HERD MANAGEMENT STRATEGIES AND LONG-TERM HOUSEHOLD SURVIVAL IN LOW INPUT SYSTEMS : THE CASE OF THE ARID ANDES

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Abstract

A survey was conducted to identify factors affecting the proportion of sheep and camelids within family herds in the arid western cordillera of Bolivia and to assess management practices, including controlled breeding rate of llamas flocks. A close relationship was detected between herd structure on the one hand, and the botanical characteristic of the dominant grazing area and total size of the farm on the other. This is related to the ecophysiological characteristics of animals. Mixed herds of camelids and sheep allow better use of the ecological diversity of rangelands. Numerical productivity at weaning and annual production are found to be significantly lower in llama flocks managed with controlled breeding. We rely on a dynamic model of mixed herds to analyse the long-term interactions between herding strategies and climate uncertainty on livestock system sustainability. The dynamic analysis shows that the control of the llama flock breeding rate strengthens the evolution of the mixed herd only when the herd is large enough so that low offtake rate satisfies the minimum family income. Thus, foregoing short-term yield can be a sound strategy to insure mixed herd viability in an extremely harsh and unpredictable environment.

Key-words: livestock systems; mixed herd composition, management practice, viability.

Introduction

Livestock production in arid environments is often characterised by the presence of different animal species managed together within family herds. In the Bolivian and Peruvian highlands mixed herds of camelids and sheep are common. They represent the main source of cash income for approximately 138,000 families. Due to their particularity, and their economic and geographic significance, these mixed herds have been a topic of interest for researchers and development practitioners. Yet, the mixed stocking of llamas and sheep has always been a matter of controversy in the context of local animal science research. Discussion was stimulated by the criticism that anthropologist Flores Ochoa (1988) addressed to researchers working in high-altitude pastoral systems. He recommended more research oriented towards a sustainable development based on Andean animal species and technologies, rather than on foreign technological improvements which would promote the spread of introduced species such as sheep and goats, considered as degraders of the ecosystem. In the development context, some people argue that specialisation towards one animal species (camelids or sheep) would allow a better use of production factors while others suggest that through mixed herds pastoral people attempt to better utilise the overall available forage and to spread risks (Browman, 1990). Indeed, there seems no need to dispute the comparative advantages of camelids concerning their adaptation to Andean conditions (San Martin & Bryant, 1989;

Genin *et al.,* 1994). Nevertheless, sheep have obviously become a part of Andean livestock systems. As underlined by Caro (1992), various socio-economic changes have contributed to increasing sheep predominance within family herds to the detriment of camelid production. These transformations indicate the capacity of peasants to integrate new elements and to adapt their livestock systems.

In the Bolivian highlands, livestock farming systems are characterised by a high degree of heterogeneity with respect to animal species raised (Caro, 1992). Pastoralists raise llamas and sheep together to produce meat for sale and household consumption. Camelids are confined to the highest areas such as the western cordillera, where pastoralism is frequently the only economic activity possible. Mixed herds of llamas and sheep are managed with large variation with regard to breeding practices on llamas (Tichit, 1998). Even with good range forage availability, some herders slow the breeding rate of llamas by controlling the number of females that are allowed to mate. These practices may constitute a crucial element for the sustainability of the livestock system, as they influence annual herd production as well as its long-term dynamics. Herders applying such practices may be driven by a precautionary behaviour. Evaluating the impact of these management practices is riddled with methodological difficulties in the identification and assessment of their long-term effects on performances, and therefore on the system's sustainability. These effects are difficult to measure in field situations, as they require monitoring of herd performances over several production cycles. Dynamic modelling is therefore an appropriate tool to explore long term interactions between herder's practices and performances, it allows to evaluate current practices in terms of effects that may be felt several years hence.

In this paper we aimed to document the relationships between herd composition and dynamics, management practices, and the satisfaction of household subsistence requirements, in order to evaluate long-term household survival.

