Sustaining Agropastoralism on the Bolivian Altiplano: The Case of San José Llanga

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Chapter 01: Project Objectives and Research Approach

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Chapter 1

Project objectives and research approach
Objetivos del proyecto y enfoque de la investigación

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Summary

This chapter provides an introduction to the Small Ruminant Collaborative Research Support Programme (SR-CRSP), including a brief review of the origin and mandate of the programme as well as how programme activities have been organised in Bolivia and elsewhere around the world. Some background is also provided on the Bolivian Altiplano and how the project research framework was developed there with respect to contemporary theory in sustainable agriculture, agropastoral systems analysis, rangeland ecology, economic development and technology transfer.

The initiative to establish Collaborative Research Support Programmes (CRSPs) was mandated by the Title XII provision of the International Development and Food Assistance Act passed by the US Congress in 1975. The mandate was for US Land Grant universities to partner with institutions in developing countries to combat world hunger, low food production and poverty. The United States Agency for International Development (USAID) was tabbed as the entity to administer the CRSPs. There were eight active CRSPs in 1994 dealing with a variety of agricultural issues and commodities. The SR-CRSP was specifically targeted at small ruminants because sheep and goats tend to be held by poorer inhabitants of developing nations. Small ruminants also tend to be a low priority in the agricultural research activities of developing nations, and the SR-CRSP would help redress this imbalance. The SR-CRSP focused on projects to improve the efficiency and output of small ruminant production through technical and policy interventions without compromising the environment-- this strategy has been intended to improve the well-being of those who produce small ruminants. Another goal of the SR-CRSP is to enhance research capabilities of host countries.

The SR-CRSP was established in Bolivia in 1991. The targeted zone for study was the semi-arid, high elevation Altiplano and the national partner was the Instituto Boliviano de Tecnología Agropecuaria (IBTA). The first goal of the joint IBTA/SR-CRSP project was to select a representative site where a typical agropastoral production system operated and learn how the system functioned. The second goal was to identify what aspects of the system, if any, were unsustainable and why. The third goal was to identify technical and policy interventions that could help promote sustainability of agropastoral production in light of predominant social, economic and/or ecological constraints. The primary study site was the Cantón (municipality) of San José Llanga (SJL), an agropastoral community located on 7200 ha about 120 km from the capital city of La Paz. By virtue of its close proximity to a prominent government research station, urban markets and an all-weather highway, SJL had been exposed to decades of technology diffusion and dynamic change in market opportunities.

The IBTA/SR-CRSP project in Bolivia was organised around four key US institutions, each of which took responsibility for one disciplinary research component. The institutions included Winrock International (economics component), University of Missouri-Columbia (sociology component), Texas Tech University (range animal nutrition and production component) and Utah State University (rangeland ecology component). Principal investigators, resident scientists, national co-investigators and students were ultimately organised according to research discipline and the respective home institution in the US. Twenty-seven Bolivian students enrolled at four Bolivian universities provided the backbone of the research effort. They successfully completed research projects largely designed by IBTA/SR-CRSP scientists. The students wrote and defended theses as partial requirements for obtaining bachelor's degrees. Several students from the US also received training opportunities.

The initial and central research question of the project was: "What is the role of small ruminants in sustaining agropastoralism on the Altiplano, and can this role be strengthened or otherwise improved through better use of technology, management or policy?" A framework for analysing

sustainability for this system is outlined in this chapter, with a focus on the maintenance of critical inputs of land, labour and capital for rangeland and cropland components. Special attention was given to potential sources of environmental degradation (i.e., over-grazing or poor cultivation techniques) and how such impacts could be mitigated. For example, would degradation be found more in the rangeland or cropland component of the system? If degradation was found, would it tend to be old or recent in origin? Is degradation an irreversible or reversible threat to the productivity of the system? Are dominant sources of degradation abiotic (i.e., related to climate or natural salinisation) or linked to activities of people and livestock? If the latter is true, are there realistic interventions to mitigate negative trends?

Research was undertaken using an interdisciplinary perspective. Work expanded to include other system components besides those strongly related to small ruminants. Dairy cattle and food crop production were thus gradually incorporated. Research questions expanded to include more social science topics such as: (1) Clarifying the role of human capital in community development; (2) noting how changing aspirations of campesinos influence rates of out-migration and hence labour availability and sustainability of the production system; (3) the role of crops, livestock and wage employment in promoting food security; (4) documenting patterns of technology adoption including examining how technical innovation and change have influenced potentially vulnerable subgroups of the resident population such as females and the very poor; and (5) economic development theory.

The period of field work at SJL was four years, 1991-5. Data analysis and write-up continued for several years thereafter. Social sciences dominated the first years of field work because understanding system structure and function was the top priority, and this could be most easily addressed using interview methods to obtain clues pertaining to long-term trends otherwise difficult to detect within our short timeframe. Evidence reviewed in this chapter indicates communities on the Altiplano have been subjected to a wide variety of social, economic and environmental upheavals in the past several hundred years. The occurrence of key events coinciding at any given time likely drive the system in different directions. Our study would only capture a small, and unique, sliver of time in the 500-year history of SJL.

Resumen

En este capitulo se presenta una introducción al Programa de Apoyo a la Investigación Colaborativa en Pequeños Rumiantes (SR-CRSP), incluyendo una breve revisión de su origen y mandato, y también de como las actividades del Programa han sido organizadas en Bolivia y en otras partes del mundo. Por otro lado, se presentan algunos antecedentes del Altiplano de Bolivia y como se desarrolló el enfoque de investigaciones con respecto a teorías contemporáneas de agricultura sostenible, análisis de sistemas agropastoriles, ecología de campos naturales de pastoreo, desarrollo económico y transferencia de tecnología.

