valuable instrument for the conservation of local varieties by promoting exchange in an informal way. During these fairs many ecotypes of target crops were identified and samples were taken for conservation measures in *ex situ* gene banks. As an example, more than 39 ecotypes of cañihua, were sampled during the fairs organized by IFAD NUS in Peru from 2002 to 2008. Furthermore, during the seed fairs organized in Arequipa and Curahuasi (also in Peru), the project was able to identify 30 accessions of amaranth (*Amarantus caudatus*) of which at least four were said to be under severe threat of genetic erosion. In order to make the fairs a self-sustainable event beyond the life of the project, efforts were made towards their institutionalization and adoption by national and local agencies. This is the case of the "Biodiversity and Popular Andean Art Fair" which will be now held annually on June 20th and 21st at the Tiwanaku Municipality, as part of the "Aymara New Year" Celebrations, and which will receive continued support from the Ministry of Culture and Development, the Ministry of Tourism and other important agencies in Bolivia. In Peru, similar efforts have led to the institutionalization of the "Cabanillas' Agrobiodiversity Fair" which is held every September in the city of Cabanillas (Puno District) in collaboration with the local Municipality, the Ministry of Agriculture, the IFAD Puno-Cuzco Corridor and other development and rural organizations. In Peru from 2001 to 2008 some 14 diversity fairs were organized by the project, with the involvement of more than 540 families from local communities.

Area 3: Documentation of knowledge on uses, constraints and opportunities

As already mentioned in the previous section, IK on uses of target crops was gathered during the biodiversity and seed fairs, germplasm collecting expeditions, and *ad hoc* socio-economic surveys carried out along the production to consumption chains of target crops. An example of the work carried out in this domain is the survey on the management of traditional food systems of quinoa, cañihua and amaranth crops in the north high plateau (Altiplano) and high valleys of Bolivia, and in the high plateau of the Department of Puno in Peru. In these communities, research was carried out regarding traditional uses of target crops, which allowed the recovery of traditional knowledge on cultivation practices, management, food culture and constraints associated with these practices. Data were gathered about food traditions, indicating a great diversity of food preparations, whose recipes are safeguarded particularly by the elder members of the community. Examples of these local recipes using Andean grains as ingredients are the K'ispiña (steam-cooked quinoa biscuits), pito (ground and toasted grains), tayach'a (k'ispiña of cañihua prepared with milk and frozen), pesq'e (boiled quinoa with milk and cheese), soups and stews (ALCOCER, 2003; ARONI *et al.* 2003). The project gathered and documented existing recipes for preparing Andean grains and also developed novel recipes in a participatory manner through discussions and focus groups with local women. Grains of quinoa, cañihua and amaranth are used for both human and animal consumption, and also for medicinal and religious purposes.

Area 4: Development of community-driven actions to enhance income generation

The lack of competitiveness in the market is perhaps the most common constraint in the promotion of NUS. This aspect is rather complex and involves interventions in many directions such as identification of agronomic obstacles hindering effective cultivation and harvest, post harvest limitations, value addition bottlenecks, and constraints in the organization of the market chain. According to the participatory workshops held with stakeholders, the main obstacles to the use of Andean grains are to be found in post harvest and value addition domains. For that reason, special attention was devoted to the development of technological solutions aimed at improving threshing and saponin removal operations. In Bolivia two prototype threshing machines for quinoa were designed, built and validated by community members. Results show that operation is optimal, with a performance of 95 kg/h of threshed grain, compared to 100 kg/day as achieved by a farmer manually. These prototypes respond to farmers' demand for lower levels of contamination by stones and grit, reduced loss of grain, suitability for small and medium operations, and easily transported field equipment at accessible prices (PACOSILLO, 2003; QUISPE, 2004).

Another area of improvement which was tackled by the project is the desaponification of quinoa grains. Saponin is an alkaloid present in quinoa (absent in cañihua and amaranth). While saponin plays an important role in conferring pest resistance to quinoa varieties (JACOBSEN *et al.*, 2000), it is in fact an anti-nutritional substance and needs to be removed from the seeds to allow human consumption. The removal of saponin has been traditionally done by women, who spend at least six hours daily task (ASTUDILLO, in press). In addition to the drudgery and time involved, there is also the hazard of inhalation of the saponin dust which may damage the eyes and respiratory tracts. A machine for saponin removal was manufactured by the project and several specimens were handed to families in the city of Uyuni (Central Altiplano), where the project had found a decrease of the use of quinoa and a reduction in the genetic diversity used by people reportedly because of the drudgery of the saponin removal process. Monitoring of the use of the machines by the communities to assess the impact in enhancing the use of highly nutritious quinoa varieties in that area (affected by malnutrition) and its expected positive impact on the conservation of local varieties was very encouraging trend in few months (Table 4)

Table 4: Number of families using the saponin removing machine produced by the project and number/types of culinary uses (December 2007 to March 2008 period).