The objectives are:

i) to identify factors affecting the proportion of sheep and camelids within the family herds in the western cordillera of Bolivia. It is intended to find out whether the heterogeneity of herd structure is linked to ecological variables (grazing land characteristics) or to socio-economic factors such as labour availability and family cash requirements

ii) to characterise management practices in relation to annual flock productivity,

iii) to use a dynamic model for analysing long-term mixed herd dynamics under management events and climatic uncertainty.

Study area

Research was conducted at Turco (17'57' S, 68'15' W) in a pastoral area in the western part of the department of Oruro in Bolivia. Elevation ranges from 3800 to 4500 m. Climate is tropical and with a low mean annual temperature of 7.6°C. Mean annual rainfall is 333 mm (average over 12 years) and is monomodally distributed (95% fall from December to March). Interannual variations in rainfall are high. With almost 300 days of frost per year, crop production is problematic.

This area presents a great diversity of plant communities. Among these, the so-called *Pajonales occupy* extensive areas. They are formed by tall, coarse bunchgrasses of *Festuca orthophylla*. It is considered a poor forage due to its roughness and very low nutritive value. (Genin *et al.* 1994). *Tholares,* located in the plain, are formed by shrubs of genera *Parastrephia* and thorny bushes of *Adesmia spinosissima* and *Tetraglochin cristatum*. Under the shrubs and in the interstitial spaces grasses find a favourable microclimate. *Tholares pajonales* in which pluriannual grasses *(Festuca* and *Stipa)* dominate are mainly found in piedmont. *Bofedales* (swamps) are perennially green, tundra-like pastures where the mat-like plant community of low-growing forbs, sedges and reeds is irrigated throughout the year by melt water from ice fields. They usually cover small areas with a high forage productivity and they are mainly located in mountains and in piedmont. *Gramadales* consist of low-growing grasses which develop over small areas of sedimentary soils in plain and piedmont. Their botanical composition is dominated by stoloniferous grasses. Using a NOAA satellite imagery of the Turco area, four types of landscape units were defined combining topographical units with plant communities : mountains, piedmont, *pajonal* plain and *tholar* plain.

Material and methods

To characterise factors affecting herd composition, data were collected from one interview per household among 93 randomly selected farms belonging to the six peasants communities of Turco district. The interview focused on land characteristics (plant communities and topography), composition of the family herd, livestock production performances, livestock sales and additional sources of income during the year, family composition and labour availability. Data were synthesised into eight variables and 27 categories and were processed through the use of Factorial Analysis of Multiple Correspondances (AFCM). The herd descriptive variable was quantitative: RA: herd structure was the ratio between numbers of camelids and sheep expressed in ovine units (OU). According to Tichit (1998) one adult llama is 2 OU, one adult alpaca is 1.5 OU and one adult sheep is 1 OU. The ecosystem descriptive variables were both qualitative and quantitative: PS: primary grazing area indicated the nature of the dominant landscape unit of the farm's grazing lands; ST: estimated total area of the farm (expressed in ha); ZH: swamp area indicated the presence or the absence of plant communities such as *bofedal* and *gramadal*. Socio-economical variables were both qualitative and quantitative: DM: labour force availability, took into account the number of people dedicated to livestock management during the year; NB: cash needs was taken as a quantitative variable which depended upon the number of children and their education level (elementary school, high school, university); RC: the percentage of cash income from camelids was the ratio of income from llamas and alpacas' meat sales over the whole income (sheep + camelids' meat sales). A new category was created if more than 50% of total family income resulted from a wage activity; CC: was the ratio of llama and alpaca meat consumption as a percentage of total family meat consumption (camelids + sheep).
Furthermore to characterise management practices and assess their effect on the performances of livestock systems, a survey was implemented. Data was collected on a monthly basis during 1995 and 1996 from 14 pastoralist households (Tichit, 1998). No statistical sampling methodology was used in choosing the households surveyed, but an attempt was made to cover the diversity of herd structures and management practices. It involved accurate herd recording of a population of 800 llama females and 1500 ewes and a quantification of households' economic requirements which represent the annual cash value necessary to cover current expenses related to food, clothing, school supplies and veterinary products. The survey was designed to identify variables and estimate parameters that influence herders' strategies, and therefore long-term herd dynamics under climatic uncertainty. Herding strategy is defined as the combination of decisions on herd structure and management practices. We use a dynamic model to assess the effect of herding strategies on livestock system performances by analysing the long-term interactions between herding strategies and climate uncertainty on livestock system sustainability.