La iniciativa para crear los Programas de Apoyo a la Investigación Colaborativa (CRSPs) fue establecida por la Provisión Titulo XII del acta para el Desarrollo Internacional y Asistencia Alimenticia pasada por el Congreso de Estados Unidos en 1975. El mandato dispone la provisión de recursos financieros a universidades Americanas que trabajen con instituciones contrapartes en países en desarrollo para combatir el hambre en el mundo, la baja producción de alimentos y la pobreza. La Agencia Internacional para el Desarrollo de los Estados Unidos (USAID) fue designada como la entidad para administrar los CRSPs. En 1994 había ocho CRSPs activos trabajando en una variedad de problemas y actividades relacionadas a la agricultura. El trabajo del SR-CRSP fue específicamente dirigido a los pequeños rumiantes debido a que ovejas y cabras tienden a ser criados por los habitantes más pobres de las naciones en desarrollo. Los pequeños rumiantes también tienden a tener baja prioridad en las actividades de investigación agropecuaria en estos países. El trabajo del SR-CRSP enfatiza los proyectos dirigidos a incrementar la eficiencia y los rendimientos de la producción de pequeños rumiantes a través de intervenciones técnicas y de políticas que no comprometan el medio ambiente—con esta estrategia se intenta como objetivo final mejorar el nivel de vida de los productores. Otro objetivo del SR-CRSP es elevar la capacidad en investigación de los países anfitriones.

El SR-CRSP fue implementado en Bolivia en 1991. La zona seleccionada para este estudio fue el Altiplano semi-árido de gran altitud y la contraparte nacional fue el Instituto Boliviano de Tecnología Agropecuaria (IBTA). El primer objetivo

del proyecto conjunto IBTA/SR-CRSP fue seleccionar un sitio representativo donde operaba un sistema de producción agropastoril y aprender como este sistema funciona. El segundo objetivo fue el de identificar, si es que existiera, que aspectos del sistema serian no-sostenibles y determinar el por que? de esta situación. El tercer objetivo, fue identificar intervenciones técnicas y políticas que podrían ayudar a promover la sostenibilidad de la producción agropastoril, considerando las limitaciones predominantes de carácter social, económico y/o ecológico. El sitio de estudio principal fue el Cantón (Municipio) San José de Llanga (SJL), una comunidad agropastoril con un área de 7.200 ha ubicada aproximadamente a 120 km de la ciudad sede del gobierno de La Paz. Debido a su proximidad a una prominente estación de investigación del estado, a mercados urbanos y a una carretera con circulación durante todas las épocas del año, SJLL ha sido expuesta a décadas de difusión de tecnología y a cambios dinámicos en las oportunidades de comercialización.

El Proyecto IBTA/SR-CRSP en Bolivia fue organizado alrededor de cuatro Instituciones Americanas clave, cada una de las cuales tomo la responsabilidad de un componente en una disciplina de investigación. Estas Instituciones fueron: Winrock International (componente económico), Universidad de Missouri-Columbia (componente de sociología), Texas Tech University (componente de nutrición animal en praderas y producción), y Utah State University (componente de ecología de campos naturales de pastoreo). Investigadores principales, científicos residentes, co-investigadores nacionales y estudiantes se organizaron de acuerdo a las disciplinas de investigación y de acuerdo con su respectiva institución originaria en Estados Unidos. Veinte-siete estudiantes Bolivianos, matriculados en 4 diferentes universidades nacionales constituyeron la columna principal de los esfuerzos de investigación. Los estudiantes completaron exitosamente con los proyectos de investigación mayormente diseñados por los científicos del IBTA/SR-CRSP. Los estudiantes redactaron y defendieron sus tesis como parte de los requerimientos para obtener el titulo de licenciados. Varios estudiantes de Estados Unidos también utilizaron las oportunidades de entrenamiento.

La pregunta inicial y central del proyecto fue: Cual es el rol de los pequeños rumiantes en el agropastorilismo sostenible en el Altiplano, y si este rol puede ser fortalecido o de otra manera mejorado a través de una mejor tecnología, manejo o política? En este capitulo se establece un marco de referencia para el análisis de la sostenibilidad del sistema, con énfasis en el mantenimiento de los factores críticos de tierra, trabajo y capital para los componentes de praderas y tierras agrícolas. Se dió especial atención a fuentes potenciales de degradación medio ambiental (p.e. sobrepastoreo o técnicas de cultivo inapropiadas) y de como tales impactos podrían ser mitigados. Por ejemplo, sería la degradación que se detecte más común en el componente de praderas o en el de tierras agrícolas del sistema?. Si se encuentra degradación, es ésta de origen antiguo o reciente?. Es la degradación una amenaza reversible o irreversible para la productividad del sistema?. Son las causas de degradación de origen abiótico (p.e. relacionadas al clima o salinización natural) o están relacionadas a las actividades de la gente y del ganado?. Si lo último es cierto, habrían intervenciones realistas para mitigar las tendencias negativas?.

Las investigaciones fueron realizadas usando una perspectiva interdisciplinaria. El trabajo se amplio para incluir otros componentes del sistema además de los estrechamente relacionados a los pequeños rumiantes. En esta línea fueron gradualmente incorporados los Vacunos para leche y producción de alimentos. Las preguntas de investigación se expandieron para incluir tópicos de las ciencias sociales, tales como: (1) Clarificar el rol del capital humano en el desarrollo de la comunidad, (2) identificar como los cambios en las aspiraciones de los campesinos influye en la tasa de migración y por lo tanto, la disponibilidad de mano de obra y la sostenibilidad del sistema de producción; (3) el rol de la producción agrícolas, ganadería y empleo por salario para lograr la seguridad alimentaría; (4) documentación de patrones de adopción de tecnología incluyendo el análisis de como la innovación tecnológica y el cambio han influenciado sobre subgrupos potencialmente vulnerables de la población residente, tales como son el de las mujeres y el de los muy pobres; y (5) teoría de desarrollo económico.

