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Project Title: Climate Variability and Household Welfare in the Andes: Farmer adaptation and use of weather forecasts in decision-making

Principal and Co-Principal Investigators:

Corinne Valdivia, Research Associate Professor
Department of Agricultural Economics, University of Missouri
200 Mumford Hall
Columbia MO 65211
(573) 882 4020
(573) 882 3958 (fax)
ValdiviaC@missouri.edu

Jere L. Gilles, Associate Professor
Department of Rural Sociology
University of Missouri-Columbia
106 Sociology Building
Columbia MO 65211
(573) 882 3791
GillesJ@missouri.edu

Roberto Quiroz, Head
Department of Production Systems and Natural Resource Management
International Potato Center
Lima Peru
R.Quiroz@cgiar.org

Christian Jetté, Program Officer
United Nations Development Program Bolivia
La Paz, Bolivia
Christian.jette@UNDP.org

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I. Preliminary Materials

A. Project Abstract

Climatic variability, characterized by periodic droughts, El Niño events, floods, and weather events such as frosts result in significant losses to rural households of the Andes. The project answered three questions: 1) What have farmers developed as successful strategies to cope with climatic variation in the Andean region; 2) How do farmers currently use information from forecasts and local sources to make production and consumption decisions; and 3) What mechanisms and institutions facilitate or constrain the utilization of climate forecast information.

Three research activities were designed. The first, research on rural livelihoods strategies to study the factors that contribute or constrain coping with climate variability. Second was to understand the role of institutions and networks in coping with climate variability, and accessing forecast information. Finally, we studied current sources of forecast information known and/or used by farmers, the characteristics of the information, of the producers of the information, and the crops affected by climate variability. Our units of analysis were rural households, rural communities, institutions and biological models. At the household level we studied diversification strategies. At the community level we studied social networks in the diffusion of local knowledge forecasts. At the institutional level we studied the role of Radio, and Early Warning and Food Security in use of probabilistic forecast. At the biophysical level we worked on modeling climate variability in local potato varieties to measure impact of local conditions.

We conducted research in three agropastoral communities in the Altiplano of Bolivia and Peru. A diversity of household strategies showed that interactions between the structures (social, market, and political), climate, and policies result in increased vulnerability through time for those constrained by access to assets. While some benefited from government policies and assistance programs –the establishment of dairy in the Altiplano- others took on commercial potato production. These farmers take into account climate forecast information, but locally generated. They have less choices and insurance mechanisms, but have flexibility to adjust planting and varieties. Producers have incorporated new varieties to their portfolio of crops, often in demand by the markets.

The study of networks in Peru and Bolivia showed that households with various strategies accessed local knowledge forecasts, but those that managed the indicators were expert potato producers. Understanding probabilities does not seem to be the main barrier in the Altiplano, traditional forecasters use techniques that include an intuitive approach to probabilities. Local forecasters are potentially the conduit by which forecasts could reach producers, if local experts believed in the accuracy of scientific forecasts. In the Altiplano widespread belief is that forecasts are only valid for the location in which they are generated, the major barrier to forecast use. These results emphasize the importance of working with local experts, and validating down-scaled forecasts. New technologies require incorporating new knowledge, which also may entail understanding new interactions with climate. All these findings point to an opportunity for collaborating with farmers and other institutions in developing local scale information products.

B. Objectives of the Research Project

The research project addressed three questions: 1) What have farmers developed as successful strategies to cope with climatic variation in the Andean region; 2) How do farmers currently use information from forecasts and local sources to make production and consumption decisions; and 3) What mechanisms and institutions facilitate or constrain the utilization of information about climatic risk. To identify how climate and other factors interact and impact the coping strategies of rural households in the Andean region of Bolivia and Peru a theoretical framework and methodologies were developed and tested. This conceptual framework was also useful to study knowledge and use of climate forecast information (local and probabilistic) and its means of access for production decisions. Specific objectives included development of a methodology to identify household strategies expressed in the economic activities and the productive capacity of households in agropastoral communities; measure the impact of El Niño event of 1997-1998 in a peasant community of the Central Altiplano of Bolivia; and study information flows, networks, transactions costs, and mechanisms to access climatic and weather information. Finally, based on the finding identify the characteristics of climatic information delivery systems suited for Andean agriculture.

C. Approach

Our framework to understand how households, individual members and communities cope with climate variability our framework is informed by the sustainable livelihoods literature. This framework provides entry points for economics, sociology and the biophysical sciences involved in our research, to address the question of how households cope and adapt to stressors and shocks. Specifically we apply household economics, political economy, network analysis, and rural sociology to understand what factors contribute to coping and adapting to climate variability. We developed a methodology to identify household economic strategies and portfolios. Focus groups, household formal surveys and in-depth interviews were techniques to collect data from these three agropastoral communities. Through cluster analysis we identify the relationship between access and control of assets, life cycle stage, and composition of strategy.

To evaluate changes through time in terms of income and diversification of the economic portfolio, cluster analysis is applied to household data from 1993, 1995 and 1999 in Bolivia. Canonical correlations and censored regressions were also used to analyze the relationship between assets and strategies; income sources, income level and diversification; and socioeconomic characteristics transaction costs and access to information. To study the effects of location and agroecological zone we validated the approach in two agropastoral communities in Puno Peru. Anccaca has similar agroecological characteristics to San Jose Llanga. Santa María a second community in Puno is closer to a large city.

We used a case study approach – multiple embedded design- to understand dynamic processes in coping and adapting to climate. The study of potato production, household diversification and coping strategies in San José Llanga aimed at understanding how people cope in the short run. A study of the factors affecting market integration (buying and selling products) identified the

socioeconomic and marketing characteristics of transaction costs, using both case study methodology and regression analysis.

Methods to study local knowledge and use of forecasts included focus groups, household surveys, and ethnographic methods. Three case studies of community networks to access information about local knowledge indicators of climate were completed. The types of networks, nodes of information, and the type of information flow were studied.

Biophysical models were developed to identify the potential performance of local varieties under climate scenarios. The formal household survey included questions on production inputs, soil types, feed resources, yields, and total outputs. Our collaborators experimented with farmers in their fields to obtain data to calibrate biological models. Potato varieties were modeled, as well as performance of animal species. Agroecological zoning maps were constructed to understand the land use potential. These combined with biological maps will be used to understand possible outcomes of various climate events, at a local scale.

The working hypotheses of this research are:

1. Access to resources, stage in the life cycle, livestock assets, quality of resources, and off farm employment are significant variables in developing distinct economic portfolios.
2. These, along with networks and experience with climatic information, are predictors of use of forecasts.
3. High transactions costs preclude farmer and household access to climate information.
4. Farmer and household diversification strategies minimize climatic risk and result in lower net income returns (following Rosenzweig and Binswanger, 1992).
5. Climatic information will be used only if risk-reducing technologies are available.