Results

Factors affecting herd composition

The AFCM showed a strong relationship between herd structure and the dominant landscape unit on the farm, except in the case of *pajonal* plain where this category did not get a strong contribution to axes. Farms located in this landscape unit belong to two sub-sets characterised by highly contrasting herd structures. The two sub-sets were identified as *pajonal* and Titiri (group of farms belonging to Titiri community). Households were set into five differentiated groups: mountain, piedmont, *tholar, pajonal* and Titiri.

Mountains: fields of camelids

Herds in the mountains were characterised by a low sheep-camelid ratio with an average of 147 llamas and 42 alpacas, and 77 sheep. Fifty percent of farms raised a male llama flock and 87% of farms also raised alpacas. The dominant plant community was the high-altitude *pajonal.* Swamp areas were abundant, particularly the *bofedales.* This plant community is the main source of forage for alpacas. Herds ranged in size from 200 to almost 800 OU. Farms had an area of more than 1000 ha. Llamas and alpacas supplied up to 75% of the family meat consumption and accounted for up to 75% of cash income in 56% and 53% of the households, respectively.

Piedmont: fields of sheep

Herd structure in the piedmont was marked by a high sheep-camelid ratio (average of 48 llamas and 80 sheep). Plant communities were diverse, dominated by *tholar-pajonal.* The relative occurrence of good grazing areas represented by *bofedales* and *gramadales* was high but the land area involved in each farm was low. In this group, the size of herds (128 to 332 OU) as well as that of the farms was small. Furthermore, on these farms the principal source of cash income was a wage activity for 38% of households.

Tholar: herds tending to sheep predominance

The herd structure varied from balanced to predominantly sheep. The dominant plant community was *tholar* shrubland. Swamp areas were represented mainly *by gramadales.* The size of the herds varied from medium to large, with an average of 471 OU, as did that of the farms comprising this group. The family's meat consumption and the cash income came from camelids.

Pajonal: llama fields

Herd structure was highly dominated by llamas (average of 200 OU from llamas and 108 OU from sheep). The principal plant community was the *pajonal* dominated by *Festuca orthophylla.* The main characteristic of this community lies in the very low floristic diversity. Most of farms did not have swamp areas. The size of the herd varied from medium to large (between 290 and 730 OU) and that of the farms from 500 to 1000 ha. Meat consumption and cash income were provided more by camelids than by sheep.

Titiri: sheep fields

Herds in Titiri were dominated by sheep. The dominant plant community was represented by *pajonal.* Few swamp areas were present in these farms. Herds were small, ranging in size from 150 to 450 OU and most of the farms covered less than 500 ha. Sheep played a prominent part in the family meat consumption. Cash income came principally from a native handicraft activity. These households had a unique historical background. Before the 1950s, Titiri people used to breed donkeys and sell them to agricultural communities living near La

Paz. In 1950, when wool prices suddenly increased, herders started to raise sheep. When truck transportation became very common on the Altiplano, they completely abandoned donkey breeding and increased sheep production. Since 1987, a European Community development project has promoted handicrafts activity. As a result sheep raising is now a secondary activity.