El periodo de trabajo de campo en SJL fue de cuatro años, 1991- 5. El análisis de los datos y la redacción de los documentos continuaron posteriormente por varios años. Las ciencias sociales dominaron los primeros años del trabajo de campo debido a que el entender la estructura y función del sistema fue la máxima prioridad, y esto se logró más fácilmente usando el método de entrevistas para identificar indicadores de tendencias en el largo plazo, de otra manera, hubiese sido muy difícil detectar cambios en el largo plazo en el corto periodo de ejecucion del trabajo en Bolivia. En este capítulo, la evidencia revisada indica que el Altiplano ha estado sujeto a una amplia variedad de cambios tanto sociales, económicos y medioambientales, en los siglos pasados. La ocurrencia de eventos claves coincidentes en un tiempo cualquiera podrían seguramente mover el sistema en direcciones diferentes. Nuestro estudio sólo puede capturar una pequeña, y probablemente única porción de tiempo de los 500 años de historia de SJL.

1.1 Introduction

In this chapter we briefly describe the origin, mandate, organisation and philosophy of the Small Ruminant Collaborative Research Support Programme (SR-CRSP). This is approached from a global perspective to a local perspective relevant to Bolivia.

1.2 Background of the SR-CRSP worldwide

To promote the capability of the world's food-deficient regions to supply their own food, the US Congress passed the International Development and Food Assistance Act in 1975 (Johnson 1994, xvii). Included in the act was a provision called Title XII—Famine Prevention and Freedom from Hunger. This provision states:

> *"…in order to prevent famine and establish freedom from hunger the United States should strengthen…capacities of US land grant…universities in programs related to agricultural institution development and research…[to] improve their participation in the US government's international efforts to apply more effective agricultural sciences to the goal of increasing world food production and in general should supply increased and longer term support to the application of science to solving food and nutrition problems of the developing countries."*

The International Development and Food Assistance Act also specified that the US Agency for International Development (USAID) should administer and fund Title XII from its existing budget. The act authorised the president of the US to create a Board for International Food and Agricultural Development and Economic Cooperation (BIFADEC) to serve as the implementing agent (Johnson 1994, xvii). The BIFADEC appointed a Joint Committee on Research and Development (JCORD) to oversee the research-related aspects of Title XII. It was BIFADEC's recommendation that Title XII-sponsored research be implemented through Collaborative Research Support Programmes (CRSPs). Small ruminants were among several priority topics initially suggested for research attention; a total of eight CRSPs remained active in 1994 covering a wide range of agricultural issues and commodities. The rationale for prioritising small ruminants had to do with the proposition that no matter what livestock research or extension occurred in the developing world, it tended to be focused more on large ruminants such as cattle, which are often held by producers who, on average, are relatively wealthier and more influential. In contrast, species such as sheep, goats or camelids [i.e., llama (*Llama glama*) and alpaca (*L. pacos*)] tend to be held by poorer people living under marginal circumstances. Small ruminants are often exceptionally hardy and inexpensive to maintain given their ability to persist on few resources under stressful conditions. Having one CRSP focus on small ruminants was therefore intended to help rectify a perceived imbalance in research and extension between large and small ruminants in the developing world and thus better satisfy the tenets of Title XII.

One overall goal of the SR-CRSP was to improve the efficiency and output of small ruminant production (i.e., meat, milk, fibre, by-products, etc.) by promotion of technical and policy interventions identified through research. Enhanced efficiency and productivity of small ruminants should then be targeted to improve the economic welfare and diets of smallholders (i.e., those persons who typically manage "smaller" flocks, often in combination with other agricultural enterprises). Such a development process, however, should not contribute to environmental degradation (Johnson 1994, xvii). Another important goal of the SR-CRSP was to strengthen research capabilities of agricultural institutions. This includes institutions in developing nations as well as their counterparts in the US.

The SR-CRSP was organised in 1978 with 17 institutions. The University of California, Davis, was designated as the management entity for the programme. Since its inception the SR-CRSP has had extensive field activities in Peru, Brazil, Morocco, Kenya and Indonesia. Several projects have been completed and turn-over in institutional participants has consequently occurred. In 1994, nine US institutions participated in the SR-CRSP. These were dominated by Land Grant universities, but also included a private voluntary organisation (PVO). Three institutions from outside the US participated in the SR-CRSP during 1994-- these were agricultural research institutions in the then host countries of Kenya, Indonesia and Bolivia. Funds for the SR-CRSP are granted for a five-year period by USAID. A minimum cost-sharing of 25% from participating US institutions was required.

Since research in developing countries was a cornerstone of the SR-CRSP, a special effort was made to select work sites that met the following criteria: (1) Sites must represent the various ecozones and production systems which typify the humid tropics, sub-humid tropics or arid lands; and (2) host countries must have established agricultural research institutions with whom SR-CRSP investigators could collaborate. Such institutions must also provide viable links to extension that are pivotal to implementation of research findings.

1.2.1 Introduction to the GL-CRSP

By 1997 the SR-CRSP was being re-engineered into a programme called the Global Livestock (or GL) CRSP, with an intermediate title of SR/GL-CRSP. The GL-CRSP was formally recognized in 1999 and the “SR” was dropped from the name. The GL-CRSP still deals with improvement of livestock systems in the poorer regions of the developing world, but the focus has been broadened to include a wider variety of livestock. It also is embracing such issues as livestock development policy, the role of livestock in economic development, and means to improve management of risk for households and societies at large. This transition is reviewed in Johnson (1997).

