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Ecological Economic Analysis of Grassland Systems: Resource Dynamics and Management Challenges- Kachchh District (Gujarat)

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Gujarat Institute of Desert Ecology, Bhuj

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Ecological-Economic Analysis of Grassland Systems:

Resource Dynamics and Management Challenges –

Kachchh District (Gujarat)

Ministry of Environment & Forests, Govt. of India

World Bank Aided

India: Environmental Capacity Building Technical Assistance Project

INDIRA GANDHI INSTITUTE OF DEVELOPMENT RESEARCH, MUMBAI

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Abbreviations

ACU	:	Adult Cattle Units
ANOVA	:	Analysis Of Variance
BDA	:	Banni Development Agency
CGP	:	Current Grazing Potential
COV	:	Covariance
CPR	:	Common Property Resource
CV	:	Coefficient of Variance
FAO	:	Food And Agriculture Organisation
GAHI	:	Gross Annual Household Income
GEDA	:	Gujarat Energy Development Agency
GIB	:	Great Indian Bustard
GP	:	Grazing Potential
GPR	:	Grazing Pressure
GSFD	:	Gujarat State Forest Department
GSRDC	:	Gujarat State Rural Development Corporation
GUIDE	:	Gujarat Institute Of Desert Ecology
ICAR	:	Indian Council Agriculture Research
IUCN	:	International Union For Conservation Of Natural Resources
LBI	:	Livestock Based Income
LMC	:	Livestock Maintenance Cost
MBI	:	Milk Based Income
BIPA	:	Milk Based Income Per Animal
MFP	:	Minor Forest Product
MSI	:	Miscellaneous Income
NGO	:	Non-Governmental Organisation
NLBI	:	Non-Livestock Based Income
NPV	:	Net Present Value
NTFP	:	Non-Timber Forest Produce
OAPR	:	Open Access Property Regime
ODE	:	Ordinary Differential Equation
OTHI	:	Other Income
PJBI	:	Prosopis Juliflora Based Income
PMR	:	Property Management Regime
RD	:	Revenue Department
SD	:	Standard Deviation
TINC	:	Total Income
TLBI	:	Total Livestock Based Income
TOT	:	Total Income
UNEP	:	United Nation’s Environment Programme
WWF	:	World Wilde Fund For Nature

1 Introduction

1.1 Background

The emergence of the discipline of ecological-economics was stimulated by the perception that many conventional approaches have been unable to capture the important feedbacks between social and natural processes, and have very limited predictive or prescriptive power (Perrings, 1997). Economic activity affects the ecological systems by its use as a source for resources and/or as a sink for wastes. Sometimes the scale of economic activity is perceived as independent of the both the rates of replacement of resources or the waste absorption capacity of the environment, forming the basis of treating environmental effects of economic activities as externalities of production or consumption (Pigou, 1932; Ayres & Kneese, 1969). However, beyond certain scales and thresholds, the pervasive nature of these externalities and the inherent limitations of ecological systems would compel one to treat the ecological variables as a part of material balance in the economic process, or as internal to the economic system itself. Ecological-Economic systems are 'co-evolutionary' in the sense of Norgaard (1984), with inter-linked time paths (Perrings, 1987; 1997). In such an approach, the starting point for ecological-economic analysis is the recognition that economy and environment are jointly determined systems and the scale of economic activity is a determinant of change and controllability of the joint system.

It can be said that one of the biggest challenges to the economics of natural resource management is how to integrate properties of the natural systems that affect the evolution of the economic activity, particularly the dynamics (Perrings & Walker, 1995). While it is recognised that the negative environmental externalities compromise the concavity-convexity conditions for social optima (Baumol and Bradford, 1972; Starrett, 1972), the problems raised by the complexity of the ecological systems goes well beyond the non-convexity of the social possibility set (Perrings & Walker, 1995). If the economic pressure on any ecological system causes it to "crash" or to undergo some pathologically irreversible condition, then the economic activities dependent on it will also be disrupted. The methods of optimal control theory have been gainfully used in such contexts involving the management of a wide range of biophysical stocks constrained by bio-economic models (Krutilla & Fisher, 1975; Fisher *et al,* 1972; Clark, 1976; Smith, 1977). Examples abound from studies on diverse natural resource management issues such as fisheries, wildlife conservation, rangeland management, rotational tree felling from forests, groundwater withdrawal and soil conservation, so much so that natural resource economics has become, in a many ways, an application of optimal control theory (cf. Conard and Clark, 1987).

This study is concerned with the economy-ecology linkages that characterise open access grassland systems or savannahs found in the arid Kachchh district in the western state of Gujarat in India. While all of these sustain the free grazing livestock of a large number of pastoral or agro-pastoral communities, some of them also support high biodiversity values of global and national significance. The central issue is the problem of resource management. However, there is very little documentation on either the dynamics of the ecological resources or the economy of these important bio-economic systems.

1.2 Rationale for the Study

Despite the enormous economic and ecological significance, there is no systematic inventory or characterisation of the grassland systems in the country or the State of Gujarat (Dixit *et al*, 2001). The state of Gujarat has an area of about 1,400 km^2 under grasslands or *vidis* and administered by State Forest Department in two categories – reserved and non-reserved (Lal and Pal, 1995). The large proportion (92%) of these *vidis* is distributed in two regions – Saurashtra and Kachchh, which have predominance of semi-arid and arid climates. About 44% of such grasslands are distributed in Kachchh district. Other than these *vidis*, there are vast stretches of grasslands in Kachchh which are open for free grazing. A significantly large population of pastoral and agro-pastoral communities in the arid/semi-arid regions of Gujarat sustain their livelihoods based on free-grazing livestock. These livestock have high dependence on both village pastures or *gauchars* and large contiguous grassland tracts[1]. This study relates to the grassland tracts and not the village pastures. However, a few of the grasslands may include some village pastures.

The grasslands in the Kachchh are severely degraded through a combination of intensive grazing, changes in institutional arrangements, nature of property rights and invasion by the exotic woody species, *Prosopis juliflora*. While grassland degradation in parts like Banni is severe, it is considerably less in the Naliya grassland tracts falling in the Lakhpat-Abdasa talukas. The former is characterised by absence of agriculture, dominance of pastoral mode of resource use and absence of property rights. The latter is used by wild ungulates such as the endangered Chinkara (gazelle) and Neel Gai (Blue Bull). It is, one of the rare sites where all three species of Bustards - Great Indian Bustard - a globally important and highly endangered bird species, Lesser Florican and the Houbara Bustard are present.

The grasslands in the two regions represent two distinct typologies. Typology-I (Banni) represents the case where grassland resources are crucial to the pastoral economy, while Typology-II (Naliya) is a case where the biodiversity values are very high. Pastoral system dominates Type-I, while agriculture is the main stay of the rural economy in Type-II. The property and resource management regimes are in striking contrast under the two Typologies. The area with the potential for grass cover in Banni is about 1610 km^2, of which 80% is at present invaded by woody cover, leaving only about 350 km^2 with grass cover. Naliya represents a large grassland tract of nearly 160 km^2.

Having said as much about the typologies, it must also be stated here that when the study began the distinction was an informed perception than one based on hard data. It was necessary to properly define the differentiation with ecological and economic data. As ecologists, our main concern in studying the two was to arrive at a sound assessment of the economic significance of the grassland systems, as distinct from the *gauchars*, so as to work towards a policy perspective on the conservation of these systems, since from a purely ecological point of view the need for conservation of these ecosystems were never in doubt. On the other hand, the economic rationale for most ecological conservation proposals has not been so unambiguous.

Of considerable interest is not only the difference in the degree of dependence on grasslands by the pastoral and agro-pastoral communities, but also the role of resource management regimes in the sustaining these resources. The typologies are, in a sense, a study in contrasts, although the issue of open access to grassland resources is the common thread. The challenge of identifying resource management options for controlling the woody invasion in the case of Banni region contrasts sharply with that of reconciling the economic significance of grasslands with goals of wildlife conservation in Naliya.