No.	Community	No. families	Amount of grains processed per culinary use (kg)					Total (kg)
			Soup	'Phisara'	'Pito'	'Mucuna'	Flour	
1	Copacabana	22	70.31	36.29	36.29	0	13.61	156.50
2	Colcha K	12	127.01	54.43	0	0	0	181.44
3	Jirira	8	22.68	11.34	11.34	22.68	22.68	90.72
4	Irpani	15	252.20	179.17	466.29	239.04	419.12	1555.82
5	Chita	14	206.38	246.30	204.12	149.69	48.53	855.02
Total		71	678.58	527.53	718.04	411.41	503.94	2839.5

Area 5: Actions addressing markets, commercialization and demand limitations

The main factor limiting the sale of these grains appears to be the quality of the product offered for sale. Today, Andean grains have very good commercial opportunities, since there is high demand in local markets that has not yet been satisfied (BENAVIDEZ, 2003; MAMANI and CHUGAR, 2003; MAMANI and Yana, 2003).

During the first phase of the project it became clear that greater investment in research was needed to reinforce the promotion of local varieties. This approach in raising demand was developed in the second phase of the project following three main lines of intervention: 1) assess the nutritional content of landraces (in raw as well as processed material) of target crops, 2) develop more attractive products, particularly for younger people and 3) carry out campaigns to promote target crops and their nutritious products. An example of the type of investigations being carried out on cañihua by the project to assess the nutritional profile of different varieties in raw and processed products is provided in Table 5.

The project is further investigating through an extensive study (collation of data and new analyses both in Bolivia and Peru) the nutritional diversity present in quinoa, cañihua and amaranth germplasm, (Table 6).

Table 5: Chemical and functional composition of different varieties of cañihua in grains, flour, cakes and desserts carried out in Peru (from GUTIERREZ, 2002).

Parameter	Var. 'Cupi' (seed) %	Var. 'Cupi' (flour) %	Var. 'Ramis' (seed) %	Var. 'Ramis' (flour) %	Cakes (g / 100g of food)	Dessert (g / 100g of food)
Protein	15.19	15.19	16.6	14.73	3.5	8.0
Water	12.25	5.22	7.94	5.30	--	--
Ashes	2.42	2.42	2.61	2.27	--	--
Fat	8.80	7.82	7.30	8.01	3.86	6.7
Carbohydrates	56.6	61.03	57.30	61.38	36.4	28.0
Fiber	9.86	8.18	8.47	8.41	--	--
Fe (mg)	--	--	--	--	2.36	8.9
Kcal	--	--	--	--	193.7	220.18

Amino acid content in 100g of proteins						
Isoleucin	--	--	--	--	1.58	1.91
Leucin	--	--	--	--	0.69	1.23
Lysin	--	--	--	--	0.84	1.16
Metionin	--	--	--	--	0.75	1.32
Phenylalanina +Tyrosin	--	--	--	--	0.46	1.20
Treonin	--	--	--	--	1.156	1.36
Tryptophan	--	--	--	--	0.90	1.21
Valin	--	--	--	--	1.024	1.80
Histidin	--	--	--	--	1.14	1.43
Digestibility (%)	--	--	--	--	93.24	95.63

Table 6: Nutritional properties in leaves and toasted grains of amaranth in Peru.

Parameter	**Fresh leaves**	**Dry leaves**	**Toasted grains**
Water (%)	85.56	--	1.14
Protein (%)	3.42	23.68	17.12
Ash (%)	2.73	18.91	2.42
Fat (%)	0.11	0.76	7.41
Fiber (%)	14.82	14.82	3.61
Carbohydrates (%)	6.04	41.83	68.30
Energy (Kcal/100g)	30.83	213.50	409.67
P (mg/100 g)	--	--	537.5
Ca (mg/100 g)	--	--	127.35
Fe (mg/100 g)	--	--	11.46

Investigations in Quinoa Real, initiated in the fields of Chacala in the Altiplano Sur region of Bolivia (see section 2 on quinoa), continued in the laboratory of LA&SAA (Análisis y Servicio de Asesoramiento en Alimentos) in Cochabamba, Bolivia. The aim was to determine the potential for transformation of each of these currently marginalized ecotypes of Quinoa