D. Matching Funds

The University of Missouri and the International Potato Center matched faculty and researcher time as proposed. We also obtained funding from the Department of Agricultural Economics for a quarter time assistantship for three years: support covered Susan Materer and Cheston Easter. We matched funding for a graduate research from the Department of Rural Sociology. Two travel research grants were obtained from Dorris D. and Christine M. Brown Research Fellowship, International Agriculture Programs, College of Agriculture Food and Natural Resources of the University of Missouri-MU for Easter and Materer's field research in Peru and Bolivia. The Social Sciences Unit provided funding for Valdivia to present at the AGU Conference in May 2002. University of Missouri funded a short-term faculty leave at the International Research Institute for Climate Prediction. The International Center for Tropical Agriculture in Cali Colombia, (CIAT) provided funding for Valdivia to present findings of the Bolivian research at the Integrated Natural Resource Management Workshop. UNDP facilitated meeting space in Bolivia. PROINPA provided facilities for students, access to vehicles for field research, and extension support to farmers in the Bolivia research site. CIRNMA provided support with vehicles and facilities for the research in Peru.

II. Interactions with decisions-makers

A. Interactions with end users

Our project included collaboration with local institutions as partners or as members of the Expert Panel. The Expert Panel role was to act as advisor to the research activities being conducted each year. The decision makers that we collaborated with are two local nongovernmental organizations that work with end users in development activities: PROINPA (Javier Aguilera and Ramiro Carrillo) at Foundation for the Promotion of Andean Crops) in La Paz Bolivia and CIRNMA (Roberto Valdivia and Jorge Reinoso at the Center for Research on Natural Resources and the Environment) in Puno Peru. With both institutions our focus has been to understand climate as a factor in the design and promotion of technologies for rural households. PROINPA worked in the community that agreed to participate in the research project in Bolivia. Our research on the roles of potato varieties in household strategies, potato diversity and climate, showed households' priorities for selection of varieties were first marketability, second taste and third adaptability to frost. Information was generated on varieties that were drought and frost resistant, so PROINPA could incorporate this in technology design and in information about the varieties. CIRNMA in Puno works in development projects, and collaborated in the research on knowledge of the use of local knowledge forecasts. They promote diversification activities in livestock, forage production, and value added activities. Our research partner in the region, the International Potato Center, is a research institution that develops information products for end-users. Our collaboration resulted in the integration of the livelihoods approach into their new research program in natural resource management. In Bolivia we collaborated with UNDP and shared research methods to identify coping strategies with the World Food Program. We exchanged methodologies with Carmen Barragán, who was mapping vulnerability in Bolivia. We had some contacts with Leeds University's Project on Natural Hazards, specifically with David Preston, Senior Fellow, School of Geography working in Tarija Bolivia. We also communicated with local institutions in Peru, and invited them to participate in the annual workshop. Intermediate Technology Development Group Eduardo Franco was invited to the second expert panel and scientific conference in July 2001. We also communicated with other institutions, Manuel Glave GRADE Peru and Rebecca Harris, IFPRI (International Food Policy Research Institute). At CIP we participated in an IAI workshop (University of Florida) on Climate Prediction Applications for the Andean Region in May 2000.

B. Description of interactions with climate forecasting community

We had the opportunity to share our research approach and findings with several institutions. We presented at the IRI Communication of Climate Forecast Information Workshop (June 6,7 and 8 2001) in Palisades NY, organized by Dr. Jennifer Philips. Valdivia spent two weeks at IRI through a faculty development leave from the University of Missouri, January 7 through the 19th, 2002. Valdivia and Gilles were invited to teach at the Advanced Training Institute on Climate Variability and Food Security, organized by IRI addressing primary data collection, livelihoods, coping strategies framework, local and scientific knowledge in July 2002. In Peru we invited the Instituto Geofísico del Peru to be part of the advisors in the Expert Panel for the project. Dr. Pablo Lagos was invited to provide advice and inform on current capabilities to forecast in the Andean region.

We collaborated with the Sistema Nacional de Seguimiento de la Seguridad y Alimentaria y Alerta Temprana SINSAAT (National System of Food Security and Early Warning), a Bolivian institution. Javier Choquevilca coordinator of this project was a member of the expert/advisory panel. This organization was a case study to understand how to reach end users.
Irene Trebejo and Esequiel Villegas from SENAHMI Peru were invited to participate in the final workshop of the project. Trebejo was also invited to participate in El Niño workshop in Guayaquil, through NOAA's Latin American program. The technical director of SENAHMI Coronel FAP Rafael Campos, presented at the final project workshop in Lima Peru, 2003. Currently the Department on Environment of SENAHMI in collaboration with Guillermo Baigorria is looking at the climatology of Andean zones. Not even this type of information was available before. With Guillermo Baigorria from CIP they developed the "solar energy Atlas for Peru". Exchange of methodologies with Irene Trebejo and Esequiel Villegas about interpolation techniques, environmental vulnerability analysis (EVA) and the use of GIS & Biophysical modeling Laboratory (GABP-Lab).

C. Coordination with other projects of the NOAA Climate and Societal Interactions Integrated Sciences and Assessments

Our coordination has mostly been with the Human Dimension program, especially focusing on agriculture and developing country settings. Valdivia and Gilles participated in the Principal Investigators Meetings of 1999 and 2002. Valdivia, Gilles, and Barreda participated in Open Meeting of the Human Dimensions of Global Environmental Change Research Community in Montreal 2003. Valdivia and Gilles presented at the Conference on Climate Prediction Agriculture and Development, organized by IRI (April 26-28, 2000), and at the "Workshop on Communication of Climate Forecast" (June 6th-8th 2001) at IRI. Guillermo Baigorria participated in the "Advance Training Institute on Climate Variability and Food Security (ATI)". 8 – 26 July 2002. Palisades, New York, USA. Gilles and Valdivia taught at this institute. Valdivia is mentor of Guillermo Baigorria working on downscaling in the Andes through a small grant funded by the Global Change SysTem for Analysis, Research, and Training secretariat (START) to the project titled: Early Climate Warning to the Andean Farmers: Linking seasonal forecast information to integrated GIS & Biophysical models (GABP-Lab with Guillermo Baigorria PI. Valdivia presented research findings at Climate and Development From Seasons to Centuries: How Our Understanding of and Responses to Seasonal Climate Variability Can Build Insight into Human Adaptation to Long-Term Climate Change (Spring Meeting American Geophysical Union May 2002). She was invited as a discussant to address the Differences in the Environmental Justice Discourses of Brazil (Agriculture) and Peru (Fisheries) on their findings on access to climate forecasts at a Workshop on Public Philosophy, Environment and Social Justice (Environmental Justice Discourses) organized by *Carnegie Council on Ethics and International Affairs* in 1999 (Merrill House, New York. October 21-22).