The issues of resource management and of bringing about sustainable resource use are complicated by the current legal and institutional arrangements. These are, in themselves, a complex enough issue

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[1] In Gujarat the village grazing areas are called 'Gauchars'. These are same as the permanent pasture category in land use records. The gauchers may or may not have the grass cover. Grassland, as defined, is a grass dominated ecological system.

meriting an independent study. However, these are a part and parcel of the resource economics problem and we need to ask the question whether the current approaches based on 'protecting' the resources by alienating control over it from the stakeholder communities makes sound economic sense or not. The perplexing question is how Hardin's 'tragedy of the commons' syndrome comes into play over resources that are not only under well defined property management regimes but also deemed as 'protected'. Given the players and rules of the resource management game, how much of the blame, if any, should be apportioned to the different players: those who, *de jure*, control the resource and/or those who, *de facto*, depend on it?

In the context of the prevailing trends in degradation and difficulties in resource management, the future prospects of grassland ecological systems are of serious concern. The ecological change is accompanied by economic consequences and the relevant issue is whether the nature of resource economics is irreconcilable with ecological conservation. The question is whether large costs are to be paid for conservation or are there definite synergies between conservation and the direct economic benefits. This leads to the biggest dilemma: the choice of analytical framework for this work.

The temptation to employ Contingent Valuation Methods was short lived as it became clear from the initial expert reviews, and in particular the caution by Prof. Perrings, that such an exercise would be fraught with serious hazards. Almost all of the grassland resources, even some of the wild fauna, have direct values and the attempts to develop TEV framework proved to be extremely unrewarding. Prof. Perrings was very emphatic that it would be much more interesting to examine the resource dynamics within an ecological economics perspective.

The importance of coming to terms with the dynamics – both the stochastic and deterministic components - could not be ignored, particularly while dealing with a grassland system undergoing quick transformation into woodland due to the mesquite invasion driven by the very livestock, which forage on the grass. While the satellite imageries could estimate with very little ambiguity the extent of invasion, it was clear that if the linear rates of invasion derived from it were true, then hardly any grassland would remain. There were many non-linear effects and feedbacks to be considered. It was apparent that modelling the dynamics would greatly aid in conjuring up the behaviour of the system over time. Formulation of a mathematical model and numerical simulation of the resulting dynamic model proved to be a valuable heuristic tool under the circumstances. The study, therefore, encompasses ecological studies, economic surveys, mathematical modelling of ecological and resource dynamics and the simulation of different policy scenarios.

1.3 Objectives

The overall goal of this study is to explore the possibilities for better management of grasslands as an ecological entity and to study the economic ramifications of various options. In this context, the major objectives addressed by this study are:

- Examine the dynamic links between the economic variables and grassland resources in a system dynamics framework
- Compare the resource economics under two major typologies distinguished in economic and ecological terms
- Undertake the differentiation in income sources and distribution in the context of different kinds of resource dependence
- Identify the better resource management options given the nature of economy-ecology linkages and policy options
- Understand the implications of various resource management scenarios on the economic returns and ecological conditions

1.4 Organisation of the Report

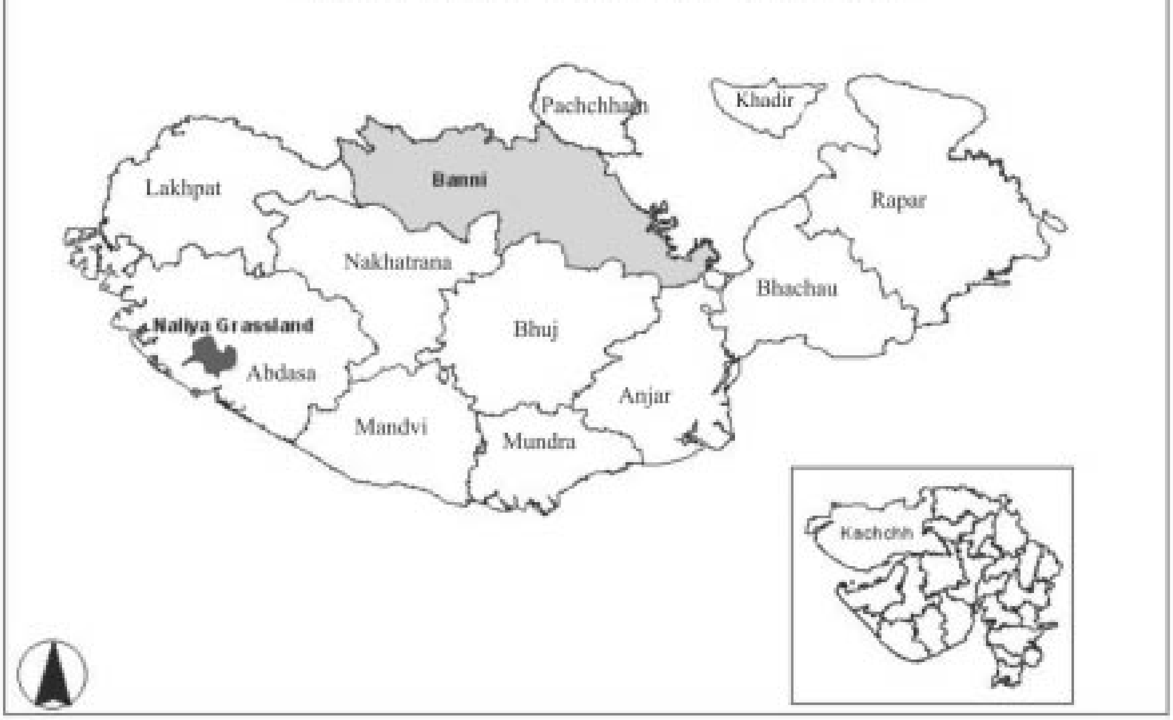
The approach adopted in this study including the analytical framework is detailed in Chapter 2. This is followed with an overview of the issues of ecology and economics associated with grasslands or savannahs in Chapter 3. An ecological-economics perspective on the study region is provided in Chapter 4. This chapter discusses the ecology, the resource base, its variability, and issues of property regimes. Chapter 5 examines the emerging trends in the pastoral and agro-pastoral systems of the region based on both primary data collected in this study and limited secondary sources. The discussion deals with demographic changes, livestock composition and strategies to cope with resource scarcity based on the primary household surveys – 387 from Banni and 174 from Naliya regions representing the two grassland typologies. Detailed statistical analysis of the survey data is presented in Chapter 6 in the form of a disaggregated analysis covering income diversification, variations in milk-based incomes according to herd sizes and inequalities. A mathematical model of resource dynamics of the grasslands in Banni invaded by woody species is presented in Chapter 7, using a system dynamics approach employing a mathematical model based on a set of difference equations. Inferences from parameter sensitivity analysis are also presented in this chapter. The dynamics of economic variables associated with the resource dynamics is elaborated in Chapter 8, which allows the computation of the Net Present Values corresponding to the different management options envisaged in the computer simulations of the dynamic model. Chapter 9 discusses the economic ramifications under different resource management scenarios simulated using the economic data abstracted from the primary surveys. The last chapter (Chapter 10) summarises the policy options and emerging issues.

2 Methodology

2.1 Background

The present study was carried out in two grassland typologies - Banni and Naliya in district Kachchh, Gujarat (Fig. 2.1). It appears that this is the first time a detailed economic data on these grassland resources was being analysed. In the case of Banni region (Type-I), the most serious degradation of the grassland resources is caused by the exotic mesquite invasion and one needs to go beyond the statistical analysis of one time data to comprehend the consequences on the resource economics. In contrast, the Naliya region (Type-II) is virtually devoid of mesquite invasion and grassland system is known to exist in a fairly stable state for a very long time. Therefore, only the Type-I case has been studied in a system dynamics framework in addition to the statistical investigations carried out for both cases. System dynamic modelling serves as an excellent heuristic tool (Bratt and Opschoor 1990; Perrings, 1994) and has been employed here to study the peculiarities introduced into the resource economics of Banni by the combination of grazing, management regimes and woody invasion.

