Coping and adapting to increased climate variability in the Andes

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Abstract

The negative impact of climate change may be reduced with mitigation strategies in developing countries. Some studies project that developing countries in the Tropics will be worse off than developed countries under different scenarios of global climate change, due to warmer climates, increased droughts and floods. Their populations are poorer, and therefore more vulnerable to climate stresses and shocks. Bolivia is an example: A country that experienced climate variability, political change and structural adjustment throughout the nineties. These forces have an effect on rural livelihood strategies. Canonical correlations identify the elements of strategies that impact on both income and diversity of the household portfolio. The ability of rural people to access resources, accumulate assets, and engage in certain activities allow some to adapt to variability in the short run, providing insights into characteristics or traits of technologies, markets, and policies that may contribute to long term adaptation.

Key words: climate variability, rural livelihood strategies, household economic portfolios, diversification, climate variability, adapting, canonical correlations

Introduction

Assessments of climate change show that developing countries in the Tropics are worse off than developed countries under different scenarios of global climate change, especially because they lack resources to invest in adaptation strategies (Kayser). Their populations are poorer, more vulnerable to the stresses and shocks brought about by climate variability and climate change (expressed in warmer climates), and increased droughts and floods (Kayser). Markets and political conditions also are important sources of stress and shock. Some households successfully cope with these events, and exhibit livelihood systems that are able to adapt. The populations of the Andes of Bolivia and Peru have persisted in agriculture for centuries, coping with climate variability, and with political, social and economic changes (Mayer; Orlove et al). Diversification has been a distinguishing characteristic of rural livelihoods in Africa and the Americas (Cotlear; Ellis). This trait is the opposite of specialization, believed to be an engine of growth in Tempreate regions. In the case of the Tropics, diversification is consistent with the need to manage climatic risk (Sakurai and Reardon), maximize use of resources (Mayer; Ellis; Valdivia et al), and achieve multiple goals (Valdivia and Gilles).

This research evaluates the factors that affect livelihood strategies, and their relationship to diversification and income generation. Changes in the strategies of Bolivian households in an Andean community are identified with data from three household surveys applied in 1993 (after an el Niño), 1995 (drought) and 1999 (a year of floods after El Niño). In the next sections we present the framework guiding the study, the charateristics of the site and its climate, the analysis of canonical correlation, and lessons for long term adaptation to climate variability.

Rural Livelihood Strategies

Sustainable Livelihoods (Conway and Chambers; Adatto and Meinzen-Dick) provide a framework for understanding the coping ability and resilience of rural peoples. To understand the relation between the capacity to cope and adapt to climate change or other external forces, we study how assets, capitals, and capabilities (Bebbington; Ellis; Valdivia and Gilles) relate to income generation and to a diverse set of activitieis expressed in the household portfolio. To identify the objectives and strategies of households and individuals in this context we use a household economic portfolio approach (Valdivia et al; Valdivia and Gilles), which is defined through political economics and peasant household economics perspectives (Ellis; Valdivia and Jetté; Bebbington; Valdivia and Gilles; Winters et al.). The purpose is to explain which factors shape strategies that contribute to both income and diversification of the economic portfolio in Andean rural communities.

About the peasant household economy and rural livelihoods

Livelihood encompasses income generating activities as well as the social institutions, intra-household relations, and mechanisms of access to resources through the life cycle (Ellis 1998). The diverse livelihood systems and strategies encountered reflect how individuals, households, and groups negotiate among themselves with their communities, markets, and society to improve their well-being, or reduce their insecurity (de Haan; Bebbington). This is achieved when rural families have the capacity to retain the benefits from their assets, activities, and investments (Valdivia and Gilles, 2001; de Haan). Resilience of peoples' livelihoods depends on their capabilities to adapt to internal and external shocks and stresses (See Figure 1, adapted from Chambers and