1.3 Background of the SR-CRSP in Bolivia

The SR-CRSP was established in Bolivia in 1991. A Memorandum of Understanding was signed between the SR-CRSP and the Bolivian Institute of Agricultural Technology (Instituto Boliviano de Tecnología Agropecuaria, or IBTA). Created in 1975, IBTA was administered within the Ministry of Peasant Affairs and Agriculture (MACA) and had a high degree of institutional autonomy. The headquarters for IBTA were in La Paz. There were five IBTA research stations in the Bolivian Andean zone including facilities at Belen, Patacamaya, Ulla Ulla, Chinoli and Tarija. Alzérreca (1992, 196-8) listed 16 research or field stations in the Andean zone overall and these were administered by IBTA and eight other governmental and non-governmental organisations. The traditional focus of IBTA has been technical production research and technology transfer on the dry Altiplano and more mesic High Valleys. The high-elevation Altiplano is described below. The mesic High Valleys, in contrast to the Altiplano, occur at intermediate elevations on the eastern slopes of the Andean Cordillera called the Cordillera Oriental, and these are sites where mixed farming systems prevail (see Section 2.2.1: *National highlights of physical geography and environment* and Section 2.3: *Overview of the Bolivian Altiplano*). Activities at IBTA were organised into five programmes. One of these was the Livestock and Forages Programme, and this was the entity which had links to the SR-CRSP. The focus of the IBTA/SR-CRSP bi-lateral collaboration was to be systems analysis, problem diagnosis, technology generation and policy-oriented research relevant to improving agropastoral systems on the Altiplano.

The primary study site selected for the IBTA/SR-CRSP programme was the Cantón of San José Llanga (or SJL), a 7200-ha site occupied by about 100 campesino (peasant) households in the central, semi-arid Altiplano. The people are *Aymara* Indians, the numerically dominant ethnic group in Bolivia (Plate 1.1). Aspects of history and the agropastoral system at SJL are reviewed in Section 2.3.2: *Regional historical highlights* and Section 2.4: *Overview of the study area at San José Llanga*).

As SJL is located relatively far from footslopes of the Cordilleras, the landscape is relatively level. The modest relief and variation in the salinity of ground water and soils, however, permits a surprisingly high degree of agricultural diversification. Households were distributed throughout six settlements in the cantón. Households managed about 5600 head of livestock in total comprised of sheep, cattle and donkeys, and about 3600 ha of croplands used to grow food crops and cultivated forages. The SJL site was primarily chosen because it was readily accessible for research and had been subjected to several decades of tech-

Plate 1.1 Aymara *campesinos at the market in Patacamaya town on the Bolivian Altiplano.*
Photograph: D. Layne Coppock

nology diffusion by virtue of its close proximity to the Patacamaya Experiment Station (see Chapter 7: *Patterns of technology adoption at San José Llanga).* San José Llanga is also only about 120 km from major urban centres of La Paz and El Alto, and has recently experienced important changes in agricultural marketing opportunities. The agricultural system is therefore dynamic and has long been affected by vagaries of climate and shifts in production practices, marketing opportunities and technology diffusion (see Chapter 7: *Patterns of technology adoption at San José Llanga*). For example, shifts in varieties and acreages of indigenous and introduced food and forage crops are pervasive. Sheep, donkeys and mechanised transport gradually led to extirpation of the llama at SJL earlier this century. More recently, smallholder dairying and forage cultivation has expanded in response to subsidisation of milk collection and growing milk markets (see Section 2.4: *Overview of the study area at San José Llanga* and Chapter 4: *Household economy and community dynamics at San José Llanga).*

Besides the main project focus at SJL, the IBTA/SR-CRSP programme also had a few secondary research sites. These tended to be located at colder and drier locales at higher elevations compared to SJL and were also more remote from major urban markets. Because of the harsher climate and poorer access to large markets, these secondary sites consequently had greater representation of camelids (relative to other livestock) and more reliance on indigenous food or forage crops (relative to introduced food or forage crops). Research conducted in the secondary sites tended to be more ancillary to the overall thrust of the programme and results are not reported fully in this volume. Secondary sites included: (1) Santiago de Machaca (3980-m elevation) located 125 km to the southwest of La Paz in the José Manuel Pando Province, Department of La Paz (Johnson 1994, 59-63; see Annex B); (2) Aguas Calientes (3800-m elevation) located about 240 km to the southwest of La Paz (Luna 1994); and (3) Cosapa (3900-m elevation) located 260 km to the southwest of La Paz and 50 km to the southeast of Aguas Calientes (Buttolph 1998).

Throughout most of the history of the Bolivian region the Altiplano has been a cultural, economic and agricultural hub for indigenous peoples. Today, however, poverty is pervasive in communities on the rural Altiplano and recent, widespread emigration of rural people to large urban areas has occurred. There is, however, considerable site variation in the extent of emigration (see Chapter 2: *National, regional and local context*). The IBTA/SR-CRSP programme on the Altiplano was, in part, designed to address these issues because large-scale emigration could be a source, or a symptom, of an apparent decline in the sustainability of agropastoral systems (see below).

The structure of the Bolivian project at SJL followed a common SR-CRSP format. Key disciplines were each represented by US institutions. Economics was in the domain of Winrock International (WI), a PVO located in Arkansas. Range animal nutrition and production was in the domain of Texas Tech University (TTU). Sociology was in the domain of the University of Missouri-Columbia (UM). Range ecology and management was in the domain of Utah State University (USU). Each of these institutions had a US-based principal investigator (PI). The role of each PI was to administer funds and provide disciplinary research leadership. It was also intended that each institution have an internationally recruited resident scientist on the ground at all times in Bolivia to oversee disciplinary research activities. One resident scientist was also appointed to serve as an overall project representative. On the Bolivian side, resident scientists were to be matched with a disciplinary counterpart (or co-investigator) from IBTA. Field work was largely carried out by 27 Bolivian students enrolled at four Bolivian universities. The Bolivian students were typically senior undergraduates who were required to conduct research and defend theses to fulfill requirements for graduation. Theses often resembled a masters (MA or MS) thesis at a US university. The Bolivian students each had a university supervisory committee, but field work was largely conceived, designed and supervised by IBTA/SR-CRSP scientists. The research priorities for the first group of students in 1991 were related to system description and problem diagnosis at SJL. After these topics were covered more attention was subsequently given to aspects of technology evaluation and experimentation in animal nutrition and forage agronomy. In terms of a disciplinary breakdown, seven Bolivian students studied range livestock nutrition, foraging ecology and animal production, five studied sociology or anthropology, five studied economics and 10 studied range ecology (including soils and water resources). Several American students also participated directly or indirectly in the project. These included one undergraduate (Harvard), three master's candidates (Michigan State, UM and USU) and one PhD candidate (USU). See the introductory materials, *Primary contributors and collaborators*, for details. Plate 1.2 depicts team members at an early stage of the project.