III. Accomplishments

A. Brief Discussion of Research Tasks Accomplished

The first activity of the project was to constitute an expert panel of researchers and potential users of forecasts in Peru and Bolivia to review the proposal and discuss development of field instruments to collect data to understand the production systems, the effect of climate especially of El Niño 97-98, and to develop the plan for field work in Bolivia the first year of the project. A team of researchers (Valdivia, Jette, Espejo, Gilles, Carrillo) developed, tested and applied the household survey. Carrillo from PROINPA monitored crops, including varieties provided by PROINPA. This was added following advice from reviewers on the role of availability of risk reducing technologies. The first household survey was developed, tested, and applied to 45 households in Bolivia. Workshop was held in Puno Peru (July 2000) to review the first year, and plan research in the second year. In Bolivia Gilles Espejo and Carrillo monitored local knowledge forecasts, conducted focus groups, and developed a formal questionnaire to study the networks through which information flows in the community. Case studies of Radio San Gabriel and SINSAAT were also completed. In Peru Valdivia, Jette, R. Valdivia and J. Reinoso adjusted the household survey to Puno, tested and applied to 110 households. Twenty families were monitored to understand the varieties of activities, flow of resources, and decision making process. At the end of the second year a workshop was held in Bolivia and Peru, because political unrest limited travel between these countries. The data base of 110 households for Peru was completed by 2002. During the third year two local knowledge networks were studied, Anccaca and Santa María in Puno by Gilles, Espejo, Machicado and Claverias. In addition two graduate students completed their master's research on Bolivia and Peru. From May through August of 2000 Susan Materer worked on a case study of the dynamics of coping in San José. From May through August of 2001 Cheston Easter conducted his field research on transaction costs and market integration in two communities of Puno. CIP worked with CIRNMA and PROINPA to calibrate biological models to simulate the performance of potato varieties. Household surveys were applied twice in Bolivia, and twice at both sites in Puno, to collect data on households and on the networks of information. A final workshop was held in Lima Peru February 26 and 27 of 2003, inviting researchers and officers from several Peruvian and Bolivian institutions. The proceedings of the workshop are being edited to be published on the web. In the next sections methods to study household coping strategies, the study of networks, and the biological models are described.

Household Portfolios and Livelihood Strategies

Focus groups were conducted at three sites at the beginning of the research. This informed the development of household surveys to collect information on household production, income and assets, as well as production during El Niño of 1997-1998, and sources of information for decisions. Data was collected of 45 households in San José Llanga, 52 households in Santa María, and 58 households in Anccaca. A data base for Bolivia was completed at the end of 2000, and for Puno at beginning of 2002. The data collected in Bolivia followed similar procedures to research in 1993 and 1995 in a project on Sustaining Agropastoral Systems in order to have comparable data. Variables were constructed to measure income and income sources, and calculate a diversity index, following procedures developed for the first two data sets. The variables included adult equivalent labor accessed by the household, age of the head of

household, livestock assets (cattle and sheep, improved and local), access to forages, off-farm income, and a measure of in-kind production and consumption. Cluster analysis was used to identify different livelihood strategies. This approach was replicated in Peru for Anccaca and Santa María. Livelihood strategies were identified with cluster analysis. To analyze the factors that influence income and diversification, two objectives in household well being in the highlands, canonical correlations were estimated using 1993, 1995 and 1999 data in Bolivia. In Peru canonical correlations were used to determine the relationship between income and diversification, and the role of the different sources of income –from agriculture and non agricultural activities - in wellbeing. To understand the role of potato and diversification in coping with climate variability, a case study was developed building on the findings on livelihood strategies. Households were selected from the different strategies identified, and in-depth interviews were conducted to understand how households cope, and which are vulnerable to stress. Ten case studies were analyzed. In Peru, field research was conducted with 20 households to understand their livelihood strategies through the year, and to determine if household characteristics and measures of transactions costs affect market integration. This was a change from the original plan, because there was no probability forecast information for the region. Regression analysis estimated the relationship between household characteristics, sources of transactions costs, and market integration, a proxy for access to new technologies.

Study of Local Knowledge Networks and Institutions

While awareness of El Niño existed among some households, most of the information on climate for decisions was based on local knowledge. Two approaches were used to understand access and use of forecast information. Three case studies were developed, the community networks, Radio San Gabriel mentioned in the survey by community members, and SINSAAT the early warning and food security project in the Ministry of Agriculture. The methodology to identify networks was based on household surveys, ethnographic methods, focus groups, and informal interviews. An ethnographic approach using non-structured interviews and detailed observations of community life was used in San Jose Llanga to determine the structure of networks. A matrix of all members of the community was created and we determined who people looked to whom for weather information. Persons who had many people referring to them were identified as nodes in the networks. The ethnographic approach is very resource and time intensive because it requires that the researcher live for long periods in the community. In Peru we experimented with the use of a survey. This method is more rapid than the ethnographic approach and requires less in depth knowledge of a community to carry it out. In Santa Maria and Ancacca we drew approximately a 50% sample of the residents of the two communities and interviewed 110 households. Using the lists of community members from which we derived our sample we also made a matrix of all members in the communities and charted how persons got their forecast information. If there were persons who were not in our sample who were regarded as nodes, we interviewed them informally to determine their sources of forecast information. The survey approach proved to be equally effective at identifying nodes and networks. It is also a much more rapid and cost-effective approach.

Biological Models for Decisions

The focus of this component of the project is to develop the capacity for modeling technological options under climatic variations in the high-plateau. The tasks included: 1) definition of agro ecological zones in the watersheds where the target communities are located, 2) the adaptation of

crop and livestock models to the soil, climate, and management conditions of the area, 3) ex-ante assessing the expected outcomes of production decisions using biophysical models (scenarios), 4) the development of tools for integrating climatic, soil, and management conditions at different spatial scales, 5) training stakeholders in the use of tools and methods developed.
PROINPA implemented a series of field experiments to select potato varieties tolerant and resistant to drought and frost. The findings were systematized together with soil and climate data and used to re-parameterize the DSSAT-SUBSTOR model. With this adjustment the model is now suitable to simulate the expected response of several potato varieties to climate variability.

B. Provide two or three overheads of key research results in bullet form. (CD)

C. Elaboration of key findings

Livelihood Strategies
Access to resources, stage in the life cycle, livestock assets, quality of resources, and off farm employment are significant variables in developing distinct economic portfolios.

- The composition of activities determines the type of diversification. If the diversification includes less covariant activities the household has the capacity to smooth income and cope with stress or shock. In Bolivia households that were able to seek off farm employment during the drought of 1995, or incorporated dairy in their portfolio increased the diversity of their portfolio and consistently had capacity to increase assets (Valdivia et al 2000; Valdivia et al 2003). This implied that diversification, a management strategy in the Andes, did not correlate inversely with income level. The nature of diversification is a function of the type and amount of assets and market opportunities, as well as labor access which is related to the family's life cycle.
- In 2000 in Peru, no differences were found in diversification index, but yes in the nature, among households in two communities. There were differences in income. Households diversifying to off farm experienced higher income. The nature of the diversification matters, if activities are less or non covariant in outcome. Households with off farm income, and/or livestock assets had high and less variable income, both in Bolivia and Peru (Valdivia et al 2003). Income smoothing was difficult for households with low diversity and a composition of the portfolio based mostly on crops (potato farmers in Bolivia in the cluster analysis of 1999 (Valdivia and Quiroz, 2003; Valdivia et al, 2003; Valdivia and Jetté, nd) and Peruvian households with diversity only within agriculture in canonical correlation analysis (Barreda et al. 2003; Valdivia et al 2003). Elderly households in Peru and Bolivia held less assets and rely more on potato production. Diversification explains a limited portion of income change when strategies cover mostly production for consumption (Peru). The relationship between diversification strategies and income levels was more robust when sales and remittances were incorporated in the portfolio, in other words when more opportunities were available (Peru).

Institutions: Markets and Networks

- Rural-urban integration plays a significant role in both Peruvian communities, as it resulted in off farm income/employment. In Bolivia off farm employment was only a strategy during drought. Market opportunities such as dairy contributed to income stability, and as collateral for losses in potato production. Markets have also provided opportunities for those that cannot

engage in dairy production. There has been a dramatic increase in commercial potato production. Household produce either purposely for markets, choosing commercial varieties, or sell if they have surplus. The interaction between climate variability and markets can have positive or negative outcomes. It has increased exposure to variability as a result of specialization in crops by a group that has lost livestock assets.