Conway). Tangible assets (natural, productive, physical, and livestock and other forms of stock), intangible assets (social capital and non-market institutions allowing access or control of assets or resources), and capabilities (human and cultural capital, and life cycle characteristics) shape livelihood strategies (Conway and Chambers; Bebbington; Adatto and Meinzen-Dick; Valdivia et al.; Valdivia and Gilles). Livelihood strategies are expressed in the set of activities that a family pursues. A diversity of economic activities is characteristic of a setting where production and consumption decisions are joint (Ellis; Valdivia et al a.), capitals are fungible (Chen and Dunn; Winters et al), and many factor and product markets are incomplete, or households are partially integrated to markets. In this setting, individuals in the household pursue many objectives – those maximizing income, managing risk, and activities of a social reproductive nature (right side of Figure 2). Many assets and strategies contribute to the capacity to withstand shocks (droughts, market failure, strikes) in fragile environments like the Andes. Factors that contribute to resilience are control of assets, the capability for collective action for negotiating with markets (Valdivia and Gilles), and including non-covariant activities. Figure 2 shows that the asset composition is important in determining investments in the various activities, and that these decisions are gender dependent. The arrows going in both directions highlight the dual nature of being resources in production, and at the same time assets because these can be invested or divested, accumulated or depleted, from one year to the next. Examples often observed are divestment in natural capital by shortening the fallow fields and not replenishing the soil, or by pulling out children from school to work in the field or because there is not enough money for school, especially in years of shocks.

Rural livelihood strategies are shaped by access and control of human, natural, productive, financial, cultural and social capital (Bebbington; de Haan; Valdivia and Gilles) structures like markets (de Janvry and Sadoulet; de Haan), institutions (Adatto and Meinzen-Dick; Winters et al), and the political environment (Ellis; de Haan; Ferguson; Bebbington).

Livelihood strategies vary (Ellis; Cotlear; Valdivia et al), influenced by linkages inside and outside agriculture (Bebbington), and family life cycle characteristics such as age, education, and the number of family members. The degree of diversification of the household portfolio of activities is determined by these characteristics and by the household's and individual's objectives, such as risk management practices, consumer preferences, and/or strategies available to cope with shocks. The choice set of the household is constrained by the combination of assets, resources, and forms of capital that can be accessed (Bebbington; Chambers and Conway; Valdivia and Gilles; Winters et al). Households with assets are able to cope with adverse events. Those with access to markets can introduce new activities like the sale of labor, which does not depend on agricultural production. This contributes to liquid capital that can be used to deal with an idiosyncratic shock. Markets and secured prices also work as an insurance, as is the case with dairy production in the Altiplano.

Household strategies in coping and adapting to events can be classified in two types: ex-ante strategies like diversification of activities, products, and resources to smooth income and consumption through times of variability; and ex-post strategies to cope with stress and shock, which may include liquidating different types of assets, borrowing, migrating temporarily, or relying on remittances (Valdivia et al a; Murdoch;

Townsend). This paper focuses on diversification and income as ex-ante mechanisms to cope and adapt to climate variability in the Andes.

Cantón San José Llanga and its climate

San José Llanga is a rural community of about one hundred families, 116 Km south of La Paz, Bolivia's capital. It is located in the Aroma province, in the central Altiplano, at an altitude of 3,786m.a.s.l . The community comprises six settlements, or neighborhoods, in an area of 7,200 hectares (Valdivia and Jetté). Some of the neighborhoods have access to water and electricity, particularly in the central portion of the community. Land farmed may be owned or accessed (share cropping and sharing of fallow fields is common). Labor accessed is a function of household availability and social relations of reciprocity, as well as payment in kind. Several varieties of potato, quinoa, barley, and fava beans are among the often grown food crops. This production is for personal consumption and to sell in the market. Alfalfa, oats, and barley are planted by some to feed (mainly dairy) cattle. Sheep and cattle are the main livestock, which may be improved animals, or *criollo* (local) often better adapted to harsh environments. Some families have members that work outside of farming, and have children outside that may send money to parents.

The climate in this region is harsh. The Aroma Province has an average rainfall of 404 mm, with a coefficient of variation of 23% (rainfall of 42 years in de Queiroz et al). Periodic droughts and ENSO (El Niño Southern Oscillation) affect this area (Washington-Allen). During the1983 and 1980 El Niño events, total rainfall was 197.6 mm, and 231 mm respectively. The differences in total rainfall during El Niño years