Fig 2.1: Locations of Study Area in Kachchh District



The nature of surveys and desk reviews cover both ecological and socio-economic themes. In the case of ecological investigations, the primary data is derived from rapid surveys, based mainly on vehicle transects to cover a very large area. Digital satellite imagery data was also used to better understand the status of grass-cover in the study areas. The socio-economic data was collected at village and household levels. The household surveys are based on stratified random samples covering approximately 20% of the households in the two typologies.

This work embodies three broad classes of investigations:

a) Limited ecological studies through rapid surveys and desk reviews
b) Detailed statistical analysis of primary data on the economic variables through household surveys
c) Computer simulations of the resource dynamics and management options using a system dynamics approach

2.2 Resource Surveys

The information available from previous short-term ecological studies on these grassland systems (GUIDE 2001) was supplemented by rapid surveys. These rapid surveys used dirt roads linking villages for vehicle transects with resource inventory at one-kilometre intervals. These inventories helped to determine the differentiation in the vegetation cover in terms of good grass cover, mesquite (*Prosopis juliflora*) thickets, grass-woody cover mix, and other herbaceous species. The distance of nearest patch of woody thicket from the sample point was also estimated to perceive the threats to indigenous species. Each parameter was visually estimated as per guidelines developed and assigned to one of the rank classes. The data collected from Banni comes from 146 sample points belonging to 20 transects and for Naliya it comes from 28 sampling points spread over six transects. Satellite imageries and available land-use/land-cover maps were also studied to obtain a synoptic view of the grassland resources in the two areas.

2.3 Sample Villages and Households

Banni

House listing was attempted initially as a prelude to the random survey. However, the effort was postponed because of large-scale out-migration due to the drought and scarcity conditions. The surveys were resumed after the return of large number of people to the villages following scanty rains. By the time the surveys were completed, the region was once again facing drought conditions and scarcity with the failure of monsoon for the second consecutive year. We have gathered some information on the economic conditions during drought and consequent migration. In this context, it was decided to randomly select entire villages representing 20% households, rather than select 20% households randomly within villages.

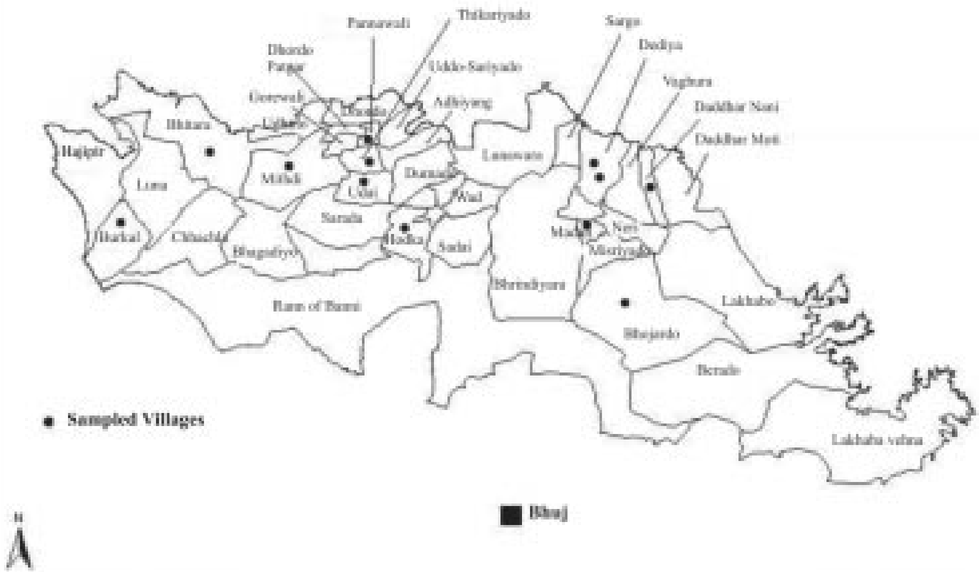
The surveys in Banni covered the entire population of 13 out of 51 villages (Fig. 2.2). The villages were grouped into five population size classes as per 1991 census[2] and villages for sampling were selected randomly from among the villages in each size class. The surveys in Banni covered 387 households in villages well distributed over the study area (Table 2.1).

Table 2.1: Villages surveyed with population and the number of households sampled

Village	Population (1991 census)	Household Size Class	Households Surveyed
Udai	15	< 10	3
Jarmariwand	26	< 10	1
Bhurkal	114	10 – 24	11
Madan	119	10 – 24	9
Pannavari	102	10 – 24	14
Bhitara Mota	140	25 – 49	32
Daddhar Nani	453	25 – 49	43
Dedia (Nana and Mota)	190	25 – 49	36
Tikariyado	167	25 – 49	42
Mithidi	454	50 – 99	50
Bhojardo	609	> 100	50
Hodka	634	> 100	96
TOTAL	3023		387

[2] The surveys were completed before census of 2001

Figure 2.2: Location of sampled villages in Banni



Naliya

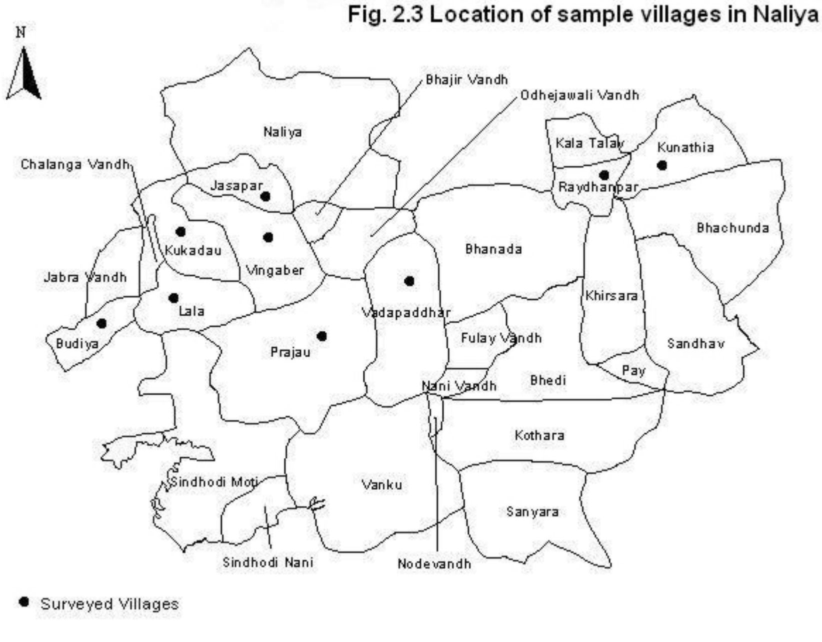
Out of 13 villages adjoining the grassland (Fig. 2.3), house listing was carried out in nine villages to facilitate stratified random sampling. Different strata of households were identified within each village using Ward's minimum variance method (Ward, 1963) of hierarchical clustering (Clustering procedure in SPSS®). Within each stratum at least 20% households[3] were randomly selected. The questionnaire-based survey covered 174 households (Table 2.2).

Table 2.2: Villages with number of households sampled in each

Village	Households	No. of strata	Sample Size
Prajau	98	8	25
Vingber	61	7	14
Budia	47	6	11
Lala	113	11	26
Jashapar	56	8	16
Kukudau	63	8	16
Ruydhanpar	96	6	17
Kunathiya	58	7	13
Vadapadhar	154	11	36
TOTAL	**746**	**72**	**174**

[3] Where there is only one household within a stratum that was included in the sample.

Fig. 2.3 Location of sample villages in Naliya



2.4 Informal Meetings & Focussed Group Discussions

Before conducting socio-economic surveys, reconnaissance of the study areas was carried out. During such reconnaissance, informal meetings with the villagers were organised to discuss various issues related to the grasslands resource economics. These discussions helped to identify various local issues and facilitated the questionnaire design. Several Focussed Group Discussions (FGD) were also organised at the village level to better comprehend the regional and local contexts of the ecology and economics. Many informal consultations were undertaken with the senior citizens and local experts who had vast knowledge and experience about the two areas. In order to understand various land related administrative and management issues in the study areas, series of informal consultations with different Government officials were organised. Focussed group discussions also helped in arriving at reality checks on the data collected.