- Social networks as a form of intangible asset play an important role in accessing and claiming labor, land, remittances and information. It played a significant role in smoothing consumption and income among the elderly through remittances, both in Bolivia and Peru. The elderly are the most vulnerable, when measured in assets and income generation. Another important role of social networks. In all communities social networks are a means to access local knowledge, specifically local knowledge forecasts.

Coping and adapting

- Income differences among households in rural communities are significant. Households with assets in dairy production are not worried about droughts or frosts. If crops are lost they have access to credit to purchase seed and food. Their source of stress and shocks are market policies and political unrest(Materer, 2001; Valdivia et al 2002).
- Potato producers are concerned about the season. If losses are experienced, there are impacts on consumption and schooling, as they have no access to credit. Markets are also a concern as good crop years often face low prices. Opportunistic activities like chuño production are used to store and sell when prices rise.
- Households smooth consumption with sheep and chuño, the latter can be stored in good years for years of stress or shock. Lack of chuño is an indicator of a bad year, which can actually be a cumulative effect of many years of climate stress.
- Who are interested in local knowledge forecasts and new information? The less diversified, more vulnerable crop producers, and the wealthier farmers investing in both dairy and potato production.

Local Knowledge Networks and who are users of forecasts

Local Networks/San Jose Llanga Bolivia

- Andean producers used forecasts to make production systems but they did not use scientific forecasts.
- Farmers used local networks organized around local experts (nodes) to get forecast information.
- Climate information networks were organized on a neighborhood level around a local expert. The expert of one neighborhood was the center of forecast information for the entire community. Neighborhoods networks were primarily connected through their nodes.
- Most farmers did not discuss forecasts with local experts but simply observed their behavior and followed their lead.
- Local experts were older and were among the most productive potato producers. They did not use scientifically generated information in their forecasting and they did not have contact with local extension services.
- Farmers in San Jose Llanga believe that forecasts are only valid for the location in which they are generated.
- Knowledge of traditional forecasting indicators is widespread, but the ability to interpret multiple and sometimes contradictory indicators is not.

Findings Extra-local sources/SINSAAT and Radio San Gabriel Bolivia
SINSAAT is the office of the Ministry of Agriculture charged with producing forecasts–especially those that are related to food security. Radio San Gabriel is the most listened to radio station for Aymara speaking producers in the La Paz Province.

- SINSAAT is not currently producing information to be used by producers. Their audiences are government agencies and non-governmental groups interested in agriculture and food security. It is using European Union assistance to develop a system for distribution forecasts down to extension workers at the *municipio* level.
- Present methods of delivering forecasts via Spanish language bulletins are not adapted to the needs of producers. They arrive after production decisions are made and are not in the appropriate language.
- The people on whom producers rely on for local forecasts do not have contacts with *municipio* level agricultural officers, so that more timely delivery of forecasts would still not reach producers.
- Radio San Gabriel is probably the best way to meet Aymara speaking producers in its broadcast area, but it does not use climate forecasts in its programming or in the forecasts that it produces.

Findings in Puno/Ancacca and Santa Maria

- Peruvian producers like their Bolivian counterparts did not use scientific forecasts.
- The structure of the networks and the characteristics of the nodes observed in Peru were similar –based on neighborhood nodes with one neighborhood node acting as a community node. Nodes were older full-time farmers.
- Knowledge of forecast indicators was widespread in the communities with non-experts citing more traditional indicators than the nodes.
- Forecasting seems to be incompatible with off-farm employment. All nodes depended on crop production for their livelihoods.
- One community with some communal cropland had open discussions of weather forecasts surrounding decisions about the use of common land. This information flow was in addition to flows through the networks.

Biological Models

Agro ecological zoning

- Agroecological zoning (AEZ) is a method that uses biophysical attributes of the land to cluster land-use types into more homogeneous areas. This exercise facilitates planning for the sustainable use of natural resources, particularly in areas with high climatic variability. The application of AEZ is limited by the lack of geospatial data, particularly in mountainous areas. Remote sensing and process-based models for both climate interpolation and crop and livestock production were used in the Ilave-Huenque, Peru watershed above 3,800 m. The results are shown in Figure 1 (Annex 1). Only 31,000 ha out of the 780,000 in the watershed can be used for mixed crop-livestock systems. The communities where the project is working at (Santa Maria and Anccaca) are representative of this portion of the watershed. Crop productivity is highly variable and is a function of climate variability.

Findings Simulation Models

- Crop and livestock simulation models were developed or adapted for the agro ecological conditions of the high plateau. Field experiments were conducted to calibrate the mathematical equations to describe the biophysical processes under cold temperatures and drought stress. Figure 2 (Annex 1) shows the confidence interval of biomass production for three potato varieties throughout the growing period. The results show that the model tends to overestimate the aerial biomass of the plant in the early development stage but as the plant matures, the simulation lies in between the 95 % confidence interval of the experimental data. The simulation at harvest time is the critical one, so the models can adequately simulate the expected yields under stressed conditions and can now be used to assess the expected yields under climatic changes.

Findings Scenarios

- Once the simulation models are validated they can be used to explain the impact of climate variability and ex-ante asses future risks. Rainfall, and temperature patterns and the presence or absence of ENSO events are not enough to explain the behavior of crops (Figure 3 Annex 1) under climatic stress. For instance, the seasons 82-83 (or 3 in the sequence), 86-87 (7), 91-92 (12), 92-93 (13), 94-95 (15), and 97-98 (18) were El Niño years. It is evident that the behavior of the climate in the highlands was different for all of those years. A similar trend is seen for La Niña (88-89 and 95-96). As can be seen in the graphs, there is not a direct relation between the presence/absence of an ENSO event and potato yield. A closer look to rainfall, average minimum temperature and absolute minimum temperature indicates that even these average figures do not correlate well with potato yield. The distribution, intensity and duration of rain or frost events are the determinants of crop behavior. For instance, water logging in critical periods explained the very low yields in 84-84 and 95-96, whereas higher yields were attained in 81-82 with similar average values of rainfall and temperature. The simulation models thus constitute a valuable tool to integrate the different factors affecting crop yields and are useful to develop alternative technologies to cope with the impact of climate variability, once the forecasting skill improves.
- Figure 4 (Annex 1) shows an example of the use of models in livestock production. The models were built and validated with farm data and then used to assess the impact of technological options to increase household income. It is interesting to note that the introduction of alfalfa is an alternative that not only decreases the negative impact of climatic variability on the economic activities of the farmers but also increases income through milk production. An additional benefit from strategic supplementation to dairy cattle comes from the environmental side. The environmental cost of producing milk, in terms of methane production, increases with low quality roughages and less efficient animals, particularly during the Andean winter. This cost is reduced substantially with adequate supplementation.
- The tools for up- and downscaling are being developed. A preliminary version is already operational. Training in the development and use of systems analysis tools is a continuous activity of the project. Not only institutions collaborating have been using the models developed for the Andes, but also undergraduate and graduate students at local universities.
- Analysis of tercile probabilities was undertaken for the Aroma region where San José Llanga is located. The rainfall and temperature were the measured in terms of crops yields. Under this new consideration, there is a drastic change in the way we measure the effects of different phases of ENSO in the agriculture. For example, under El Niño year, a statistical approach

gave a probability of 60% of a Normal season and only 27% of a dry season. Under potato crop conditions, the probability of a dry season is increased to 53%, with a normal season probability of 47%, making a potato crop highly risky under El Niño.