provide an idea of unpredictability. Even if producers knew and incorporated information about El Niño, the range of outcomes was large. This is true also for non-El Niño years: For example, in 1992-1993 annual rainfall was 388.5 mm, while it was only 241.9 mm in 1995. In addition, farmers have to deal with the uncertainty of onset and distribution of the rains throughout the growing season. From July to April the uncertainty is especially important, since this period is crucial for crops. In 1998-99 precipitation was 422 mm, 78 days of rainfall. During the Niño event of the previous year (97-98), rainfall was 359 mm in 57 days. Major rainfall deficit months were December and January – 60% and 30% respectively – while October, November, and March were months of 50% surplus in 1998-99 (Bolivia-MAGDR, 1999). Coupled with this is the risk of frost. Potato and quinoa are vulnerable to both (Le Tacon et al.), the probability of potato being affected by frost being 30%. The probability of 90 days of production free of frost in Patacamaya is 62%, while for 120 days it is 45% (Le Tacon et al.). Spatial variation with several plots of different soil types geographically dispersed, staggered planting, and several potato varieties are some management strategies used to deal with variability in agricultural production (Le Tacon et al.).

Empirical model development

In most field studies, researchers are interested in establishing relationships between a set of explanatory variables and a response variable. This is typically performed using multiple regression or other regression techniques. The exercise is then repeated for each response variable. In the canonical correlation analysis, one examines the linear relationship between a set of explanatory variables and a set of two or more response variables (Afifi & Clark, 1984). This is of particular importance when multicolinearity

within the variables of either or both of the sets is expected. Canonical correlation analysis identifies the maximum correlation between the independent variables and the two dependent variables. This approach is appropriate for this study, as we look at two objectives in livelihood strategies, income, and diversity; and we consider several resources/assets/activities in achieving these two objectives. Although households do have several objectives in mind, including the social reproduction of the family, we focus in this study on two that can relate to the portfolio of economic activities that households construct. Climate variability and other sources of stress and shock have an impact on the set of activities. We look at a combination of diversification to smooth income, and of income that creates a buffer to respond to stresses and shocks as the two dependent, or response, variables. The response variables are Total Income (cash and in-kind) generated by the household in a year, in Bolivianos (Y1), and the diversity index of the household economic portfolio (Y2). The Inverse Hill Index (Valdivia et al. 1996) – used to estimate diversity – measures the number and share of income generated by each activity of the economic portfolio (see Table 1 for the means, standard deviations, and diversity index formula). All productive final activities are considered, and include food crops, cattle, sheep, dairy production, and sales of labor.

Nine independent variables are chosen to represent assets, resources, and activities that generate income and diversification. Embedded in the variables are the notions of access, in the sense that formal property is not the definition used. After evaluating the correlations among several possible variables, the following are selected (see Valdivia and Jetté): the age of the household head (X1), adult equivalent labor units (X2), hectares of forages (X3), number of local sheep (X4), number of improved sheep (X5),

number of criollo cattle (X6), number of improved cattle (X7), annual off-farm income from salaries in Bolivianos (X8), and in-kind and cash income from food crops valued in Bolivianos (X9). The age of the head of household is chosen to represent the stage in the life cycle. When a male head of household is not present, the age of the female head of household is used. Education is often used in identifying human capital, but there was a significant negative correlation with age, so we kept the later as an indicator of stage in the life cycle. Labor is measured in terms of adult labor equivalent (Valdivia and Jetté), calculating only the labor available to the household by gender and age. Hectares of forage represent a feed source especially important when using new breeds of cattle and sheep. It reflects adoption of a new technology that provides buffers against climate variability (alfalfa especially). *Criollo* cattle reflect the accumulation of value in animals, which is a common practice in the Andes. It is an asset for investments. Improved cattle, on the other hand, focus on dairy production, are a secure source of cash as prices were supported, and serve as a marketing channel that has been in existence for ten years. They provide collateral for loans (Materer) and are reliable when there are droughts. *Criollo* sheep, as well as improved sheep, are sources of savings for consumption in the household. It is an activity controlled by women and is a source of consumption smoothing through the year. Improved sheep is another asset that contributes to consumption, of greater value but requiring higher quality feed. Off-farm income from wages reflects the capacity of some household members to secure income from non-agricultural activities, which is a mechanism to reduce vulnerability to climate through diversifying to non-covariant activities. Some studies have found this to be a constant in the household portfolio (Winters et al.; Reardon et al). Finally, total production of food

crops for consumption and for sales is the last explanatory variable. It is interesting to note that many developers think or envision an Altiplano specializing in livestock production, while in reality food crops, especially potatoes, are the central activities of all households, be it for market or private consumption, and as a buffer stock when freeze-dried (Materer).