2.5 Questionnaire Development and Household Surveys

Based on the feedbacks from the reconnaissance surveys and informal discussions with various stakeholders (villagers, NGO representatives, local environmentalists and government officials), structured questionnaires were developed for the household socio-economic surveys. Open-ended questions were kept to the bare minimum and quantitative formats were designed through an iterative process involving several rounds of field trials. Owing to the differences in the issues, different sets of questionnaire were developed for the two typologies.

The questionnaire covered following major themes: demography, dependence on natural resources, assets, income sources, and management options. Ranking of the responses to various alternatives was used to quantify the perception of communities. The questionnaires were tested in the field several times and evaluated in terms of the overall interest evoked from the respondent, clarity and ease of understanding by the respondent, and the time taken for completing the survey of per household. The questionnaire used for the two study areas are included as Annexure-I and Annexure-II.
Once the questionnaires were finalised, a team of surveyors, proficient in the local language, i.e., *Kachchhi*, were put through trial surveys. This was important for developing their capability to

undertake the survey, understand the scope of the questions, comprehend the inter-linkages between different parts of the questionnaire and to train them in cross-checking the responses. Much stress was laid on the ability of the surveyors to communicate with the respondents effectively in a simple and easily understandable manner. Household surveys were conducted separately in the two regions- first in Banni during September-October 2000 and later in Naliya during November-December, 2000.

It is important to mention here that the study period was marked by two consecutive poor rainfall years (1999-2000) and thus migration of pastoral families was prevalent, especially in Banni. To capture the process of migration and its impact on pastoral economy, efforts were also made to sample those households who were on-migration route and settled in other parts of Kachchh. A separate questionnaire was developed targeted at these families (Annexure III). A total of 36 such families were sampled.

2.6 Data Set and Incomes

Data employed for the analysis come from the primary survey of 387 households randomly distributed in Banni region. This section explores the patterns of household income by source. A few important comments regarding income data are called for at the outset. The survey has attempted to capture all kinds of income received in cash. All the incomes represent the gross income per household and no attempt was made to adjust the data for family size, age and/or gender composition of the household, although it may be desirable in certain kinds of studies to use income equivalence scales (cf. Deaton and Mullbauer, 1982).

The quality of expenditure side data was not been reliable enough to be useful in computing the net income for each household. In the case of Banni region, the dependence of livestock on the open access pastures is so overwhelming as to make any attempt to compare social costs of grassland resource with the paid out costs of livestock maintenance, and more so because of the general lack of reliability to the queries regarding expenditure on livestock maintenance. In the case of Naliya, where the dependence on the grassland is not as total like in Banni, the social cost of grassland use has been attempted. However, a sub-sample of meaningful data on paid-out expenses on livestock could be abstracted from the dataset of both typologies.

Naliya being an agro-pastoral area, subsistence agriculture is an important part of the economy. Therefore, in the case of Naliya, all the production data of agricultural outputs and livestock products have been assigned imputed values based on the mean producer prices surmised from the survey. However, in the case of Banni no imputed incomes have been attributed to own consumption of livestock products. Neither in Banni nor Naliya, have values been imputed to rent for land or self-occupied housing. Similarly, no values have been assigned to family labour involved in crop or livestock rearing.

The survey elicited data on animal stock and turn over for the two consecutive years (current and previous). Attempts to gather such information covering a five-year span (current and past four) were given after the trials showed that, in general, it was nearly impossible to elicit meaningful responses. Detailed data on livestock – composition, adult, sub-adult, sale, purchase, births and deaths – was collected. The dependency of livestock on open access grasslands was also ascertained. In both typologies, queries on people's perceptions on ecological changes yielded useful responses in the form of both quantitative scores and open-ended answers (Annexure IV). In the case of Banni, contrary to expectations, the respondents were rather forthright in disclosing the incomes from the woody resource such as those from charcoal making and NTFP collection, which are deemed illegal under the current policy regime. Despite the apparent lack of reluctance to provide income data from the woody resource, the recorded data is still likely to be a case of under reporting of income. However, it is not possible to estimate the degree of under reporting.

2.7 Data Analysis

The data collected through sample surveys were vigorously analysed to discern the patterns in the pastoral systems, especially in identifying the relationship between resources and the economics of the region. Although, the data were examined for both the study areas, more in depth analysis were made in the case of Banni, because of the peculiarities introduced by the woody invasion and pastoral economy.

As discussed earlier, we had sampled 387 households from Banni and 174 households from Naliya area. However, in the course the analysis of data on various aspects, some households (datasheets) were not considered for the analysis as these datasheets either provided incomplete response to a particular question or were highly inconsistent with the responses to other questions. Therefore, during the entire analysis, one would find different sample size for different sets of analysis. In Banni, for instance, the entire migration related data was analysed with a smaller sample size of only 130 families, and the most of the income related analysis was conducted on a sub-sample of 251 families. The relevant sample size is defined while describing the results through table or graphs. Due to linkages of one set of data as obtained from one section of the questionnaire to the other sections, we created a relational database using MS Access software. The statistical analysis was carried out using SPSS® software.

In order to test the distribution of data (normality) and other basic statistics of the parameters of interest, we used the descriptive statistics including the frequency distribution, means, standard deviations, coefficient of variations (CV) etc. In order to test the difference in the means of a parameter between more than two independent populations we applied One-Way Analysis of Variance (ANOVA). ANOVA was used in testing various income related parameters across different categories such as herd sizes, herd types, migration, etc. In the household surveys, multiple questions were used to codify the qualitative data relating to perception of respondent on different natural resource management related issues. On a particular issue (e.g., the perceived causes for grassland degradation) there may be significant difference among different groups (e.g. herders, non-herders, migratory and non-migratory). The differences in the perception between two or more independent populations were analysed using Chi-Square test. The null hypothesis (H0) tested was: the proportion of households having a particular perception is identical among the different social, cultural and economical community groups.

To investigate the relationship among continuous variables we used correlation analysis. However, it is a general caveat that linear correlation analysis would be valid only if the relationships are nearly linear. Further, in order to explore the relationship and response of explanatory (independent) variable on the response (or dependent) variable, we used regression analysis wherever applicable. We used simple, multiple and logistic regressions on different data sets. The simple regression was used in exploring the various relationships between the resources and economic variable such as herd size and the livestock based income. Logistic regression has generally been used to estimate the probabilities of an event to occur as explained by one or many independent variables. Here the dependent variable is converted into a binary variable with a value of 0 or 1. We used this method to determine the best predictors for the migration probability of a herder. The statistical tests were applied following Zar (1984) and Pagano and Gauvreau (2000).

2.8 Inequality Measures & Resource Dependency

Inequality is one of the characteristic features of any economic system. If there is a great deal of disparity in the incomes of people in a society, the sign of such economic inequality are often quite visible in the social stratification. While it is, perhaps, easy to perceive inequality in an intuitive way, it is hard to find ideal measures to quantify it unambiguously despite many indices and measures (Sen, 1999). In this work, we are not concerned so much with income inequality *per se* in its own right, but more about how different resources contribute to increasing or lowering it. The property of decomposability allows inequality measures such as the coefficient of variation[4] (CV) and Gini Coefficient[5] (G) to be partitioned either over subpopulations or sources (Shorrocks, 1982). It is the latter type of decomposition, that we are interested in this study.

The inequality measures have been used in several studies to bring out the differences in resource dependence and relative importance of various resource bases in either increasing or decreasing inequality within and across different socio-economic strata (Adams, 1994; Ercelawn and Dolberg, 1984; Nugent and Walther, 1982). Beyond measuring disparities, the inequality measures can be used to compare the relative importance of different resource base in bringing about that income (or wealth) distribution among different geographically separated regions, socio-cultural groups or at differing points of time e.g. pre and post droughts. We have used the three commonly used measures of inequality – Lorenz Curve (for graphical representation), Gini coefficient (G) and CV – to explore the contribution of different resources (grass, woody biomass, farm, livestock, etc.) in shaping the income distribution across and within different strata.