Real. The results of the laboratory analyses indicated that the ecotype Achachino is characterized by an exceptional nutrition profile (protein 18.29%, fat 3.11% and fiber 6.28%). Achachino also showed good properties for the preparation of pasta (followed by Kellu and Pandela ecotypes). The analysis of sugar indicated that the ecotypes Pandela and Toledo are best for bread-making and also have an ideal sugar content for the preparation of juices. With regard to the preparation of biscuits, measurements of starch grains indicated that Pisankalla had the best texture for these products as its starch grains were the smallest (0.004 mm) of all (grains characterized by diameter ranging from 2.17 to 2.57 mm). According to the Bolivian regulation "Cereals - quinoa grain - classification and requirements"[1], the grains of quinoa are classified as follows: 1) extra-large (size 2.2 mm and beyond), 2) grains of prime class (1.75-2.2 mm in diameter). These ecotypes would therefore fall easily into the good quality categories. The laboratory analyses revealed the highest protein content is in Achachino (18.29%) and the lowest in Pandela (13.34%). The fiber content was highest in Lipeña (9.11%), which is an interesting result in view of the important role that fiber plays in the diets of people affected by cardiovascular disease, diabetes and obesity.

Greater consumption at the family level (particularly among children) is being promoted by the project through novel and more attractive recipes for cookies, cakes, juices and other products. Collaboration with the private sector is already resulting in the development of nougat, muesli, drinks and other commercially viable products for the three crops. In Bolivia, participatory culinary aptitude tests were organized to test biscuits and cakes prepared with quinoa, cañihua and amaranth, including a variety of juices made of these grains combined with fruits. Recipes for promoting these uses at family level have been published and disseminated (ALCOCER, 2003; ARONI *et al.*, 2003). At an industrial level quinoa flakes, noodles, popped quinoa and cañihua and fine flour have been elaborated. Amaranth energy bars with honey were obtained, as well as granola with oats, almonds, peanuts, sesame and dried fruits; and a combination of amaranth with milk and grated coconut called "millcoco", as well as biscuits (ROCHA, 2003). Recipes to prepare 'alfajor' (two biscuits filled with caramel) with quinoa, quinoa pies and orange cake with cañihua flakes were also developed.

In Peru, taste tests of boiled grain flours and desserts as well as of cañihua-based dishes, were made. The process of expanded products for nougat elaboration was studied. The best combination of cañihua and corn was de-

[1] Norma Boliviana "Cereales-quinua-en grano-clasificación y requisitos"

termined to obtain expanded products by extrusion. With quinoa, malt procedure parameters have been studied for beer development and other parameters have been determined for the production of chocolate. Instant quinoa and cañihua have been obtained, with high nutrient and energy levels, at competitive production costs. A nutritious beverage from germinated cañihua and pineapple juice, with important nutrient properties and at competitive costs was developed. A coffee-type beverage of toasted cañihua was obtained and could compete with conventional coffee, having the advantage of being caffeine-free. Expanded popped grains with artificial flavouring and colouring could be introduced into the market in a competitive and successful way. Finally a liquor based on quinoa, pineapple and maca (*Lepidium meyenii* Walp.) was also developed.

Area 6: Research and development-oriented activities to strengthen national capacities.

Weak national capacities for tackling the promotion of NUS represent a common situation in most countries, both in developed and developing countries. Building capacities entails the enhancement of physical infrastructures, technologies and tools as well as education. With regard to human resources the project has been equally active. Since 2002 and continuing throughout 2005 (first phase) and during the start of the second phase (mid 2007-2008), many courses were carried out in communities collaborating with the project, targeting community members (particularly women), stakeholders in the value chains, students and researchers. More than 40 courses were undertaken by the project both in Bolivia and Peru, which have directly benefitted more than 2,000 people. These courses covered a broad range of themes, from surveying, collection, characterization of plant genetic resources to cultivation practices, participatory evaluation, harvest and post harvest technology, food technology, value addition, quality standards and marketing. In addition to the courses, also three manuals for the cultivation of Andean grains were produced and disseminated to communities during the courses. In addition 29 university students (from UNSA-Puno, UNA-Puno and EPG-UNA in Peru and UMSA and UTPO Universities in Bolivia) were trained in research fields of interest to the project (from conservation and cultivation to nutrition and marketing) while carrying out their thesis work. Capacity building on agri-tourism was initiated in 2008 in the community of Santiago de Okola to enable the local population to raise their incomes through the promotion of local agricultural biodiversity and the landcape.