These variables capture the tangible assets/resources that households access or control – in this case their livestock, forage/land, and production capacity of food crops. They also capture the human capital, both in terms of where they are in the life cycle – using age and labor access – and the ability to be employed outside of agriculture (linkage with both agricultural and non-agricultural markets). Intangible assets – such as the social capital and networks that facilitate access to resources like land and animals through non-market relations – are embedded in the way variables are defined.

Results of the Canonical Correlation Analysis for 1993 1995 and 1999 in San José Llanga

Strategies and Responses in 1993

The two canonical correlations were greater than zero (Table 2), and the first canonical correlation (0.92) was larger than the highest pair-wise correlation between the explanatory and response variables shown by X9 (all income from food crops) and X16 (Total Income of the Household) of 0.79. It is thus evident that the canonical correlation analysis improved our capability of relating the two sets of variables. The standardized canonical coefficients were interpreted since variables had different units (Table 2). The first canonical variable for the explanatory variables (Strategy) corresponds to the sum of

X9 (all food crops), X7 (number of head of improved cattle), X8 (off-farm income), and, with a lighter weight, X3 (hectares of forages). All other weights are near zero. The second canonical variable is a weighted difference of X9 (0.87), X1 (age of the head of household) (0.65), X8 (0.37), X6 (head of *criollo* cattle) (0.32), X3 (-0.40), and X2 (adult equivalent units of labor)(-0.35). The first canonical variable for the response variables corresponds to the X16 (Total Income), whereas for the response 2, there is a weighted difference with more emphasis on diversity (X17).

The redundancy analysis (see Table 3) showed that the first canonical variable of the explanatory variables explained 53% of the variance in the response variables. The second canonical variable, in turn, explained only 14%. The two combined explained 67% of the variability in the response variables. It can be stated that the strategies analyzed are fair predictors of the responses. The power of prediction from the response variables to the strategies is weak, with a cumulative proportion of 34%. A more in-depth look at the power of prediction through the squared multiple correlations (see Table 4) showed that both the first and second canonical variables of the explanatory variables are good predictors of income (0.85). The power of prediction for diversity was lower (0.49) for the second canonical correlation. In turn, the first canonical variable of the response set have some predictive power for X9 (0.61), X7 (0.59), and X3 (0.51). This predicted power is a bit enhanced by the second canonical variable: 0.64, 0.64, and 0.54, respectively. Households that pursue strategies dominated by crops, forages, and improved cattle have a positive effect on income. The relationships explaining diversity are not as strong in this year.

Strategies and Responses in 1995

The two canonical correlations (Table 2) were greater than 0 ($p<0.0001$) and larger than the largest pair-wise correlation between X8 (off farm income) and X16 (0.72). The first canonical variable for the strategies corresponds to off-farm income. The second strategy is a weighted difference between improved cattle plus forages and off-farm income. For the response variables, the first canonical variable is associated with income whereas the response 2 is a weighted difference of the two variables with more emphasis on diversity.

The canonical variables of the strategies explained 74% of the variation in the response variables. The first strategy explained 48% and the second 26% (See Table 3). The canonical variable from the responses explain only 29% of the variance of the strategies. Income can be adequately predicted by both canonical variables (Table 4) determined from the strategies ($R^2>0.86$). In the case of diversity, only the second strategy showed some predicting power ($R^2=0.62$). On the other hand, the first canonical variable of the responses showed some predictive power for off-farm income ($R^2=0.48$). The second response canonical variable showed a better predicting power: 0.65 for off-farm income, 0.57 for forages, and 0.45 for improved cattle. In a year of drought, a strategy of off-farm income, and of endowment of assets (cattle and forages), had a positive response, i.e. consistent with higher income and diversity. These results make evident that off-farm income is not necessarily related to diversity, but that diversity is related to a strategy of multiple factors, which the second canonical correlation and variables express.