The IBTA/SR-CRSP project established a main office in La Paz. The vast majority of student research activities were undertaken at the SJL site. At least in the first couple of years of the project the Bolivian students lived in the main barrio (town or settlement) of the cantón and therefore were able to immerse themselves in the daily lives and seasonal routines of the resident campesinos.

It is critical to note that the primary objective of the first few years of research was gaining knowledge of how the agropastoral production system worked and what factors, if any, most threatened sustainability of current and future productivity. This was essentially a farming systems research approach (Harwood 1979). Given the short time-frame for the project, a high reliance had to be made on interviews with campesinos to provide critical insights concerning system function and generate and confirm hypotheses relevant to longer-term system dynamics. Social science thus had a co-dominant role with technical disciplines such as animal production, animal nutrition and range and forage ecology. In this regard the IBTA/SR-CRSP activity was unusual for Bolivia. Rather than embracing community-based approaches for problem identification and analysis, traditions of Bolivian agricultural research institutions have tended to be based more on classical experimental approaches on research stations (Yazman 1995; see Section 8.3: *Recommendations*).

We have observed many positive outcomes of the IBTA/SR-CRSP collaboration, but one of the most important and enduring is probably the investment in disciplinary and interdisciplinary training for 27 young Bolivian scientists. As one consequence of their experience on the project, these students have gained an intimate knowledge of campesino problems on the Altiplano. This will shape their attitudes and professional choices for years to come. This training effort, in concert with other initiatives, will hopefully help move Bolivia further in the direction of community-based approaches for problem identification, technology generation and formulation of more effective agricultural policies (see Section 8.3: *Recommendations*).

Plate 1.2 *Some student researchers, resident scientists and support staff of the Bolivian SR-CRSP in 1992.* Photograph: D. Layne Coppock

1.4 Background of the SR-CRSP on the Bolivian Altiplano

1.4.1 Research setting

It has been estimated that Andean peoples and their native camelids (i.e., llama and alpaca) have roamed the Altiplano for at least 7000 years BP (Browman 1974). It is thus a region with a very long history of herbivory, and consequently it has been speculated that the dominant plant communities had become adapted to the peculiar grazing pressures imposed by camelid production systems (Flores 1988). With the arrival of the Spanish conquistadors in 1535, however, came new livestock species such as sheep, cattle, horses and donkeys. The breeds of these livestock which adapted to high elevations became known as Criollo. Criollo animals gradually became accessible to indigenous peoples on the Altiplano. Where new urban markets flourished and alternative forms of transport became available starting in the early stages of the Republican Era in the 1800s, native species of livestock (i.e., camelids) and cereals (i.e., *quinoa, cañawa, oca*) slowly gave way to encroachment by exotics, especially in those parts of the Altiplano which had more moderate climate regimes (see Section 2.3.2: *Regional historical highlights*). The gradual predominance of sheep grazing, in particular, has been blamed for the apparent widespread environmental degradation of rangelands on the Altiplano (LeBaron et al 1979). It has been proposed, for example, that the grazing behaviour and hoof action of sheep have been detrimental to plant communities which evolved under different (i.e., more moderate) pressures from camelids (Flores 1988).

The Altiplano has also endured marked changes in climate, which in some cases could confound long-term effects of grazing. The Altiplano is essentially an alluvial plain that contains a series of remnant, endoreic lakes, the largest of which is Lake Titicaca. Studies of historical lake levels and other indicators have been interpreted to suggest that we are currently in a dry period which has persisted for hundreds of years (Dr. H. Alzérreca, rangeland ecologist, personal communication). The point is that persistent aridity alone can lead to reductions in cover and productivity of rangeland vegetation and facilitate change-over of entire plant communities from domination by grasses to domination by woody plants (Archer 1989). The postulated increase in aridity of the Altiplano could exacerbate effects of grazing and accelerate vegetation change in some cases. The Altiplano is also a region characterised by pervasive salinity, frost and drought which affect grazing resources. Increased salinisation of the Altiplano appears to be an inevitable consequence of erosion of the Cordilleras and closed hydrological cycles (see Section 2.3.1: *Regional highlights of physical geography and environment*). In contrast, however, there is little or no hard evidence of other environmental trends which could be affecting grazing resources.

Gaining an appreciation for possible climate trends, climate cycles and interactions of climate with grazing on the Altiplano is important. The role of climate versus grazing in determining vegetation dynamics has become a subject of recent debate (reviewed in Ellis 1992). In some cases, arid systems having <400 mm of annual precipitation are characterised by high annual variation in precipitation with coefficients of variation exceeding 50%. These systems may reportedly be governed more by climate fluctuations than biotic interactions. Sharp changes in precipitation can result in unpredictable, catastrophic rates of animal losses and rarely allow herbivores to reach densities at which they can markedly affect vegetation composition or productivity. Plant-animal interactions in such systems may therefore be only loosely coupled; this would be further exacerbated where plant communities are naturally dominated by herbaceous annuals and soil substrates are less susceptible to erosive forces (Coppock 1993). Hence, the role of heavy grazing in shifting vegetation composition and causing degradation (i.e., erosion) in such systems may be hard to prove, since climate plays such a pervasive role in ecosystem change. Prescriptions to destock such systems, with the goal of improving sustainable productivity of the environment, may therefore be ineffectual in ecological terms and inappropriate in terms of the undue economic penalties imposed on herding societies (Ellis and Swift 1988; Behnke and Scoones 1993). In contrast to arid systems, semi-arid systems may exhibit more of the classical features of grazing-mediated vegetation change and pose more scope for environmental degradation. Semi-arid systems are often defined as having a lower limit of 450 mm of precipitation per annum (Coppock 1993). Annual variability in precipitation tends to be less in semi-arid systems compared to arid systems. Drought frequency may also be reduced in semi-arid systems, herbaceous plant communities are more commonly dominated by perennial species, and there is more consistent opportunity for more tightly coupled interaction between plants and herbivores. Herbivores can more regularly achieve stocking rates which alter plant communities (Coppock 1993). In this type of system carrying capacity concepts become more relevant and periodic destocking could promote some objectives pertaining to sustainable resource use. Where the Altiplano could fit on such a continuum was unclear.