What this means

1. Farmers in the Andean region have developed many diversification strategies, some successful in coping with climate and other factors, while others are becoming increasingly vulnerable. Those that are vulnerable and in farming seek information about climate forecasts from local sources. Those that have crops in their portfolio seek information, though the degree of actions they may take with the information may be constrained. Farmers in developing countries have other stressors and can't benefit from forecasts. Previous work indicated that because of their level of vulnerability farmers are not willing to risk change. Other stressors play a greater role than climate. Only farmers that are specialized and wealthy can bet on forecasts.

Our research indicates there is a diversity of livelihood strategies even in one community. Farmers in the Andean communities have been coping and adapting to climate variability and other stressors. Our research shows that the interactions between the structures (social market and political), climate, and policies may result in increased vulnerability through time for households constrained by their assets, increasing vulnerability. While some farmers benefited from the government and foreign assistance agencies in the establishment of dairy activities in the Altiplano, many did not have the land and irrigation resources to take advantage of this opportunity. These households have relied increasingly on potato marketing, and therefore do take into account climate, but locally generated. They also have less choices and insurance mechanisms, but still flexibility to manage resources to adjust planting and varieties. Households experiment and have been incorporating new varieties in their portfolio of crops. New technologies on the one hand require new management knowledge, as well as understanding of the interactions with climate. This creates an opportunity for collaborating in the production of information for decisions. On the other hand, increased dependence on capital intensive technologies like tractors, which are rented, has limited the flexibility in planting decisions.

New technologies with supporting policies and secure markets have provided opportunities for some rural households to incorporate activities less sensitive to climate variability. These households are more diversified in non covariant activities, and still pursue local knowledge forecasts for potato planting. These households can assume the risk of loss when climate stress or shock takes place. Secure dairy markets provide an insurance (credit) against crop losses. Political unrest and privatization are the shocks of concern to this group. Our study in Peru and Bolivia showed that households with various strategies accessed local knowledge forecasts, but those that managed them were expert potato producers. It also suggests that institutions (rules of the game, organizations, and networks) are a vehicle to facilitate coping and adapting, but a disconnect exists with local rural people. Changes in government decision making processes are creating an opportunity in Peru and Bolivia to strengthen institutions and build capabilities to adapt.

2. Farmers don't incorporate scientific forecasts in their decisions because of a preference for locally based forecasts. Previous work in more developed countries has suggested that a barrier to forecast use has been lack of understanding of probabilistic forecasts. Considerable effort has been placed on educating users on how to interpret these.

Understanding probabilities does not seem to be the main barrier in the Altiplano. The local, traditional forecasters that producers rely upon, use techniques that include an intuitive approach to probabilities. Local forecasters are potentially the conduit by which forecasts could reach producers. If local experts believed in the accuracy of scientific forecasts, this information would be incorporated into their predictions. In the case of Altiplano producers, the widespread belief that forecasts are only valid for the location in which they are generated – i.e. a forecast produced by an office in Lima or La Paz is only valid (at best) for Lima and La Paz.– is the major barrier to forecast use. Improvements in the communication of forecasts will not lead to increased use of forecasts, unless there is a way to overcome this belief. These results emphasize the importance of working with local experts and with validating down-scaled forecasts.

3. The current research suggests that we should modify some of our beliefs about indigenous knowledge. It has long been noted by anthropologists and folklorists that traditional knowledge disappears with modernization and the incorporation of indigenous peoples into global and national economic systems. Traditional knowledge becomes confined to the elderly and is lost when they die.

The situation found in the 3 communities examined in this study suggests that these ideas need to be modified. Although local climate experts are elderly, the knowledge of traditional forecast indicators is not limited to this cohort of individuals. Knowledge of traditional indicators remains widely distributed across age and economic groups. The ability to manage multiple, sometimes contradictory, indicators is being lost however. Almost all of the local experts were nearly full time farmers who spent nearly all of their time in their villages working on their farms. People with off-farm or non-farm activities did not spend sufficient time in the field to develop accurate forecasts and people who were primarily livestock producers were not as interested in forecast information. In short one of the techniques that farmers use to deal with risk, income diversification, is undermining their abilities to forecast climate risk.

Because traditional knowledge is still widespread and because it uses some indicators that have a scientific basis, the best way to improve and to communicate forecast information is probably through a partnership with local experts. We propose that local scale information tools act as a means to communicating and discussing forecasts, providing a space to asses the perceptions of risks, and the actual risks that any new technology entails, and that farmers evaluate.

D. List of Publications and presentations arising from this project;

Publications

Valdivia, C. and R. Quiroz. 2003. "Coping and Adapting to Increased Climate Variability in the Andes." Selected Paper American Agricultural Economics Association. July 27-30, Montréal Canada. http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=9073&ftype=.pdf

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Markowitz, L. and C. Valdivia. 2001. "Patterns of technology adoption at San José Llanga: Lessons in agricultural change." Chapter 7 in Coppock, L. D. and C. Valdivia (eds). *Sustaining Agropastoralism on the Bolivian Altiplano: The Case of San Jose Llanga.* Rangeland Resources Department, Utah State University. Logan, Utah. 266 pp.

Coppock, D. L., C. Valdivia, J. Yazman, C. Jetté, J. de Queiroz, L. Markowitz and I. M. Ortega. 2001. "Conclusions and Recommendations." Chapter 8 in Coppock, D. L. and C. Valdivia (eds). *Sustaining Agropastoralism on the Bolivian Altiplano: The Case of San Jose Llanga.* Rangeland Resources Department, Utah State University. Logan, Utah. 266 pp.

Agricultural Economics Working Papers

Valdivia, C., C. Jetté, R. Quiroz, J. Gilles and S. Materer. 2001. "Peasant Household Strategies in the Andes and Potential Users of Climate Forecasts: El Niño of 1997-1998." Agricultural Economics Working Paper AEWP-2001-4. Department of Agricultural Economics, University of Missouri. Columbia, MO.

Materer, S., C. Valdivia and J. Gilles. 2001. "Indigenous Knowledge Systems: Characteristics and Importance to Climatic Uncertainty." AEWP-2001-03. Department of Agricultural Economics, University of Missouri. Columbia, MO.

Materer, S. and C. Valdivia. 2000. "Analysis of a Climatically Variable Production season." AEWP-2000-10. Dept. of Agricultural Economics, University of Missouri. Columbia, MO.

Materer, S. and C. Valdivia. 2000. "Household Production Strategies in a Climatic Variable Zone." AEWP-2000-9. Dept. of Ag. Economics, University of Missouri. Columbia, MO.

Abstracts

Valdivia, C. and J. L. Gilles. 2003. "Coping and adapting to climate variability in the Andes: strategies and local knowledge." Open Meeting of the Human Dimensions of Global Environmental Change Research Community. 16-18 October. Montréal, Canada.