Strategies and Responses in 1999

For this year, one of average rainfall following el Niño, the highest pair-wise correlation (0.79) between explanatory and explained variables corresponded to in-kind and cash food crops and income. The first canonical correlation was much higher than this pair-wise correlation (Table 2). The second canonical correlation was also significant ($p<0.001$). The first canonical variable for the strategies corresponds to in-kind and cash food crops, a year with crop production, especially potatoes responding to market incentives (Materer). The second canonical variable of the strategies was a weighted difference between improved cattle and age, with a larger weight on improved cattle. For the response variables, the first canonical variable is a weighted difference between income and diversity with a larger weight on income. In this year, food crops have a significant impact on the income objective. The second canonical variable corresponds to diversity, and is consistent with a positive relationship to assets like cattle and a negative relationship to age of the household head. The canonical variables of the strategies explained 71% of the variation encountered in the response variables (see Table 3). The first component explained 36% and the second 35%. Conversely, the canonical variables from the response variables only explained 27% of the variability shown by the strategies, which means that response variables are not useful in predicting the components of the strategies. The first canonical variable from the strategies explained 72% of the income and had no prediction power for diversity. In turn, the second canonical variable of the strategies explained 81% of the variation in income and 62% of the variation in diversity. Both the first and second canonical variables of the responses

also showed a good predicting power for in-kind and cash food crops (R2 >0.81) (see Table 4).

Overall, improved cattle, in-kind and cash food crops, off-farm income, and forages seem to be the most important elements of strategies used by the households in SJL. The analysis was able to separate the variables into two main strategies for each year analyzed. The first strategy seems to have – over years – the objective of maintaining the highest income possible. In-kind and cash food crops was the variable associated the most with this strategy. Off-farm income and improved cattle contributed to this strategy in one of the years, 1995 – a year of drought which is consistent with income smoothing and coping in the literature. The second strategy seems to have a dual objective: income, and diversification. Improved cattle and forages seem to be the components contributing the most to this strategy throughout the years. Age is also a determinant factor in relation to diversity and income. The in-kind and cash food crops variable is also an important component of the strategy. The strategies explained more than 80% of the variation in income and up to 62% the variation in diversity.

Coping and Adapting

Canonical correlations of 1993, 1995, and 1999 are all significant. What do these results mean in terms of coping and adapting to variability? In 1993, a year of average rainfall, the first canonical correlation indicates that households having high values of food crops, improved cattle and off farm employment will score high in response variable 1, which has a large contribution in income and is negligible on diversity. So for a year characterized by average rainfall, all these activities contribute to income. At the same

time, the second canonical correlation indicates that households that have a combination of food crops, old age, and are low in labor and forages, may have a positive income but a negative effect on diversity, which may increase vulnerability. A decrease in diversity may result in increased vulnerability if families can only rely on crops, which is convariant with climate. It may not increase vulnerability if the income sources are off farm employment or if the elderly receive remittances. In San José Llanga the elderly are bequeathing their assets and relying more on family networks because of their loss of labor availability.

In 1995, a year of drought, it is interesting to note that off-farm employment is the only factor that scores high with a response variable 1 that is high in income, and negligible in diversity. This is consistent with the fact that off-farm employment becomes a buffer with climate stress. The second canonical correlation in this year is a bit more complex to explain. Households having a high amount of forages and improved cattle but low off-farm employment and food crops will attain a high strategy 2 value. For the responses, high values of diversity and low in income will score high on response 2. This highlights that an important mechanism to maintain diversity is based in building buffers such as livestock and forages, and is especially useful during drought periods like 1995. The low value in income in response 2 is consistent with low productivity of food crops in that year.

In contrast, 1999, also an average year of rainfall following el Niño, shows that households with a strategy based on food crop production correspond to a response 1 that is high on income and negative on diversity. On the other hand, households high in improved cattle and with young household members correlated with a response variable

high on diversity and negligible on income. The results seem to indicate a tradeoff based on access to resources or assets. Household that mainly have access to land for food crops, may benefit in good years, and lose during bad years. This has an impact, as income will be variable. Only if accumulation takes place in the good years, buffers can be built for the bad years. In the Andes chuño is an example of this possibility, both for home consumption and for market. For consumption as this freeze dried potato can be stored for many years, and it also is a value added product that commands higher market prices. Potato production for markets has increased through the years since 1992. It has become a strategy for a group of families that link to markets, and can provide an opportunity for accumulation, though prices were decreasing in 1999-2000. Households that are more diverse and rely on livestock activities appear to have a consistent income in years of stress and average years, and smooth income from year to year.