Besides climate fluctuations and large-scale shifts in herbivore species on the Altiplano, there has also been a pronounced human dynamic which affects natural resources. During the 1700 and 1800s the human population on the Altiplano remained relatively low, largely related to lingering effects of massive depopulation during the early colonial period, routine epidemics and high rates of child mortality (Klein 1995). The human population on the rural Altiplano began to steadily grow from the early 1900s up through the 1960s, afterwhich time a decline in some rural populations has been evident, especially in the drier central and southern portions of the Altiplano. This population depletion is largely attributable to a rural exodus to the vicinity of large urban locales (see Section 2.3.2: *Regional historical highlights*; Plate 1.3). Large urban markets have grown in this century, affecting the types of animals and crops produced as well as placing pressure on other resources such as water, soils and fuelwood. Markets can be very dynamic. For example, the campesinos at our study area reported that the 1960s and 1990s were times when the profitability was highest for potato production and dairying, respectively (see Chapter 7: *Patterns of technology adoption at San José Llanga*), which suggests that shifts in demand for key commodities occur. Land tenure systems have periodically changed on the Altiplano. A popular revolution in the early 1950s finally eliminated the last vestiges of the hacienda system and initiated various land reforms. One outcome was that many campesino communities regained legal ownership of their lands. Policies to better distribute tax wealth to rural areas, and privatise lands that have been communally owned in recent times are other issues currently under debate that will affect natural resource dynamics (see Section 2.4.2: *Local society*).

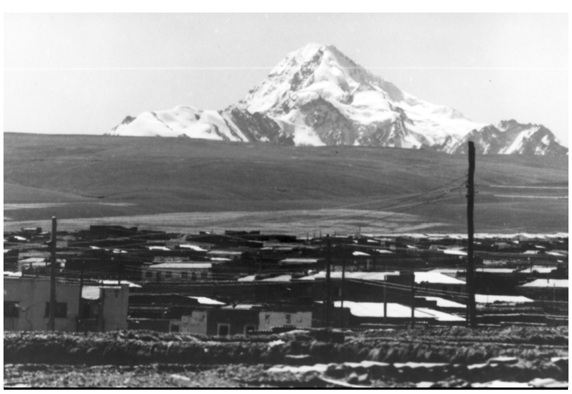

Plate 1.3 *Panorama that captures important contemporary elements of the Bolivian Altiplano. Rapid urbanisation is represented by the outskirts of the city of El Alto, a large suburb of La Paz. Immigrants come to El Alto from the semi-arid rangelands in the distance.* Photograph: Courtesy of *Presensia* (La Paz)

1.4.2 Project framework and initial research questions

1.4.2.1 Focus on role of small ruminants in system sustainability and drought management

The SR-CRSP project in Bolivia was initially guided by one overall research question (Gilles and Malechek 1990), namely: "What is the role of small ruminants in sustaining agropastoralism on the Altiplano, and can this role be strengthened or otherwise improved through better use of technology, management or policy?"

This question is interdisciplinary and oriented towards farming systems analysis (Grove 1992) rather than a disciplinary approach. This question was also strongly oriented towards improving the role of small ruminants in mitigating negative effects of drought. Drought was increasingly recognised as a pervasive influence that appeared to be crippling whole societies in the developing world (Dr. D.L. Coppock, IBTA/SR-CRSP, personal observation). To answer the initial question requires that the role of small ruminants be understood in the context of the structure and function of an aggregated and dynamic crop-livestock system. Despite the core focus of the project on the Altiplano, it was hoped that generalisable insights could be obtained that would be relevant to better understanding problems of agropastoral systems worldwide. Small ruminants were to be the hub of our analyses in Bolivia since they are the target commodity of the SR-CRSP.

1.4.2.2 Our context of sustainability

Sustainability of agriculture is a problematic concept subject to several interpretations (NRC 1989; Francis and Youngberg 1990). Here we adopt a conceptual framework of Dr. D.L. Coppock (IBTA/SR-CRSP, unpublished). The focus of this framework is the sustained output—or at least potential capacity for sustained output—of commodities a, b, c, etc., or their aggregates from a given locale. In this context sustainability refers to the process of maintaining a level of output. A distinction can be drawn between this use of the verb "sustaining" versus the phrase "sustainable agriculture". A sustainable agriculture in the United States has been defined as agricultural practices which share three common features, namely: (1) social acceptability (both to farmers and society at large); (2) economic viability; and (3) environmental soundness (Dr. D.L. Coppock, IBTA/SR-CRSP, personal observation). Our use of the word "sustaining", in contrast, focuses more on the optimal combinations of inputs required to sustain or maintain a commodity output.