Area 7: Establishment of effective links between conservation and crop value chains

Interventions along the value chain for each of the three Andean grains were made in a two-step approach in both countries. First an assessment was conducted of the value chains to map out their functioning, members, bottle necks and opportunities for their enhancement. Second, selected interventions were developed together with the stakeholders to address their weaknesses and limitations. To strengthen the links across value chain actors a number of initiatives were made, including the development of collaborative agreements, for example between Aiquile Municipality in Cochabamba (Bolivia) and the Local Amaranth Producers to provide school breakfast to local schools, or the agreement between two amaranth producer organizations also in Bolivia who signed agreements with the Andes Trópico Company for the regular supply of products to their factories. With regard to the value chain of quinoa and cañihua, three producer organizations signed purchase and sale agreements with the Andean Cereal Processor of La Paz. These agreements include commitments to deliver high quality products for higher prices (up to 20% higher than those present in the market at the time of the transaction) (SARAVIA and ROJAS, 2002). A particular case was the linking up of cañihua producers of the Llaitani community (Cochabamba) and the Irupana organic Andean food enterprise in La Paz. These links started in 2004 with the establishment of participative evaluation lots with accessions from the National Andean Grains Gene Bank and local variety grains. The work was supported with capacity building courses about the productive process of cañihua crops. Visits from the head of the Provider Development Area of Irupana to Llaitani community were promoted, starting a strong bond between two productive chain links of the cañihua crop.

Area 8: Development of policy and legal frameworks and public awareness

In both Peru and Bolivia seminars were held involving representatives of the Ministries of Agriculture and Commerce and from the private sector to discuss ways of promoting quality introduction of standards for Andean grains while maintaining diversity in production systems.

One fundamental task to promote quinoa, cañihua and amaranth in national and international markets is support in the development and review of technical regulations that determinate quality standards of Andean grains. Through a coordinated work with the Bolivian Institute of Quality and Standardization – IBNORCA, technical regulations for cañihua and quinoa were developed (IBNORCA, 2002), the first of their kind in the country and in the Andean region. This has allowed access to export markets, because exportation of products is not possible without the establishment of quality standards. Furthermore, the development of technical regulations for amaranth was supported as well as the revision and actualization technical regulations for quinoa.

These achievements were later supported by other projects managed by the PROINPA Foundation and, in the framework of the NOREXPORT Programme, a regional trade and capacity-building group, work is being done for the development of Andean technical regulations. The Projects for Andean Cereals Regulations are being negotiated, with the participation of representatives from the IBNORCA network and its counterparts in Colombia (ICONTEC), Ecuador (INEM) and Peru (INDECOPI). Furthermore, a project has been developed for the regulation of popped quinoa. The regulations developed allow quality standardization (in this case quinoa and processed products), contributing to better commercial flows, thus eliminating possible customs barriers (Soto, 2008).

Using radio, television and newspapers, the nutritional value of cañihua, quinoa and amaranth has been promoted. Recently a strategic alliance has been established between the 'Alexander Coffee' coffee-shop chain[2], the PROINPA Foundation and 'La Paz on Foot'[3] (an eco-tourism organization) with the support of the Italian NGO UCODEP[4] and Bioversity International to implement a campaign to promote the consumption of these Andean grains. The campaign has had the purpose of informing customers about the nutritional benefits, agrobiodiversity, and recipes of the Andean grains through educational cards placed on the tables of the Alexander Coffee shops. Likewise, this company has developed novel products prepared with Andean grains. In the month destined for the promotion of quinoa, a quinoa cake, a quinoa "wrap", a quinoa salad and a new quinoa biscuits were also presented to the public with great success.

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[2] www.alexander-coffee.com

[3] www.lapazonfoot.com

[4] www.ucodep.org

Recommendations on the Way Forward

For quinoa, increased demand for export to Europe is leading to booming cultivations both in Bolivia and Peru, often without any crop rotation. The impact of this practice on the fragile soils of the Andean region needs to be assessed in order to avoid negative repercussions on the agro-ecosystems that would jeopardize future cultivation. Sustainable cultivation practices need therefore to be developed to allow farmers to seize emerging income opportunities while maintaining both diversity and ecosystems functionalities.

Over the last five years, the variation in climate patterns has been very high in the Andes with profound effects on local cultivation. During participatory workshops with farmers, the IFAD NUS project has recorded an increase of production losses in Andean grains in the order of 23 % on average. Urgent studies are needed to assess the impact of climate change on the genetic diversity of Andean grains and evaluate how this can be better mobilized in order to mitigate risks associated with such changes.

As demand for functional foods and alternative non-food products (such as the industrial use of saponin) from Andean grains rises, more research should be directed towards the development of community-based technologies and capacity building interventions in order to empower farmers to benefit from these emerging opportunities.

Greater linkages should be created between biodiversity-rich but economically poor regions of the Andes and tourism companies so as to promote sustainable, community-based eco-tourism initiatives. Andean grains, like many other native crops from this region, can offer local populations profitable opportunities for income generation and a more holistic and multidisciplinary approaches for their promotion should therefore be emphasized.

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