Diversity of management practices and effects on flock numerical productivity

Our survey showed that breeding practices and male offtake practices varied greatly between both species and between flocks for a given species. We define breeding practices as the combination of mating practices and caretaking practices (herder‘s intervention on the mother - young relationship at parturition). Mating practices, but not caretaking, varied between llama flocks (females never abandon their young, thus herders do not have to act over the mother - offspring relationship). Some herders bred all adult females (> 2 years) each year. We define such flocks as “uncontrolled”. Others selected for mating two-year-old females, females that did not produce any offspring in previous years and females that have lost their offspring within their first weeks of life. We call them “controlled flocks”. No particular trend was observed for the mating practices between sheep flocks (rams were always introduced into the ewe flock in June where they remained until November), but two types of flock caretaking were observed for this species. Some herders reinforced the mother - young relationship by reducing the need for the mother to travel. The presence of the shepherd induced the ewes to remain near their young to facilitate the formation of bonds. We define such flocks as “high care”. Others had low flock supervision at lambing and many lambs were orphaned a few hours after birth. Then, in order to control the mortality of orphaned lambs, herders bottle-fed them. We call these “low care flocks”.

For both species, male offspring offtake practices occurred at two stages: males were slaughtered or sold just after weaning (6 months for lambs and 12 months for llamas), or later at maturity (18 months for wethers and 36 months for llamas). During the annual production cycle, we analysed the way breeding practices were combined with the offtake practices of young males. In controlled llama flocks and low-care sheep flocks, male offtake was usually delayed until males reached maturity, whereas in uncontrolled llama flocks and high-care sheep flocks, male offtake occurred earlier (at 6 and 12 months respectively for lambs and llamas). Delayed male offtake appeared to be a response strategy for compensating a lower number of individuals (related to controlled reproduction in llamas or low lamb survival attributable to lack of care of the mother - young pair) with a higher individual live weight. The efficiency of these practices was evaluated through annual flock performances.

Flock numerical productivity as an indicator to evaluate management practices

Uncontrolled llama flocks reached higher annual numerical productivity than controlled ones (70% and 44%, respectively). This difference is significant, indicating that uncontrolled breeding practices were more efficient than controlled ones. Due to a lower rate of fecundity (47% versus 80%), controlled llama flocks produced 37% less offspring each year than uncontrolled ones. In the case of sheep, numerical productivity at 6 months of high-care flocks was higher than that of low-care ones (83% and 69%, respectively). This difference is not significant and it was not possible to conclude whether high-care practices were more efficient in increasing numbers than low-care ones. High- and low-care sheep flocks started with the same fecundity rate and low-care flocks produced 17% less offspring than high-care ones at weaning. The higher decrease in numerical productivity during the first month after lambing in low-care flocks illustrated that bottle-feeding was insufficient to control lamb mortality.

At the level of the annual production cycle, the endogenous flock growth rate is influenced by the tradeoff between replacement (in this case 50% of the numerical productivity at weaning as all young female are kept) and female culling rate according to household subsistence requirements. However, this is not the only determinant of herd evolution in arid areas. Numerical productivity is also influenced by an environment that is radically unpredictable. This situation highlighted that efficiency of management practices, on the basis of their annual outcomes, only provided a partial assessment, which was inadequate to understand why some pastoralists chose to reduce their annual production. The short-term restraint illustrated by controlled breeding practices may be better understood in relation to their role in terms of anticipating uncertainty.
Flock growth rates in bad years were investigated through interviews with pastoralists who reported flock performances during 1983 and 1992 droughts. Herders involved in controlling the breeding rate of their llamas, even in good years, stated that this practice aims at preserving females during bad years, which resulted in an average growth rate higher than in uncontrolled flocks (estimated respectively at 5% versus 2%). In uncontrolled flocks, herders reported that lactating females showed reduced survival during drought periods. Conversely, there were no reports that breeding practices could influence the rate of growth of sheep. Sheep were liable to heavy loss during bad years, as their average growth rate was always lower than that of llamas (-2%). This highlighted the importance to assess management practices on a longer-term perspective.