Lorenz Curve

The *Lorenz Curve* is a plot where the percentages of population arranged from the poorest to the richest are represented on the horizontal axis and the share of cumulative income enjoyed by the percentage of population is on the vertical axis. It is obvious that zero percent of the population has zero percent income while 100% of the population owns all of the income. These two points form the diagonally opposite corners (lower left and upper right) of a unit square. The Lorenz curve thus runs from the lower left corner to the upper right. If everybody in the system had the same per capita income, the Lorenz curve will be the diagonal of the unit square representing absolute equality and any departure from this diagonal line is an indication of inequality. With increasing inequality, the curve starts to fall below the diagonal in a loop that is always bowed down towards the bottom right corner. Beyond graphical representation, there is very little that can be done with the Lorenz curve.

Coefficient of Variation

One of the most widely used measures of inequality, which is scale independent, is the coefficient of variance (CV), which is nothing but the relative dispersion of income from the mean income. The merit of CV is that being scale neutral it can be used to compare different distributions with higher or lower means.

Gini Coefficient

The Gini Coefficient (G) is fundamentally different from measures such as CV in the sense that it measures pair-wise differences. It represents all conceivable pair wise or 'two-person inequalities'. In this approach, inequality is made up of the total of all pair-wise absolute differences in incomes. The Gini coefficient is obtained as a normalisation of the sum by dividing it by all possible pairs considered (n^2) and the mean.

2.9 Decomposition of Inequality

Although the relative magnitudes of the differences in income inequality among the different groups are fairly sensitive to the choice of the inequality index utilised, the rankings are not. For analytical

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[4] CV is the standard deviation divided by mean, μ: $C = \frac{1}{\mu}\sqrt{\sum_{j=1}^{m}\frac{n_j}{n}\left(y_j - \mu\right)^2}$

[5] The Gini coefficient, G, is defined as: $G = \frac{1}{2n^2\mu}\sum_{j=1}^{m}\sum_{k=1}^{m}\left(n_j n_k \left|y_j - y_k\right|\right)$

convenience, as well as brevity in exposition, we utilised the squared coefficient of variation (CV^2). The advantage of this measure is that it can easily be decomposed into the portions attributable to inequalities in the different sources of income, especially when some components of income can be negative, and total family income is the sum of income from all the sources. Nugent and Walther (1982) described the application of this measure in decomposition of rural income inequality in Indian conditions. For the purpose of this study, we applied the decomposition of income inequality within the Banni data.

Suppose there are three different sources of income, Y_1, Y_2 and Y_3 for any family. Since total family income Y is equal to the sum of Y_1, Y_2 and Y_3, this implies that when one considers the deviation of the incomes (i.e., $y = Y - \mu$; $y_i = Y - \mu_i$) from the means (indicated by lower case letters):

$$y = w_1y_1 + w_2y_2 + w_3y_3$$

where, w_i is the proportion of average income from i^{th} source to average total income.

Since the variance of y equals the squared coefficient of variations in Y, CV^2, can be expressed as follows:

$$CV^2 = w_1^2 * CV_1^2 + w_2^2 * CV_2^2 + w_3^2 * CV_3^2 + \\ 2 * w_1 * w_2 * COV_{1,2} + 2 * w_2 * w_3 * COV_{2,3} + 2 * w_3 w_1 * COV_{3,1}$$

where, $COV_{i,j} = (Y_i - \mu_i)*(Y_j - \mu_j)$, is the covariance of Y_i and Y_j

This permits the decomposition of the overall inequality index into the contributions from inequality associated with each source separately and the cross or interaction terms, which depend on both the magnitude *and* direction (i.e., the sign) of the covariance between the incomes of different sources. In particular, it can be seen that covariance terms can be either positive or negative depending on whether the deviations of the two income sources from their respective means are both in the same direction or are in opposite directions. To enable comparison across categories, the relative contributions of the absolute contributions of the components (CV_i^2 or $COV_{i,j}$) to the overall CV is computed as a normalisation by dividing each component by CV^2 (i.e., either CV_i^2/CV^2 or $COV_{i,j}/CV^2$). The sum of these relative contributions is unity, so that the components become comparable, while the overall variation is normalised to unity (Nugent and Walther, 1982).

2.10 Modelling Resource Dynamics

The modern econometric analysis of natural resource problems is considered by many to have its origins in the work of Hotelling (1931), which emphasises the role of an inter-temporal or dynamic approach (Hanley *et al*, 1997). The dynamics of the grassland resource economics is being examined using an approach proposed by Perrings (1997).

The work of Perrings integrates an ecological model of rangeland resource dynamics into an economic analysis using an econometric approach, specifically one using utility function, under an optimal control theory perspective. Environmental stochasticity is introduced into the approach using parameters with a non-zero standard deviation. The resource dynamics in the work of Perrings is based on two state variables: a) Livestock present in a year on the rangeland [X] and b) the carrying capacity of the rangeland or the maximum cattle that the rangeland can support in that year [K]. Unlike in the usual ecological models where the carrying capacity is assumed to be a constant, it is assumed to be a state variable and a function of time and stocking level itself, since stock of livestock alters the grazing potential. The utility function that incorporates the costs and benefits of livestock off-take is examined in the light of the dynamics of rangeland resources mediated by stochastic effects, particularly erratic rainfall.

We have adapted this approach to study the dynamics of ecological-economic system in the Banni region. For this we propose a modelling framework with three state variables: a) Livestock present on the grassland system [X], b) Grazing potential of the grassland [K], and c) Area invaded by woody species displacing grassland [W]. The total area that can be covered by grass and woody species is a constant while the grazing potential is now both a function of livestock levels and extent of woody invasion. The variability of rainfall and stochastic effects are incorporated in the same way as is in Perrings. Growth of livestock is assumed to be function of rainfall, mean availability of graze and the effective grassland area. The utility function is constructed to account for benefits and costs from different resources (grassland or woody) through the use of appropriate production functions. The property rights regime is assumed to be essentially open-access, implying that there are no well defined economic or social incentives for the herders to take the external costs of resource degradation into their stocking strategies. The short and long-term fate of the grassland is assumed to be irrelevant to the utility maximising decisions of livestock owners.

The major steps in this system dynamic modelling effort to understand the dynamics of the ecology-economy linkages of Banni region are outlined below:

a) Constructing an ecological model to capture the basics of ecological dynamics, that is realistic enough to contain the 'core' ecological or resource degradation problem. This model is developed both at the conceptual level keeping in view the ecological issues followed by a concise dynamic mathematical model.
b) The model of ecological dynamics provides the constraints for the renewable resources – grass and wood that are determinants of income in the economic model
c) Defining a generalised utility function (sum of Benefits minus Costs) and giving it a definite form distinctive to the problem in hand. This problem-specific function then relates the benefits and costs to the resource base in a dynamic form.
d) The Net Present Values are computed using these set of equations over a 50-year time horizon using a social discount rate of 10%
e) Computer simulations are carried out to examine the dynamics and various ramifications. These simulations lead to inferences on the modes of resource management and policy. Scenarios may be visualised and simulated by the appropriate choice of parameter values and constraints

System dynamic modelling software Stella Research® was used for numerical simulations and symbolic mathematics software Macsyma® was used for mathematical analytical work.

3 Savannahs & Grasslands

3.1 Background

Grasslands/savannas cover substantial areas of the tropical region and form an important ecological and economic sub-system. Tropical grassland with scattered trees or Savannah (Bourliere and Hadley 1983) is one of the most common landscape units in the tropics. The savannah consists of a series of ecosystem types forming a distinct biome (Huntley and Walker 1982; Sermiento 1984). Savannah is defined as (see: Sarmiento 1984, Frost et al. 1985):

> An ecosystem of the warm (lowland) tropics dominated by herbaceous cover consisting of mostly bunch grasses and sedges that are more than 30 cm in height at the time of maximum activity, and show a clear seasonality in their development, with a period of low activity related to water stress. The savannah may include woody species (shrub, trees, palm trees), but they never form a continuous cover that parallels the grassy one.