Barreda, C., C. Valdivia, and R. Quiroz. 2003. "Diversification of economic portfolios to deal with climate variability: Case study of livelihood strategies in two Andean communities." Open Meeting of the Human Dimensions of Global Environmental Change Research Community. 16-18 October. Montréal, Canada.

Valdivia, C. and R. Quiroz. 2003. "Coping and Adapting to Increased Climate Variability in the Andes". Session Income and consumption smoothing in developing countries. Selected Paper American Association of Agricultural Economics Meeting. July 27-30, Montréal Canada.

Espejo, Rigoberto, Jere Gilles and Hector Machicado, 2003 "El Valor de los estudios de redes para la difusion de informacion climatica," Presented at the Final Workshop of the Research Project on Family Viability and Well-being in the Andes: Producer adaptations and Use of forecasts in decision making. February 26-27. CIP, Lima Peru.

Gilles, Jere, and Rigoberto Espejo, Conocimientos cientificos y locales. 2003 Presented at the Final Workshop of the Research Project on Family Viability and Well-being in the Andes: Producer adaptations and Use of forecasts in decision making. February 26-27. Lima Peru.

Valdivia, C. 2002. "Local Level Factors Affecting Forecast Use and Application." Session with Emma Archer. Human Dimensions of Global Change Principal Investigators Meeting, October 23 – 25, Seabrook Island, South Carolina.

Gilles, J.L. 2002. Panel member, "Eliciting User Needs and Methods from Different Disciplines." Human Dimensions of Global Change Principal Investigators Meeting, October 23 – 25, Seabrook Island, South Carolina.

Valdivia, C., R. Quiroz, P. Zorogastua and G. Baigorria, 2002. "Climate Variability, Andean Livelihood Strategies, Development and Adaptation in the Andean Region." Invited presentation Climate and Development From Seasons to Centuries: How Our Understanding of and Responses to Seasonal Climate Variability Can Build Insight into Human Adaptation to Long-Term Climate Change. S 123. Spring Meeting American Geophysical Union Vol 83, No 19, 7 May.

Valdivia, C. 2001. "Andean Livelihood Strategies and the Livestock Portfolio." *American Anthropological Association 100 Annual Meeting*. Invited Session, Contentments and Contentions: Living with Livestock. November 28- December 2. Washington DC. Abstract p 437 Arlington VA.

Valdivia C, J. Gilles, R Espejo and R. Carrillo. 2001. "Current Users and Diffusion Nodes of Local Climate Forecasts in the Andes of Bolivia: Lessons on potential users, timing and content of climate forecast communications." IRI Communication of Climate Forecast Information Workshop Proceedings. June 6,7 and 8. Palisades NY. p. 31.

Gilles, J., S. Materer, and C. Valdivia. 2001. "Re-evaluating Climate Forecasting: Lessons from Indigenous Systems." *64th Rural Sociological Society Meetings*, August 15-19. Albuquerque New, Mexico.

Valdivia, C., J. L. Gilles, and S. Materer. 2000. "Climate Variability, A Producer Typology and the Use of Forecasts: Experience From Andean Semiarid Small Holder Producers." *Proceedings of the International Forum on Climate Prediction Agriculture and Development*. International Research Institute for Climate Prediction. Palisades, NY p.31.

Gilles, J., F. Galindo, C. Valdivia, and S. Materer. 2000. "Knowing the Future: Climate Forecasting, Farmers and the Food System." *63rd Rural Sociological Society Meetings*, August 14-18. Washington D.C. Abstract and paper available.

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Valdivia, C. 2001. "Andean Livelihood Strategies and the Livestock Portfolio." *American Anthropological Association 100 Annual Meeting*. Invited Session, Contentments and Contentions: Living with Livestock. November 28- December 2. Washington DC. Arlington VA (submitted paper for special edition Culture and Agriculture)

Valdivia, C. and R. Quiroz. 2001. "Rural Livelihood Strategies, Assets, and Economic Portfolios in Coping with Climatic Perturbations: A Case Study of the Bolivian Andes." Social Organization and Land Management Session, Integrated Natural Resource Management for Sustainable Agriculture Forestry and Fisheries, 28-31 August, International Center for Tropical Agriculture, CIAT, Cali Colombia.

Monographs

Easter, Cheston Completed May 2002 "Effects of Transaction Costs and Household Participation. Market Integration Within the Southern Highland Region of Peru." Unpublished MSc Thesis Agricultural Economics University of Missouri Columbia.

Materer, Susan Completed August 2001 "The Role of Potato Production in Diversified Household Economic Portfolios: Study of San José Llanga, Bolivia" Unpublished MSc Thesis. Agricultural Economics University of Missouri Columbia.

Seminars Presentations and Posters

Espejo, R., J. L. Gilles, C. Valdivia and C. Jetté. 2003. Poster: "Using network analysis to improve forecast use among vulnerable farmers: The Case of Bolivia." Open Meeting of the Human Dimensions of Global Environmental Change Research Community. 16-18 October, Montréal, Canada.

Valdivia, C. and J. L. Gilles. 2002. Poster: "Climate Variability and Household Welfare in the Andes." Farmer Adaptation and Use of Forecasts in Decisions. Human Dimensions of Global Change Principal Investigators Meeting. October 23-25. Seabrook Island, South Carolina.

Valdivia, C. 2002. Seminar "Dealing with Climate and Other Changes in the Andes of Bolivia: Rural Households and their Strategies." January 16, International Research Institute for Climate Prediction, Palisades NY.

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Quiroz, R. 2000. Second International Conference Geospatial Information in Agriculture and Forestry. January, 10 - 12.Coronado Springs Resort, Lake Buena Vista, Florida .

Valdivia, C. 2000. "Climate Variability and Household Welfare in the Andes." Seminar Series, Department of Agricultural Economics, March 3rd MU.

Valdivia, C 1999. "Climate Variability, Household Strategies and Technology in the Andes." National Oceanic and Atmospheric Administration, Office of Global Programs. Seminar, September 15. Washington DC.

Valdivia, C. 1999. Discussant. "Differences in the Environmental Justice Discourses of Brazil and Peru." Workshop on Public Philosophy, Environment and Social Justice." Environmental Justice Discourses. *Carnegie Council on Ethics and International Affairs*, October 21-22.Merrill House, New York.

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Climate Variability and Household Welfare in the Andean Region. Final Workshop. 2003. Lima Peru Proceedings are being edited and will be soon published on the web.

Climatic Variability and Household Welfare in the Andean Region. Second Expert Panel and Scientific Meeting. NOAA. July 10-12 , Puno, Peru, and 16-17 La Paz, Bolivia. 2001. Two separate meetings were held as a result of political unrest that precluded travel in the Altiplano. (Program and abstracts available at http://www.ssu.missouri.edu/clima/SegundoPanel)

Presentations in Puno, Peru July 10-12 2001 (Hosted by CIRNMA).