Long-term mixed herd dynamics under management events and climatic uncertainty

In order to deal with the effect of climatic uncertainty and herding strategies on long-term mixed herd dynamics, a viability model was constructed. The model focuses on the long-term interactions between household subsistence requirements and inter-annual variability of mixed herd performances. It represents household wealth that grows or declines as a result of both the endogenous herd growth rate (influenced by the environment and breeding practices) and the effect of the direct management decisions (Doyen & Tichit, 1999). Changes in wealth (herd size) are mainly determined by the balance between household needs (minimum income) and each of the species growth rates. The model represents a differential game system where the state variable is wealth and the decision variables are both herd structure and offtake rate. The adversity component is introduced through the climatic variations that influence endogenous growth rates. Analytical results showed that thanks to the complementary growth rates of both species, a mixed herd allowed the herder to take advantage of a wider range of environmental situations. They also indicated that management practices consisting in controlling the breeding rate of llama flock strengthened the evolution of the mixed herd only when the herd was large enough so that relatively low offtake rate satisfied the minimum income.
Results are illustrated here with two simulations based on the same climatic scenario. By dividing his total wealth between both species (with 60% llamas), the herder secured long-term herd evolution. Trajectories show the interaction between endogenous growth of both species and culling rate over the herd dynamic. Figure 1 shows that the herder who did not control the breeding rate of his llama flock secured a minimum income at each time period with an initial herd composed of 36 llamas and 76 sheep (i). Conversely, the herder who chose to control the breeding rate of his llama flock even in good years, needed a larger mixed herd (27% larger in wealth) in order to secure herd viability: 46 llamas and 97 sheep heads (iii - Fig. 2). All trajectories starting below these thresholds (a wealth of respectively 3630 and 4030 US$) are not viable in finite time (ii & iv). Given that the culling rate depends on herd size, it decreased as herd size increased. Thus, to satisfy the minimum income, rich herders adopted a lower culling rate than poor ones. The only deterministic situation (only one

decision is viable) appeared at critical thresholds i.e. when herd size was on the discriminating boundary and adversity was such that herd yield only permitted to harvest a minimum income. In this case, the herder’s decisions were reduced to exchange all his wealth for the species with the highest growth rate. This decision has been described for various pastoral systems; it is referred to as "upstocking" (Mace and Houston, 1989). In relation to our case study, we think that the exchange of wealth from one species to another is not likely to occur, mainly because the market for females is nearly non-existent even on good years. Thus, another decision to avoid herd destitution, which is not taken into account in our model, would be restriction of consumption. This has been reported by (Barth, 1961) as a way to compensate for income fluctuation.