The experiences of strategies and their impact on diversification and income indicate that households relying mostly on food crop production will attain high income in years of average rainfall, but will not be able to achieve this during droughts, which is obvious. It also highlights the fact that in the case of Bolivia off-farm income seems to be mostly an activity that becomes important during stress – 1995. Elderly households seem to be less capable of diversifying, and only in 1993 seemed to have a positive relationship to income, but consistently negative with respect to diversity. Finally activities like forage and dairy seem to contribute to a diversified portfolio in agriculture, because of their nature as a buffer (feed) and cash source through milk sales.

Conclusion: Lessons from short term variability

The study of livelihood strategies over the span of seven years using three data points underscores the dynamics of household activities that turn on and off according to events. Food crop production has been an effective activity in generating cash and in-kind income for the households, but it does have drawbacks when droughts or floods occur. The effect of markets has shifted the weight of production for consumption to production for markets, but the households pursuing this strategy are less diversified and more exposed to climate variability. The frequency of the climate events will have an impact on the ability to produce seed, and therefore on the ability to increase production in a following good year of rains. In terms of the resilience of the livelihood strategy, it appears that building buffers and support systems as was the case of dairy production in the Altiplano, allows for activities that adapt better to variability. Some have positive externalities, as the introduction of forages not only allowed for dairy but also for improved sheep, a woman income domain (Valdivia and Gilles). It may have also displaced sheep as women have to manage both sheep and cattle. Linkages to markets, through employment, and sales of dairy products and value added crops have buffered some families from climate variability, allowing them to cope with events during this period, and may in the long run contribute to adaptation. This will depend on the ability of rural families to continue to develop their capacity to negotiate. Overall, the livelihood strategies of this community speak to flexibility, opportunistic behavior, and testing of new activities, qualities that are consistent with adaptation. Concerns remain about the elderly and poor families that are depleting rather than accumulating assets, even during

average rainfall years (Materer). These groups require targeted policies that can foster their ability to conserve rather than deplete resources in times of stress or shock.

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Table 1. Means and Standard Deviations of Explanatory and Response Variables 1993, 1995, and 1999 in San José Llanga, Bolivia.

Year	1993		1995		1999	
Variable	Mean	Std D	Mean	Std D	Mean	Std D
Explanatory	N=45		N=45		N=45	
X1- Age (HH* years)	51.4	14.69	53.7	14.5	54.69	15.74
X2-Labor (adult equiv)	2.7	1.43	2.49	1.43	3.49	1.81
X3-Forages (has)	2.3	2.68	3.81	3.4	4.41	4.23
X4-Criollo sheep (head)	8.75	11.84	8.13	15.3	4.89	11.82
X5-Improved sheep (head)	11.57	21.35	17.58	27.63	22.04	33.74
X6-Criollo cattle (head)	1.1	1.68	1.36	1.64	1.09	2.12
X7-Improved cattle (head)	2.02	2.4	3.67	3.08	3.67	3.83
X8-Off-farm income Bs	469	1090	1638.76	4913.63	123.33	464.37
X9-All Food Crops Bs	1438.17	1295	1302.82	1099.4	6271.92	8750.45
Response						
Y1- Income all (Bs)	4682.68	4241.05	7438.99	7166.47	15777	15583
Y2- Diversity Index DI	3.1	1.57	3.43	1.84	3.48	2

- HH is household head, mostly male. Std D is standard deviation.
- Sources: Household Survey Data of 1993 1995 and 1999.
- Diversity Index :DI where n is the number of activities in the household portfolio and p is the income share of total income from the activity i.

$$DI = 1 / \sum_{i=1}^{n} p_i^2$$

Table 2: Canonical Coefficients for Explanatory and Response Variables (Standardized) and Canonical Correlations Strategies and Objectives of Households in San José Llanga, Bolivia in 1993, 1995 and 1999.