Any given commodity is produced as a function of basic inputs including land, labour, management and capital, all under various degrees of control by producers. This can be shown as a Venn diagram in which the central intersection of three spheres yields optimal combinations of inputs needed to sustain output of a given commodity (Figure 1.1). Change in any given input may be negative or positive, reversible or irreversible, etc. The currency in which output is evaluated varies with the analytical objective. For example, aggregate income per household per year, aggregate caloric yield of agropastoral products per household per year, or some grand total figure that integrates income and consumption value of commodity production could be used. This currency would be graphed as a time series. The overall Venn diagram in Figure 1.1, here representing some aggregate system feature, could also be broken out into other Venn diagrams representing a grazing livestock subsystem or a crop agriculture subsystem. Outputs of key animal products or crops could be portrayed as time series with their own specific

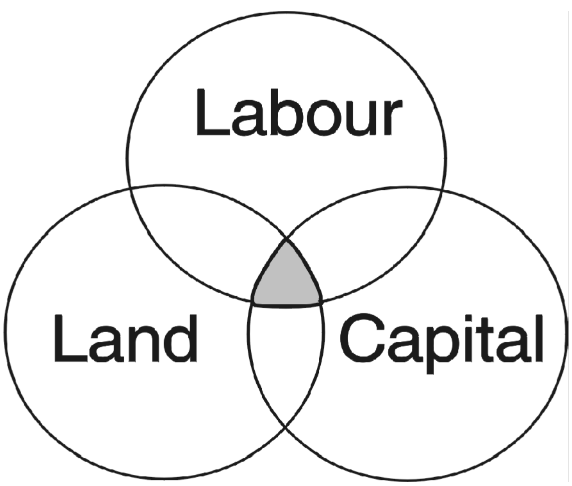

Figure 1.1. *Conceptual diagram of how inputs of land, labour and capital are related to sustaining output from a production system. The shaded intersection of the three circles represents a zone of optimal combinations of inputs. Deviations of a system outside of the shaded area implies suboptimal combinations of inputs that could undermine system productivity and sustainability. The diagram can be viewed as representing an agropastoral system in aggregate or viewed as representing cropping and rangeland components in isolation. Capital is assumed to include the livestock component.* Source: Dr. D. L. Coppock (IBTA/SR-CRSP, unpublished)

factors of production. Each Venn diagram thus could have value in providing an inventory from which source(s) of change in commodity output could occur. For example, a long-term decline in output of a food crop such as *quinoa* for a household could be traced to proximal changes in management, capital investment, loss of labour, increased environmental degradation of crop land (human-induced or abiotic), and/or a long-term drop in precipitation. Potential causes for a decline in the output of marketed sheep per household could be similarly depicted and analysed. The Venn diagrams can also be identified as to household, community or regional levels of resolution. Factors affecting inputs would change as scale of resolution changes. Aggregate Venn diagrams also permit depiction of feedback loops between crop and livestock components. Finally, it is notable that the land, labour and capital components are divisible among households and within households, as will be shown, this impacts both management choices as well as household well-being.

1.4.2.3 Features of agropastoral systems

Agropastoral systems are often characterised according to the nature of their crop-livestock interactions. Agropastoral systems are defined based on the mix of animal and plant products produced at the household level on an annual basis. Jahnke (1982, 66-110) reviewed general features of pastoral and agropastoral systems. Pastoral systems are those in which livestock products provide the mainstay of the economy and grain is either obtained through barter or irregularly cultivated on a very small scale. In contrast, an agropastoral system is one in which livestock products and home-grown crops are co-dominant in household economies.

Well-balanced agropastoral systems should be superior in terms of their stability and resilience features compared to pure pastoral or pure cropping systems, especially in marginal environments. In this context stability refers to the ability of a component to maintain productivity in the face of perturbation. Resilience refers to the ability of a component to regain its original productivity following a perturbation; a less resilient component takes more time to recover. Because crop production is intimately linked to rainfall it tends to be unstable, yet crop production also confers the potential for rapid recovery (i.e., high resilience) from prolonged drought because all that is required is one good rainy season to produce a good crop. In contrast, livestock production tends to be more stable under perturbation because several consecutive rainfall failures are often required to decimate herds or flocks. Despite the greater stability of livestock in response to drought compared to crops, once livestock populations have been reduced by a severe perturbation it takes a longer period of time for them to recover once the perturbation has ceased. This is particularly true for larger livestock such as cattle, which may require over a decade to achieve pre-drought levels of productivity (Dahl and Hjort 1976; Cossins and Upton 1988). Small ruminants are notable for often being more stable under drought perturbation than cattle; small ruminants are also more resilient than cattle by virtue of their rapid rates of reproduction and flock recovery (Mace and Houston 1989).

Agropastoral systems often have complex crop-livestock interactions, and these interactions tend to be more loosely coupled as aridity increases (McIntire and Gryseels 1987). There are several reasons for weaker crop-livestock interactions in the more arid locales. In some cases increasing aridity simply means a greater likelihood of regular crop failure. In other cases crop production is pursued as a means to compensate for decreased productivity of livestock following a prolonged drought. Crop production therefore is pursued when livestock production is less viable and vice versa, leading to a lack of tight integration (Coppock 1994, 122-5). There are four major crop-livestock interactions. These include:

(1) Use of livestock manure as a fertiliser for cultivated fields. In parts of the agropastoral Sahel having nutrient-poor soils, for example, it has been proposed that livestock manure is required for crop production to be viable. In this case rangelands have been shown to be critical sources of extensively harvested nutrients which are ultimately concentrated and transported by animals (Williams et al 1993). Manuring fields can occur in several ways. In some cases it can result from animals directly depositing dung on fields when they graze on crop residues (Powell 1986; Williams et al 1993). Where animals are corralled at night people may supply labour to transport manure from livestock corrals to cultivated fields (Coppock 1994);

(2) Use of crop residues for animal feed, either as cut-and-carry forage or for grazing. Crop residues become available in dry seasons and can provide a critical nutritional boost for livestock. Much research has been devoted to quantifying effects of various species and varieties of crops and crop management practices on the nutritive value of crop residues (Little and Said 1987; Reed et al 1988). Crop residues are also used to supplement diets of grazing animals to improve conversion efficiency for grazed portions of diets;

(3) Use of animal draft power for tillage (Starkey and Faye 1990). Use of cattle and equines for ploughing can replace human labour and increase yields by expanding acreage under cultivation (Quiroga 1992, 149); and

(4) Animals are often sold to provide strategic cash flows for crop production inputs such as tools, seeds and fertilisers (Jahnke 1982, 55).