Valdivia, C. 2001. "Variabilidad Climática y Bienestar Familiar en los Andes: Adaptación del Productor y Uso de Pronósticos en la Decisiones." (Climate Variability and Household Welfare in the Andes: Producer Adaptation and Use of Forecasts in Decisions)

Valdivia, C., C. Jetté, R. Quiroz, J. Gilles, R. Carrillo, R. Valdivia, J. Reinoso, E. Ortega, C. Guerra y M. Cruz. 2001. "Estrategias de Vida y Perturbaciones Climáticas en Dos Zonas de Altiplano." (Livelihood Strategies and Climatic Perturbations in to Zones of the Altiplano)

Gilles, J. L., C. Valdivia and R. Espejo. 2001. "Reconsiderando El Vínculo Entre Productores y Pronósticos Climáticos." (Re-Thinking the Linkage Between Producers and Climatic Forecasts)

Materer, S. and C. Valdivia**.** 2001. "Estrategias de Vida y Variedades de Papa en una Comunidad Boliviana." (Livelihood Strategies and Potato Varieties in a Bolivian Community)

Easter, C. 2001. "Productores Rurales y Costos de Transacción, un estudio de caso" (Rural Producers and Transaction Costs, A Case Study)

Valdivia, R, E. Ortega and C. Guerra. "Andes Clima Puno Peru Estrategias Familiares, Estudio de Caso en dos Comunidades, Santa María y Anccaca" (Andes and Climate in Puno Peru. Family Strategies A Case Study of Two Communities, Santa María and Anccaca)

Baigorria, G. and R. Quiroz. "Hacia un Entendimiento del Impacto Biofísico de la Variabilidad Climática" (Towards an Understanding of the Biophysical Impact of Climate Variability)

Lagos, P. "El Instituto Geofísico del Perú. Pronósticos de Tiempo y Clima para los Andes." (The Peruvian Geophysical Institute. Weather and Climate Forecasts for the Andes)
Claverías, R. "Cultura y Resiliencia en los Sistemas de Producción en las Comunidades de Puno". (Culture and Resiliency in the Production Systems of Puno Communities)

Presentations in La Paz, Bolivia. July 16-17, 2001 (Hosted by UNDP)

Carrillo, R. "Estudio del comportamiento de la producción de papa en San José Llanga: Segundo Año" (Study of the performance of potato production in San Jose Llanga: Second Year)
Espejo, R. and R. Carrillo. "Pronósticos Locales y Redes de Información Agroclimática. Estudio de Caso San José Llanga" (Local Forecasts and Agro-climatic Information Networks, A Case Study of San Jose Llanga)
Espejo, R. "Redes de Información Climática en San José Llanga" (Climate information networks in San Jose Llanga)
Gilles, J. "Perspectivas de los Pronósticos Climáticos: Nodos y Redes" (Insights in to the Climate Forecasts: Nodes and Networks)
Materer, S. and C. Valdivia. Estrategias de Vida y Papa (Livelihood Strategies and Potatoes)

Climate Variability and Family Welfare in the Andean Region: Family Adaptation and the Use of Climate Forecasts in Decisions Making. July 10-12, Puno Peru. 2000. Panel meeting of researchers and experts, organized in collaboration with the International Potato Center and Centro de Investigación de Recursos Naturales y Medio Ambiente (CIRNMA). (Abstracts available).

Valdivia, C. "Profiles of Users of Climate Forecasts: Experience from San José Llanga."
Materer, S. "Production Strategies under Risk: The Case of San José Llanga."
Lagos, P. "Andean Climate Forecasting."
Claverias, R. "Knowledge of Andean Farmers About Climate Predictions: Elements to verify these."
Baigorria, G. "Crop Simulation Models and Applications."
Jetté, C. "Factors Related to Poverty in the Altiplano."
Choquevilca, J. "SINSAAT, Food Security and Early Warning Systems in Bolivia."
Quiroz, R. "Dairy Production in the Bolivian Altiplano, and future Developments."
Carrillo, R. "Introduction of Frost Tolerant Potato Varieties in San José Llanga."
Carrillo, R. "The Agricultural Calendar, Decisions and Climate: Experiences from San José Llanga in 1999."
Valdivia, R. "A Preliminary Assessment of Potential Research Sites in Puno."

Technical Reports

These are field research reports and papers prepared for submission to journals.

Espejo, Rigoberto. 2002 Pronósticos Climáticos Locales de San José para la Campaña 2001-2002.(Local Forecasts for the 2001-2002 Production Cycle in San José) Technical Field Report, mimeograph.

Valdivia, Roberto, Edith Ortega, Carmen Guerra, and Corinne Valdivia. 2002. Estrategias Familiares en dos Comunidades de Puno (Family Strategies in Two Puno Communities). Reporte Técnico, CIRNMA. Technical field report.
Materer, Susan and Corinne Valdivia. Diversity Through Potatoes: Study of Livelihood Strategies in the Bolivian Altiplano (for Mountain Research and Development).
Materer, Susan and Corinne Valdivia. Impacts of Climate, Age, Education and Resources on Coping Strategies in the Bolivian Altiplano. (mimeograph).
Valdivia, Corinne and Christian Jetté. Climate Variability and Household Welfare in the Andes (for World Development)
Valdivia, Corinne, Christian Jetté, Roberto Quiroz and Guillermo Baigorria. Rural Livelihood Typologies of Technology and Policy to Address Adaptation. (for Agricultural Systems)
Easter, Cheston, Corinne Valdivia, and Harvey James. Transaction Costs and Households Characteristics in the Market Integration of Rural Households of Southern Peru. (mimeograph)
Claverias, R. 2000. "Conocimientos de los Campesinos Andinos sobre los Predictores Climáticos: Elementos para su verificación." (Andean Peasants' Climate Forecast Knowledge: Elements to verify these knowledge). Mimeograph.
Espejo, R., J. Gilles, C. Valdivia, and C. Jetté. 2001. "Estudio de Redes de Información Climática en San José." (Networks of Climatic Information in San José Llanga.) Mimeograph.

E. Discussion of any significant deviations from proposed work plan

The project experienced three delays. The first was beginning of research activities due to funding. The second took place from June through July2001 in the Bolivian Altiplano. A farmer organization led a protest, closing down major roads that communicate Peru and Bolivia. This precluded the joint workshop, and delayed field work on networks in Bolivia. The work could not start until September-October, when Dr. Gilles was able to return to the Altiplano to work with the researchers. Finally Co Principal Investigator Dr. Roberto Quiroz was scheduled to spend two weeks in Columbia MO in November, taking advantage of a meeting he attended in Minnesota. We had to reschedule for August 2002 at CIP. We also decided to wait for the outcome of el Niño 2002-2003 to hold the final workshop, which took place at CIP in Lima in February of 2003. The original project proposed study of household's transactions costs in accessing forecast information. Forecasts were not relevant to the region so even though households heard about El Niño event, this was not part of decision making process, therefore the emphasis on local knowledge forecasts. We decided to study transaction costs in integrating to livestock markets.