Year	1993		1995		1999	
	N=45		N=45		N=45	
Explanatory	Strategy 1	Strategy 2	Strategy 1	Strategy 2	Strategy 1	Strategy 2
X1- Age (HH years)	-0.07	**0.65**	-0.07	-0.08	0.04	**-0.35**
X2-Labor (adult equiv)	0.01	**-0.35**	0.06	0.03	0.07	0.2
X3-Forages (has)	0.19	**-0.39**	0.28	**0.49**	0.14	0.25
X4-Criollo sheep (head)	0.05	0	0.12	-0.16	0.03	-0.18
X5-Improved sheep (head)	-0.02	0.05	-0.03	-0.22	-0.05	0.08
X6-Criollo cattle (head)	0.02	0.32	-0.16	-0.09	-0.03	0.1
X7-Improved cattle (head)	**0.36**	-0.12	0.18	**0.58**	0.07	**0.47**
X8-Off-farm income (Bs)	0.29	**0.37**	**0.69**	**-0.52**	0.02	0.11
X9-Food Crops All (Bs)	**0.38**	**0.86**	0.29	-0.29	**0.97**	-0.31
Response	Response 1	Response 2	Response 1	Response 2	Response 1	Response 2
Y1- Income all (Bs)	**0.97**	**0.57**	**0.98**	**-0.35**	**1.05**	0.07
Y2- Diversity Index	0.06	**-1.12**	0.08	**1.04**	**-0.4**	**0.98**
Canonical correlation	0.92	0.61	0.93	0.77	0.92	0.78

- HH is household head, mostly male.
- Bold indicates significant weight.
- Sources: Household Survey Data of 1993 1995 and 1999.

Table 3: Redundancy Analysis: cumulative proportion of the standardized variance explained by the opposite canonical variable

	1993	1995	1999
Of Response to			
Strategy 1	0.3042	0.1910	0.1273
Strategy 2	0.3371	0.2911	0.2747
Of Explanatory to			
Response 1	0.5353	0.4823	0.3626
Response 2	0.6715	0.7445	0.7063

Table 4: Canonical Redundancy Analysis: square multiple correlation between A) the strategies and the canonical variables of the responses, and B) the responses and the canonical variables of the strategies.

Year	1993		1995		1999	
	N=45		N=45		N=45	
In Canonical Variables	1	2	1	2	1	2
X1-Age (HH years)						0.3844
X3 Forages (has)	0.5133	0.5361		0.5656		0.3516
X7-Improved Cattle (head)	0.5938	0.6372		0.4468		0.4460
X8-Off farm income (Bs)			0.4821	0.6503		
X9-Food Crops All (Bs)	0.6111	0.6416			0.8128	0.8245
Y1-Income All (Bs)	0.8503	0.8514	0.8640	0.8674	0.7218	0.8081
Y2-Diversity Index	0.2203	0.4915	0.1006	0.6216	0.0034	0.6046

HH is household head, mostly male.

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Figure 1: Livelihood Components, Flows and Exogenous Factors

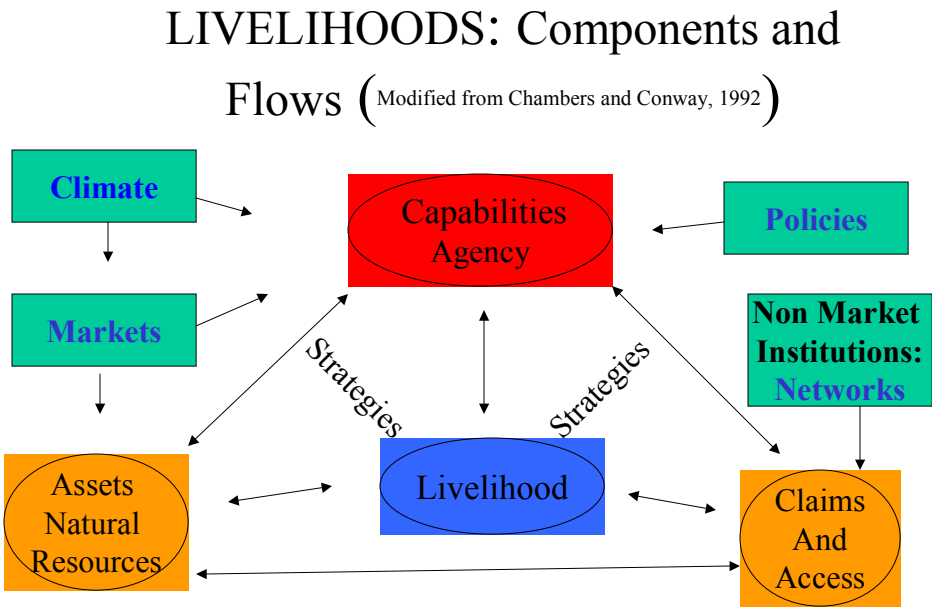

Figure 2: Livelihood Strategies: Assets Decisions and Activity Portfolios