Discussion

The typology we propose indicates that there is a great heterogeneity in the ways of managing pastoral activity. This heterogeneity is related to the different sets of constraints and opportunities that herders face. This result agrees with Norman's assertion that constraints lead to the most important differences in farming systems and that differences in herd size and composition among households are as much a function of households' economic strategies as they are a factor of families' access to pastures (Norman, 1992). Camelids and sheep play complementary roles in the use of the available resources and in the products they supply. Raising various species of livestock is viewed as a sound strategy to spread different kinds of risks (drought periods, disease outbreaks, possibilities of choice for animal off-take in relation to reproductive capacities, market price fluctuations). This diversification extends past the strict pastoral sector and embraces handicraft activity from camelid fibre and wool and non-agricultural employment. It allows a higher flexibility in the functioning of livestock systems according to changeable production conditions which is a fundamental feature in low-input, extensive traditional systems (Orskov & Viglizzo, 1994).
We show that management practices also contribute to promote the sustainability of livestock systems. Management decisions on herd structure and culling rate strongly influence herd viability. The viability model demonstrates that the impact of controlled breeding practices can only be assessed in a long-term perspective. We showed that only some herders should promote rapid increase of livestock between droughts. The evaluation of controlled breeding practice in llama flock demonstrates that foregoing short-term yield favoured mixed herd viability in the long-term. But this practice is closely related to wealth level. These qualitative results are similar to those found by Mace (1993) who used a dynamic optimality approach to demonstrate that in order to maximise long-term household survival, only wealthy households should slow herd-breeding rate.
By assessing long-term effects of management practices, we provide some insight into the pastoralists' foresight capacity when confronted by uncertainty. A mixed herd enables herders to take advantage of opposed species-specific traits. Llamas behave as a stabilising component owing to their ability to thrive during environmental perturbation, whereas sheep, which have a faster growth rate in good years, promote rapid recovery from drought. At this stage, our results are likely to contribute to the debate about the efficiency of maximising strategies, as these strategies need to be related to the livestock system sustainability. Policies that advocate destocking, assuming that ecological carrying capacity is being exceeded, are increasingly common especially in drylands (Scoones, 1993). Several studies have underlined the role of droughts in increasing wealth differences between rich and poor pastoralists (Galaty, 1981; Fratkin and Roth, 1990). Analysing the 1984 drought in north-eastern Africa, Fratkin and Roth (1990) showed that although the rich herders lose proportionally more of their total herds than the poor, they are able to better overcome the drought by having larger absolute herds than the poor. From these findings, they pointed to the efficiency of

maximising herd size between two droughts. If sustainability (related to household survival) is a common goal to pastoralists, as all of them are not wealthy, they are likely to develop differentiated strategies according to their wealth level. If rich herders can afford to develop precautionary behaviour, poor herders have to take risks, and rapid herd growth when forage is available is likely to remain a sound practice to avoid destitution of small herds when droughts occur. Our approach aims to demonstrate that while unable to master exogenous uncertainty, herders can anticipate and mitigate it thanks to particular breeding practices. These practices are directly linked to the set of constraints facing each pastoralist and to his assets and therefore cannot be standardised to the overall community. Moreover, they have to be viewed on a larger time-scale than the immediate or annual ones. In the case we were interested in, the choice of animal species to breed and their management, assume great importance in the functioning of the farm since llama and sheep are not interchangeable species and have effects both on the short-term domestic economy and on the long-term sustainability of the enterprise. The concept of sustainability remains, however, a questionning concept which attempts to crystallise various fluid and highly complex concepts, and to synthesise parameters which are often time-dependent (WCDE, 1987; Mebratu, 1998). In this sense, assessing sustainability is often a lure that masks an incomplete knowledge of complexity and uncertainty. Nevertheless, it translates a fundamental concern of human beings and of institutions seeking to insure their durability and to aid in long range planning.