For the Altiplano it was likely that at least three of the major interactions above would be directly relevant to understanding the role of small ruminants in sustaining agropastoralism. Sheep and camelids are corralled on the Altiplano, and thus manure is known as a common input for cultivated fields (Quiroga 1992, 150), crop residues are often an important feed source for livestock (Alzérreca 1992, 191), and since sheep are an important form of capital storage and income generation (Quiroga 1992, 150), some revenue from sheep sales would be expected to be diverted into crop production. To the extent that revenue from sheep sales helps support draft cattle, sheep could also indirectly underpin the tillage interaction as well.

We postulate that an agropastoral system is adequately functioning in a biological, ecological and economic sense when: (1) cultivated fields are receiving an adequate amount of manure; (2) crop residues are harvested and utilised by animals at a high rate of efficiency; (3) tillage of fields occurs to the desired extent each year and timing of tillage is optimal; and (4) capital for purchasing the traditional, routine inputs for cultivation via animal sales is not limiting. What could thus weaken or undermine the traditional role of small ruminants in sustaining agropastoralism? Anything that detracted from the four features of an adequately functioning system above is a candidate. Lack of sufficient labour, animals and reliable markets would be prominent.

1.4.2.4 Sustainability and environmental degradation

Under the banner of the overall research question given at the beginning of this section, there are several lower-order questions which dealt more directly with the interactions of small ruminants with their environment; these questions relate to the role of humans and livestock in directing range ecosystem dynamics reviewed earlier in this chapter (see Ellis and Swift 1988; Ellis 1992; Behnke and Scoones 1993). These have been interpreted from the original project proposal (Gilles and Malechek 1990):

(1) Has heavy grazing by small ruminants degraded Altiplano rangelands? If so, has this degradation occurred in distant times, recent times, or both?
(2) If environmental degradation is found, is it instead more attributable to abiotic or other unmanageable factors unrelated to human or livestock activity? For example, is drought or natural salinisation a cause of more environmental problems than heavy grazing per se?
(3) Are there discernible interactions between abiotic and biotic factors which result in environmental degradation?, and
(4) If biotic factors are important in environmental degradation, are there realistic changes in range management, development of new range technology, or economic policy which could ameliorate negative effects?

The prevailing view of Andean technical agencies is that over-grazing of the Altiplano is pervasive and that populations of small ruminants and humans are unsustainable, in part because of past degradation of rangelands which limits productive output today (Flores 1988; Alzérreca 1992). In some cases the emigration of campesinos from the rural Altiplano to large urban areas in recent years could reflect a permanent degradation of their agroecosystems; on the other hand it could reflect changing social aspirations (C. Jetté, IBTA/SR-CRSP, personal communication; see Section 4.3.1.2: *Living standards, household structure and human population dynamics*). In the official view there are several possible solutions. One is to encourage campesinos to leave the Altiplano and take up potentially more profitable agriculture in the tropical lowlands, where government investments in infrastructure and technology have recently occurred (see Section 2.2.2.3: *National highlights of social history: 1951 to 1996).* Other solutions would be to prescribe technical or policy interventions to either help arrest degradation and/or rehabilitate degraded sites (Alzérreca 1992).

Compared to the small ruminant/rangeland grazing component, the original proposal by Gilles and Malechek (1990) did not focus as much on the cultivation component of the agropastoral system given this was to be a "small ruminant project." We subsequently further developed the cultivation component to embrace a whole-systems perspective. Inclusion of the cultivation component allowed us to consider another suite of questions as follows:

(1) Is there a declining output of products for the agropastoral system as a whole? If this is the case, which component is becoming less productive, the rangeland component or the crop component?; and
(2) If the crop component is becoming less productive, what could be the cause(s) of this trend? Is the cause primarily human (management) related, abiotic, or an interaction between the two?

The inclusion of the crop component has thus allowed us to come full circle. We can again use Figure 1.1 as a point of reference. The full inclusion of a cropland component also allowed us to address another pervasive issue, namely the contention that inappropriate dry-land cultivation, not over-grazing, is the main source of environmental degradation in the arid and semi-arid areas of the Altiplano and elsewhere in the world (Alzérreca 1992, 189; Pimentel et al 1995).

As we consider the attributes of a dynamic agropastoral system, it is pertinent to recall that our field presence was limited to less than four years; i.e., 1991-5. This is a narrow window of observation. Material reviewed earlier in this chapter indicated that social, economic and ecological contexts on the Altiplano are ever-changing; some change much more rapidly than others. Our short period of observation would thus coincide with one particular combination of social, economic and ecological events. For example, it was noted earlier that the campesinos at SJL reported that the 1960s were a time of higher market demand for sheep, while more recently there has been a higher market demand for dairy products. Such shifts should alter household motivations in terms of resource use and strategies for income generation. Marginal returns to investment for various enterprises would consequently change over time. What this means is that our ability to extrapolate our results to a future scenario at SJL would be highly problematic. This could simply be due to shifts in markets, regardless of a larger dynamic of climate or ecological change.

1.4.2.5 Other sustainability factors: Community leadership, new technology and urban markets

Work expanded to include other system components besides those strongly related to small ruminants. Dairy cattle and food crop production were thus gradually incorporated. Research questions expanded to include more social science topics such as: (1) Clarifying the role of human capital (i.e., leadership, entrepreneurial activity, etc.) in community development; (2) noting how changing aspirations of residents influence rates of out-migration and hence labour availability and sustainability of the production system; (3) the role of crops, livestock and wage employment in promoting food security (Fafchamps 1992; Webb et al 1992); (4) documenting patterns of gender and wealth bias in technology adoption (Biggs and Clay 1988; Pfaffenberger 1992); and (5) economic development theory, specifically whether technology adoption favours economic diversification or specialisation (Bromley and Chavas 1989; Shucksmith 1993) and the extent that non-market (i.e., social) relations augment market relations to better-manage risk (Alberti and Mayer 1974).

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