Grasslands/savannahs form a large area for potential use by man invariably for grazing of livestock and seldom for growing of crops, production of fuel wood, recreation and tourism. In fact these are the most extensive land use types of grasslands in the world, occupying nearly 30 million km^2 or 23% of the earth's land surface (FAO 1978). The grasslands are generally in areas of low and erratic rainfall. Therefore, their productivity is low ranging from 1 ha supporting 3-5 animal units in temperate region to 50-60 ha to support 1 animal unit in arid region (Heywood, 1995). Nevertheless these lands support most of the world's 3000 million head of livestock (FAO 1978). Increasing anthropogenic pressure in the form of faulty land use practices, overgrazing, overstocking and agricultural activities have resulted in severe degradation of grasslands all over the world (Solbrig and Young, 1993). Some of the important examples of such large-scale degradation are Africa's Sahelian and Sudanian zones, while in parts of the North Africa, the Mediterranean, the Near East and South East Asia, the degradation of grasslands due to overstocking has resulted into the desertification (FAO, 1978).

3.2 Resource Dynamics of Grasslands

The grasslands dynamics in terms of diversity, productivity and its economic role are primarily determined by the soil moisture regime, soil texture and the availability of the nutrients. However, the other exogenous factors also play an important role in shaping the ecological and socio-economic values of grasslands. Among these, major factors are climatic fluctuations, fire and herbivore grazing, including livestock grazing (Perrings and Walker 1995). All these factors – determinants of grassland diversity and productivity, exogenous climatic factors and grazing pressures are interactive in nature and therefore each of them play an important role in the grassland dynamics (Knoop and Walker, 1985). The impacts of these factors and their interaction are more pertinent and visible in the arid and semi-arid systems because of their characteristics of high fragility and low resilience power. For example, rise in grazing pressure can and does have the effect of lowering the resilience of arid and semi-arid grasslands to external stress. It has been documented that the sensitivity of the composition of species in semiarid rangelands is affected by the livestock grazing pressure by changing the species distribution and physiological status of plant, which in turn is affected by the climatic fluctuation. Moreover, the increase in grazing pressure implies a reduction in the proportion of palatable species and increase in the proportion of unpalatable and woody species (Perrings and Walker 1995).

Similarly, the rainfall pattern and intensity, controls the soil moisture regime and the patterns of soil erosion across different topographical elevations, which in turn determines the vegetative productivity of grasslands. In such a situation, the formation of rill and gully changes the dynamics of runoff, resulting into the patchiness of grasslands, favouring the potential of development of woody plants in the area, which reduces the economic productivity of the grasslands. Interestingly, the grazing also plays an important role by exaggerating soil erosion process and the deposition of eroded soil (Stafford-Smith and Pickup 1990). Also, the sensitivity of the composition of species in semiarid rangelands to extreme events is a function of economic decisions. Thus the level of grazing pressure affects the status of plants in the system, which in turn is sensitive to the extreme climatic changes.

Another exogenous factor, fire, also plays an important role in maintaining the dynamics of grasslands. The periodic controlled fires help in suppressing the germination of woody seedlings (Knoop and Walker 1985) and thus maintain the nature of grasslands. However, increased grazing pressure in such rangelands raises the probability of establishing the woody seedling by reducing the availability of 'fuel' (grass cover) and thus effect of fire as a control. Once established, the woody plants generate positive feedback by effects. By reducing grass cover (through livestock grazing) more water passes through to subsoil and enhancing the competitive ability of deep-rooted plants. The net effect of such exogenous factors is that grassland is transformed from one state to another, towards more woody cover (ecological changes), which has less economic attraction as far as dependent animal husbandry is concerned (economic changes). Thus the dynamics of grassland based economic system are not independent of the dynamics of grassland as an ecological system.

The impact of degradation in terms of productivity loss is recorded more in the grazing lands as compared to the croplands (Dregne and Chou, 1992). The consequences of grassland degradation are more intensively felt in agro-climatic zones where grassland based pastoral system has been the basis of traditional pastoral economic systems. The regulations, that existed in the past over the use of rangelands have either been abolished or disappeared. Many common property resources that had some form of traditional management norms are now being abused, in the form of 'open access resources', enhancing their degradation rates.

3.3 Ecological Invasions

Grasslands all over the world are always subjected to the invasion of woody species (Archer 1994). Such changes from open savannah/ grassland vegetation to shrub land have been well documented in many semi-arid and arid regions (Acocks, 1964; Buffington and Herbel, 1965; Blackburn and Tueller, 1970; van Vegten, 1981, 1983; Archer et al., 1988; Hacker, 1984). These increases in woody species may cause reduction in grass cover and loss of productive pasture (Hennessy et al, 1983; Knoop and Walker, 1985); a loss in biodiversity and wildlife habitat (Archer, 1995); and may also lead to changes in distribution of moisture and soil nutrients, substantially enough to start the process of desertification (Schlesinger et al., 1990). In most of these cases, the encroachment of woody species has mainly been attributed to human activities (Skarpe, 1990). The possible causative factors in the shift from grassland to shrubland include the exclusion of fire allowing woody seedlings to establish; increased grazing pressure reducing herbaceous competition as a constraints to shrub establishment and growth (Skarpe, 1990; Collins, 1987; McPherson and Wright, 1990; Harrington, 1991); and also increased atmospheric CO2 levels favoring C3 woody plant over C4 grasses (Polley et al, 1994).

Many workers have identified the good grass cover and biomass as key factors in limiting the woody plant encroachment (Walker et al, 1981; Walker & Noy-Meir, 1982; Noy-Meir, 1982). A theory of woody invasion in overgrazed grasslands and savannah system explains that savanna is a system, where two functionally separate soil layers create separate niche for two distinct vegetation components with different life forms. In natural condition, both woody species and grasses have access to water in the surface soil, although a healthy grass layer may out-compete woody species in that zone. Therefore, any factor, which reduces the grass biomass and subsequently the capacity of grasses to exploit moisture from upper soil profile, promote woody plant growth. Grazing, for instance, by removing the grass biomass, negatively affects the rate of transpiration, root initiation and biomass accumulation and cut-down their ability to control the critical resources, like the soil-moisture. In the absence of grass cover, water penetrates deeper in the soil where the deep-rooted woody cover exclusively uses it and promotes the woody growth (Skarpe, 1990). Those plants of retrogressed sites cannot pre-empt resources sufficiently to exclude invading woody plants.

At another level, the livestock grazing also helps in spreading the seeds of woody species in grassland. The rapid invasion of grassland by leguminous shrubs (like mesquite) has mainly been attributed to the livestock as effective vectors for seed dispersal (Brown and Archer, 1987, 1989; Glendenning 1952). Livestock ingest the seeds, scarify the hard seed coat; transport the seed away from mature competitors and host-specific predators; and deposit in moist, nutrient–rich dung that suppresses competition from surrounding grasses

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3.4 Mesquite Invasion

Mesquite (genus *Prosopis*) is a thorny shrub or tree of the legume[6] family, which occurs naturally in arid and semiarid areas of North and South America, Northern Africa and Asia. Most of the over 40 species of mesquite are native to South America, considered to be the area of origin for mesquite. Some of the highly undesirable *Prosopis* species include *Prosopis alba*, *P. juliflora*[7] (now *P. chilensis)*, *P. cinerea*, *P. nigra*, *P. ruschifolia*, *P. stephaniana* and *P. tamarugo*.

In its natural range, during the Holocene period, Prosopis is said to have evolved with the megafauna in the New World (Moony et al. 1977), many of which were extinct by the end of Pleistocene (Martin 1967). With the extinction of these species, the seed dispersal was severely restricted until the advent of domesticated livestock. When growing in their native ranges, *Prosopis* species tend to be controlled by a number of indigenous insects and diseases. For example, bruchid beetles attack the seed of *P. alba*, *P. chilensis* and *P. tamarugo*, whereas a fungus can badly damage *P. cinerea*. Once transported to a suitable habitat in a new range by human efforts, however, the plants are free of natural predators and tend to spread prolifically.