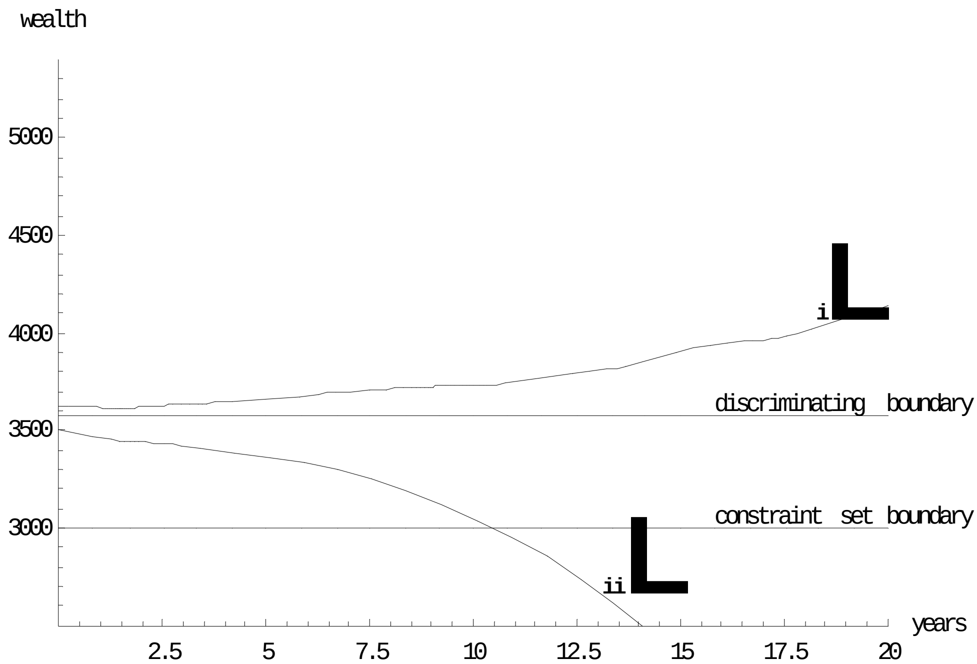

Figure 1: Strongly viable wealth evolution in a mixed herd with uncontrolled breeding rate of llama flock i). Initial wealth is 3630 US$. Herd structure is made up of 60% of llamas and offtake rate on females satisfies minimum income (600 US$) at every point in time. The discriminating kernel boundary is the threshold above which household's wealth should stay if minimum income is to be satisfied at any time in the future. The constraint set boundary is the wealth level at which minimum income is always satisfied in absence of climatic uncertainty ii) non viable wealth evolution.

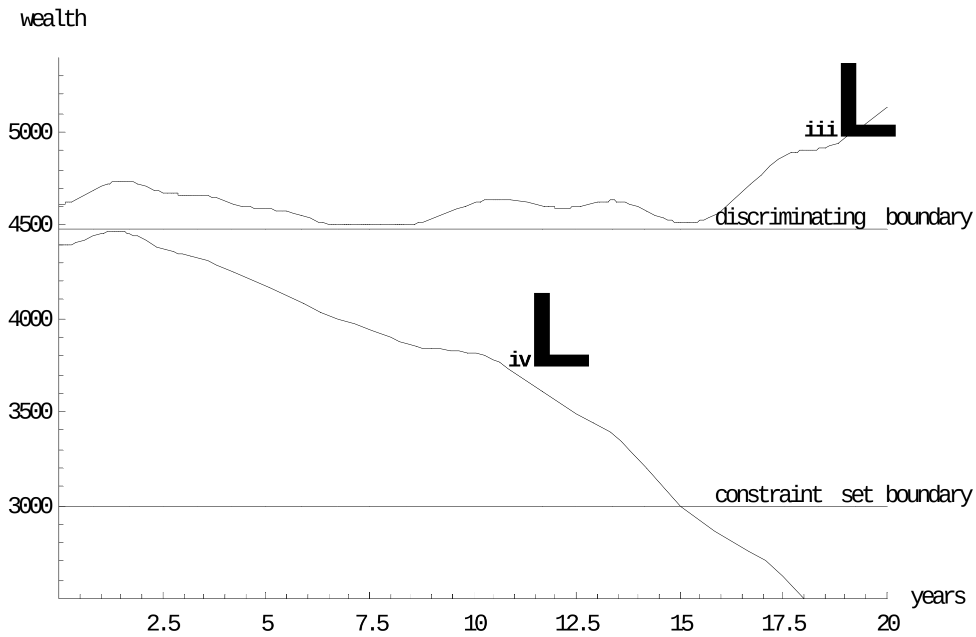

Figure 2: Strongly viable wealth evolution in a mixed herd with controlled breeding rate of llama flock iii). Initial viable wealth is 4618 US$. Herd structure is made up of 60% of llamas and offtake rate on females satisfies minimum income (600 US$) at every point in time The discriminating kernel boundary is the threshold above which household's wealth should stay if minimum income is to be satisfied at any time in the future. The constraint set boundary is the wealth level at which minimum income is always satisfied in absence of climatic uncertainty. iv) non viable wealth evolution.

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