IV. Relevance to the field of human environment interactions

A. Describe how the results of your project are furthering the field of understanding and analyzing the use of climate information in decision making

Besides the points highlighted in the findings section, our research on household portfolios and livelihood strategies shows that diversification is pursued with different degrees of success. As a

result, information needs are not homogeneous. Some producers are more interested in livestock related technologies, others in food crops. Our research shows that some groups (the elderly and resource poor) are more vulnerable to events like El Niño, but also to excessive rains as has happen in the last two years(non ENSO). In collaboration with PROINPA we found that households using clean local potato varieties have very high yields, indicating that there are technologies available, and access to these would allow farmers opportunistic use, with high yields in good years that can be stored as freeze dried potatoes (Chuño). Our research on the diversity of potatoes in the household portfolio shows that chuño is a buffer important for coping strategies, especially for the elderly and the resource poor. On the other hand households with livestock and cash activities like dairy have access to credit when crops are lost. Markets have been an incentive to introduce more dairy and potato production. Drought and El Niño Event have decreased livestock assets of elderly and households with little access to forage, resulting in decreased diversity. In the productive years, households can make use of information for decisions related to crop varieties/seeds and inputs, soil type and location, and time of planting. Livestock producers delivering milk have found that floods and political unrest affect milk marketing and reduce cash income. The elderly most likely benefit through income transfers and temporary employment within the community, and could benefit from mitigation policies like food and work programs. In Peru labor markets are important to households with land constraints. Santa Maria's households are in better position of linking to markets to sell livestock products, even though Anccaca has more production of livestock.
Our research shows that currently rural households at our sites don't use scientific forecast information. They know about el Niño, and hear local forecasts in the radio but they don't find the messages to be applicable to their localities. Households use local forecasts that are based on observation of a series of biological and natural indicators, along with dreams. Observations of natural indicators are combined with observations of plants and behavior of animals. These seem to indicate that local conditions (soil type, location, fertility and moisture) and natural conditions (observation of constellations, frosts at certain times of year, and wind intensity and direction) are elements to consider, and consistent with the modeling results. The network analysis of local knowledge forecasts shows that nodes of information are those trusted producers because they are good farmers, buenos paperos (good potato producers). Our CIP collaborators are now including the approach on livelihood strategies in the design of a Challenge Program on Sustainable Mountains and the Natural Resource Management research.

B. Describe how this research builds on previously funded research funded by HDGEC

Previous research in Fisheries in Peru and Agricultural Producers in Brazil found that there are asymmetries in access to information and that not all benefit in the same way. Research in Brazil indicated that only some households could benefit because of lack of alternatives with poorer families. We are finding that access to resources is asymmetric and some households would benefit more than others from information on climate forecasts, because it would allow more vulnerable groups to opportunistically benefit from technologies (seed potato varieties that are clean) when a good season occurs. Unlike those studies the forecast information available in the Andes does not correlate with local conditions.
A summary of who would benefit from information in Africa (Blench) indicated that those with more specialized activities and greater resources to withstand a loss would benefit from climate

forecast information. We find that families with more resources are more diversified, and are not as dependent on the outcome of the climate, as those that rely on crop production.
Research on local knowledge forecasts for the Andes indicates that observation of the Pleiades has a relation to El Niño (Cane, Orlove and Chiang's research). Our research shows that farmers look at the constellations, but also look at other indicators, which point to local characteristics as very important in crop planting decisions. The models that CIP also yield similar results.

C. How is your project explicitly contributing to the following areas of study?

1. Adaptation to long term climate change: our research is looking to the role of market and non market institutions that facilitate coping and adaptation in the highlands. The panel research in Bolivia is especially important as observations span a decade and show the changing behavior of households. They are responding to market incentives and government policies in their change of technologies (introduction of dairy and commercial potato varieties), but their integration to markets is partial, which indicates that understanding non market institutions and their role in coping should provide insights into adaptation.
2. Natural Hazards Mitigation: Droughts, floods and frosts are the major natural hazards affecting the Altiplano households. Findings on coping strategies, the role of women, and their use of assets (as well as asset depletion) will inform NGOs working on relief, in terms of interventions that can help households cope with the lag effects (lack of seed and lack of food are felt also in the next production year) of natural hazards to mitigate depletion of human capital.
3. Institutional dimensions of global change: our study focus on how rural communities look out to the forecasting community and other institutions that target reduction of vulnerability. Our research shows the disconnect between them.
4. Economic value of climate forecasts: in this research we are looking at the households that would benefit from access to information, and at the household typology in relation to access to information. We expect that the integration of the biological models with the strategies will allow for simulation of events and outcomes, which will allow us to identify risks. At this time there is no use of "outside" forecast information.
5. Developing tools for decision makers and end-users: see four. CIP has and continues to develop models for decision at local scale (START funded project is a first for the Andes) to provide value added products of forecast information.
6. Sustainability of vulnerable areas and or people: our focus is the Andean region. This region is characterized by a fragile environment, and rural populations are among the poorest of the region. Our understanding of the relationship between the effects of climate and other factors like markets, policies and non market institutions, in a framework that looks at the relationship between the capitals (natural, human, social, productive), provides insights regarding the interaction of capitals and resiliency and adaptation.
7. Matching new scientific information with local indigenous knowledge: our project provides recommendations into the development of forecast products and the area of communicating probabilities, stressing that scale is a central issue.
8. The role of public policy in the use of climate information: we have proposed research in this area as we consider it an essential next step in bridging the gap between potential users and producers or processor of forecasts.
9. Socioeconomics impacts of decadal climate variability: in terms of insights our panel study of Bolivia highlights the relationship between the climate variability impact and markets

and policies. When households have more flexibility to engage in several economic activities they have less need to deplete capital assets (livestock mostly).

10. Other: Our research has a gender dimension as the livelihoods and household portfolios framework looks at the role of individuals in securing the welfare of the family. The case study research in Bolivia shows that women manage the diversity of potatoes. Previous research also found that women control the income of sheep that is invested in human capital (welfare expenditures in nutrition, health and education). The impact of negative shock events in resource poor households is resulting in pooling out children from school and less food consumption.

V. Graphics- CD

- **A.** Graphic Depicting Overall Project Framework and Approach (see PowerPoint file Valdivia III.A.C.D, 2002)
- **B.** Graphics with key research results
- **C.** Biological Models (appendix of last year)
- **D.** Map of region covered by study
- **E.** Photographs from fieldwork to depict study environment

Website address: http://www.ssu.missouri.edu/clima

COLLABORATORS

Collaborating Institutions in the region*:*
PROINPA, Promotion and Research on Andean Crops-Bolivia
CIRNMA, Center for Research in Natural Resources and the Environment, Peru
SINSAAT, Sistema Nacional de Seguridad Alimentaria y Alerta Temprana (National System of Food Security and Early Warning)

Co-investigators in the region*:*
Guillermo Baigorria, International Potato Center
Percy Zorogastua, International Potato Center
Bruno Condori, PROINPA-Bolivia
Ramiro Carrillo, PROINPA-Bolivia
Rigoberto Espejo, Sociologist, Bolivia
Carolina Barreda, International Potato Center
Edith Ortega, agronomist – field assistant, CIRNMA Peru
Carmen Guerra, agronomist-field assistant, CIRNMA Peru
Hector Machicado, Sociologist, CIRNMA Peru

Graduate Students*:*
Susan Materer, M Sc Agricultural Economics
Erin Feinauer-Whiting, Ph.D Rural Sociology
Cheston Easter, M Sc Agricultural Economics
Jose Galindo, PhD, Rural Sociology

Expert Panel:
Ricardo Claverias, (Sociologist) CIED Centro de Investigación y Educación en Desarrollo, Perú
Pablo Lagos, (Climate and Weather) Instituto Geofísico del Perú
Javier Choquevilca, (Early Warning and Agronomy) SINSAAT Sistema Nacional de Seguridad Alimentaria y Alerta Temprana, Bolivia
Javier Aguilera, (Agronomist drought frost) PROINPA Bolivia
Jorge Reinoso, (Economist Andean Development) CIRNMA
Roberto Valdivia, (Agronomist) CIRNMA