Prosopis has numerous eco-physiological adaptations, which make it an aggressive invader of grasslands and savannas. Prosopis seeds are potentially long-lived in the soil (Tschirley & Martin, 1960), which can germinate and grow well on a wide range of soil types having a variety of physical and chemical properties including highly saline or alkaline soils (Ueckert et al., 1979) and moisture regimes (Scifres & Brock 1971). After germination, their seedlings quickly develop a deep taproot, which enable them to effectively access soil moisture at depths not effectively used by grasses (Brown and Archer, 1990). There are reports of penetration of roots up to 60 feet underground. During seed germination, a substantial proportion of the carbohydrate in the embryo is devoted to root system development (Mooney et al 1977) and thus record less developed stems and leaves at the early years. As a result of this resource partitioning, Prosopis seedling can quickly be establish in the grasslands. Seedlings are capable of vegetative regeneration within a week of germination (Scifres and Hahn, 1971), can survive repeated cutting or shoot removal for several years (Weltzin, 1990) and can even survive very hot fires (Wright et al. 1976). The herbaceous biomass affects germination and establishment of mesquite (Bush and Van Auken 1990). Archer (1995) recorded that high mesquite seedling establishment are related to the periods of drought or overgrazing when competing plant cover and vigour are reduced.

[6] Plants of the legume family are nitrogen fixers and can improve soil fertility

[7] *Prosopis juliflora* and *Prosopis chilensis* are synonymous. The former name, which is more popular, is used in this work.

Unlike many legumes, mesquite pods do not split open at maturity and, therefore, seeds remain within the pods. The livestock and many wildlife species consume these pods for their high sugar content and disperse the seeds (Fisher et al., 1959, Mooney et al 1977). Livestock are more effective agents of Prosopis seed dispersal than the wild fauna (Brown and Archer, 1987). Livestock (mainly cattle, camels, sheep etc.) normally consume these pods. A high proportion of seeds escape mastication and are scarified in the digestive tract, improving their germination rate two to three fold relative to non-ingested seeds (Mooney et al, 1977). Cattle may defecate as many as 14 times in a 24 hours period (Weeda 1967). Thus substantial portions of landscapes can be impacted by dung, depending upon the number of animals and their temporal and spatial patterns of movements.

After its establishment, Prosopis plants initiate a chain of events by altering the soil and microclimate. With the development of Prosopis clusters, the soil nutrient level increase and light levels and high temperature extremes decrease. This gradual transformation from 'high light-low nutrient' to 'low light-high nutrient' condition ultimately drives succession from grassland to woodland, with a mix of species (Archer, 1995)[8]. One of the major impacts of invasion of mesquite in water scarce arid and semi-arid regions is the change in water balance. In North Texas, one mature plant of mesquite was found to use up to 20 gallons of water per day during ideal mid-summer growing conditions (Ansley et al. 1991).

3.5 Conclusion

The discussion presented here serves as a backdrop to the grassland system that is the subject of this study. There are two kinds of processes that bring about change in the grassland – savannah systems: natural succession and disturbances introduced by human activity. One of the most severe threats to grasslands ecology is the unintended consequence of the invasion by introduced species. Such ecological invasions have proved to be nearly irreversible and have caused major changes in the economic activity based on the grassland resources.

[8] In case of Banni, however, due to high soil salinity, the process of succession is highly restricted and thus almost pure patches of Prosopis thickets are formed in the grasslands.

4 Grasslands of Kachchh

4.1 Background

Grasslands are one of the major ecosystems of the Kachchh district. In ecological terms these grasslands are grouped under *Dichanthium-Cenchrus-Lasiurus* type (Dabadhghao and Shankarnarayan 1973, Yadav and Singh 1977). These grasslands belong to the degraded stage of vegetation community that is prevented from progressing towards climax community due to the continuous grazing and thus record low productivity (Pandya and Siddha 1982). Although the grasslands are parts of almost every ecosystem types in Kachchh, they are predominant in parts of Lakhpat, Abdasa and Nakhatrana taluka and Khadir bet (Bhachau taluka) and Banni (Bhuj taluka). Besides supporting the regional economy, through animal husbandry sector, these grasslands also play an important role in performing various ecological functions, including the maintenance of biodiversity. More than 450 km^2 area of grasslands fall within PA network in Kachchh, supporting many rare and endangered animals and bird species, such as great Indian Bustard, Houbara Bustard, Lesser Florican, Chainkara, Wolf, Fox, Desert Cat, Caracal and spiny tailed lizard.

The grasslands in the Kachchh are severely degraded through a combination of overgrazing, changes in institutional arrangements, nature of property rights and invasion by the exotic and woody species *Prosopis juliflora*. While grassland degradation in parts like Banni is severe, it is considerably less in Lakhpat-Abdasa *talukas*. In the past, certain traditional systems of resource use and management appear to have been relatively sound in environmental terms and viable under subsistence economy. There are evidences to suggest that these systems were somewhat successful in conflict resolution. However, the traditional ways of resource use, livestock management and institutions have been subject to changes brought about by economic factors: both internal and external. These changes have brought large scale changes in the overall conditions of the grasslands, resulting into the large scale degradation of these resources.

4.2 Grassland Typologies

In the present study we have selected two grassland typologies: Banni grasslands in Bhuj taluka and Naliya grasslands in Lakhpat taluka in western Kachchh. Both these typologies are quite distinct in their ecological and socio-economic functions. The former is characterised by near absence of agriculture, dominance of pastoral mode of resource use and absence of property rights. The latter support the best grassland resources in the district and wild animals such as Chinkara – an endangered herbivore and Great Indian Bustard - a globally endangered bird species. There are thus two grassland typologies in environmental-economic terms represented by Banni and Lakhpat-Abdasa (or the Naliya) regions. The present chapter details the resource base of both typologies, including availability of resources, their use pattern and changes over the years. Following is the description of two typologies. The deliberations presented in this chapter are based on the secondary information, while findings of some primary surveys also presented to help better understanding.

4.3 Banni: Typology-I

Banni grassland is located on the northern fringe of Bhuj taluka between $29^{0}19'$ and $23^{0}52'$N latitude and $68^{0}56'$ and $70^{0}32'$E longitude (Fig. 2.1). The entire area is flat without any gradient, forming a low alluvial tableland rising 2 to 10 m above sea level. The plains of Banni represent an embayment between the Kachchh mainland uplift in the south, the Pachchham uplift in the north and the Wagad and Bela uplift (Rapar taluka) in the east. Towards northwest, lies the marshy salt flat of Greater Rann of Kachchh. In the southern part of Banni, there is an intervening stretch of salty waste known as

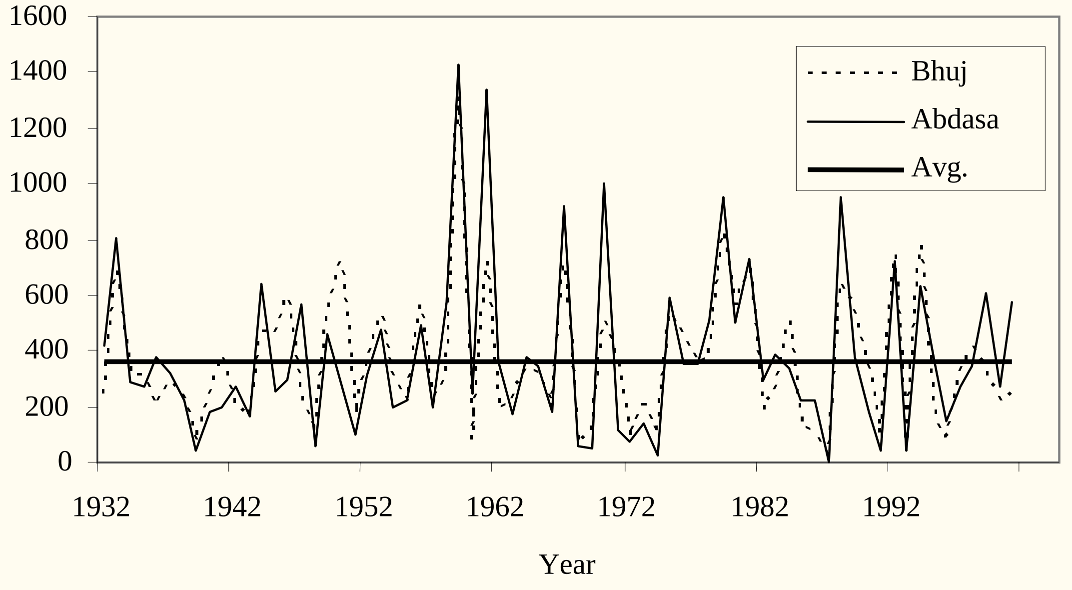
Little Rann of Banni, which separates the Banni from Kachchh mainland. Thus essentially Banni represents a transitional land between rocky mainland of Kachchh and Greater Rann of Kachchh. The geographical extent of the area stretches along 105 km long and 16-26 km wide belt parallel to the coastline of district Kachchh (Bharara, 1987). There have been several estimates about the total geographical area of the Banni. These estimates range from 1312 ha (Singh et al, 1993) to 3847 ha (Jadhav et al, 1992). The different estimates of the extent of Banni could be because of the improper demarcation of the area and possibly because of difference in the surveying techniques by different teams.

4.3.1 Physio-Climatic Regime

The Banni soil is generally alluvial and sandy with inherent high salinity. The soil salinity is highly variable from 1.0 to 15.0 M mhos/cm and the pH ranges between 6.5 and 8.5. About 60% soil cover is of moderately fine texture with higher proportion of silt and clay (Singh and Kar, 2001), therefore the overall permeability is very low. Moreover, due to low elevation without any gradient causes flooding and water logging in the entire area during rainy season. Such soil conditions with high level of salinity, low permeability and water logging minimise the potentiality of the area in terms of agricultural production and therefore grassland-based animal husbandry remains the only viable economic option in the area.

The climate of Banni region is no different from the rest of the district, which experiences peculiar arid conditions with low and erratic rainfall and long dry spells of summer months. The maximum summer temperature varies from 42^0 to 44^0, sometimes reaching to 47^0. Average winter temperature is 11^0 but often dips down to freezing point. The annual evapo-transpiration is 1887 mm and relative humidity between 50 and 60% (Rao et al, 1996). To understand the rainfall pattern of Banni, the rainfall data of last 70 years between 1932 and 2001 of Bhuj taluka have been used for analysis. Similar to the rest of Bhuj taluka, Banni region also receives extremely low rainfall with very high coefficient of variation, up to 68%, sometimes reaching up to 79% (1982-91), indicating very high variability in the rainfall pattern from year to year. More than 80% of rains come during monsoon from June to September.

Fig. 4.1: Rainfall pattern (in mm) in study areas



Based on the rainfall of Bhuj and Abdasa taluka for Banni and Naliya respectively

The long-term average rainfall (for last 70 years between 1932 and 2001) for Bhuj taluka has been calculated as 353 mm per annum. During last 70 years, 42 years (60%) received the below average rainfall (Figure 4.1), which indicates the extreme variation in distribution of rainfall both in time and space. Consequently, droughts are quite recurrent in the region. Of the total 42 below average rainfall years during last 70 years, 32 (76%) were drought years, including 16 moderate droughts (50-75% of average rainfall) and the rest 16 severe droughts (below 50% of average rainfall). Such uncertainty in the rainfall pattern and frequent occurrence of drought years, the grassland productivity of the region is severely affected. The low productivity potential of the area in such climatic conditions forces the migration of pastoral communities.

4.3.2 Flora & Fauna

The Banni region has very good potential for floral richness. Because of the diversity of grass flora, Banni is still considered as a preferred grazing land, despite reduction in the extent and quality of grassland. Several workers have explored Banni in the past for its floral diversity. There are varying records as far as number of plant species from Banni region is concerned. Pandya and Sidha (1982) recorded about 41 plant species from in and around Bhrindiyara village, including grasses, herbs, shrubs and trees. Bharara (1987) recorded 30 different species of grasses from Banni. Banni Development Agency (BDA) recorded 22 grass species, while an additional 11 plant species were recorded by ICAR (1977). Kadikar (1994) recorded a total of 25 grass species of which 12 were palatable while the rest were termed as salt tolerant grasses. More recently GUIDE (1998) listed about 23 grass species from Dhrodo experimental sites on grassland regeneration while Bhatt et al (2002) listed about 10 grass species from entire Banni region.

Some of the dominant grass species recorded from Banni includes *Sporobolus helvolus*, *S. pallidus*, *Desmostachya bipinnata*, *Dichanthium annulatum*, *Censhrus cilliaris*, and *C. setigerus*. Although at present the upper canopy is largely dominated by woody shrub *Prosopis juliflora*, but there are records of large patches of *Acacia nilotica*, *A. Senegal*, *Salvadora persica*, *S. oleoides*, *Capparis decidua*, *Tamarix indica*, *Ziziphus jujuba* and even *Azadirachta indica*. Some of the important annual halophytic species included *Suaeda fruticosa*, *Zygophyllum*, *Cressa cretica* and *Portulaca* spp.

Faunal diversity of the area is also noticeably rich. There are records of presence of blue bull, chinkara, black buck, Indian hare, wild boar, jackal, grey wolf, caracal, hyena, fox, jungle cat etc. (GUIDE 1998). In addition, Banni also supports rich diversity of avi-fauna, herpeto fauna and invertebrates. A total of 273 species of birds have been reported from Banni, which include 100 residents and 107 migratory species (Tiwari and Rahmani 1997).

4.3.3 Property Management Regimes

During princely rule, the Maharao of Kachchh declared Banni as a *Rakhal (*reserve grassland) where only milch cattle were allowed to graze, and sheep and goats were strictly prohibited. Permanent human settlements were also not allowed. However, later sheep and goats were also allowed to graze in the area but grazing was regulated by imposing fee at various rates for different categories of livestock ranging from Rs. 0.12 per annum for each sheep and goat to Rs. 2.5 for buffaloes. These grazing regulations were in force until 1957. Later, the grazing regulations slowly disappeared, and the emergence of open access regime. All kinds of livestock from every part of the state and neighbouring states gained free entry into the area. Besides resident livestock, large numbers of livestock used to immigrate for grazing during 3-4 months of monsoon (Bharara, 1987; Ferroukhi 1994).

Old records of the Revenue Department designate Banni as revenue wasteland, which was managed as grassland, mainly to meet the fodder demand of the livestock under the ownership of the Revenue Department. However, in 1955, an area of about 3847 km^2 of Banni was designated as 'Protected Forest' (PF) and brought under the purview of Indian Forest Conservation Act, (FCA) 1927. Although notification of the area as PF brought some legal restrictions on the use of natural resources of the area, since the ownership remained with the Revenue Department, these regulations could not be imposed. Realising this, in 1957 the Conservator of Forests, Junagadh made an attempt to take over the area under the administration of Gujarat State Forest Department (GSFD), but the Chief Revenue Commissioner, Rajkot rejected the demand of the ownership transfer, stating that the quality of grassland will not alter by merely changing the ownership and therefore retained the ownership with Revenue Department.

The year 1960-61 was an important benchmark year in the ecological and socio-economic history of the area when Forest Department took one of the major management interventions to stop the advancement of Rann on the northern fringes of Banni. An area of about 31550 ha was planted with exotic woody species, *Prosopis juliflora*. The species was chosen for plantation in view of its ability to establish and survive in the saline soils and low moisture regimes, without evaluating its ecological and associated socio-economic consequences in the future.

Since the formation of the Gujarat State, there have been many governmental efforts to address the socio-economic and ecological problems of Banni. The formation of Banni Development Agency (BDA) in 1966 was one of the steps taken on the basis of recommendations made by Ministry of Agriculture, Government of India. BDA was given the responsibility of ensuring the fodder demand of resident livestock population by making grass plots, protecting them and for the collection, storage and disbursement of grass during scarcity period. In addition, BDA also took up the task of construction of village ponds to meet the drinking water demand of the local livestock. A summary of various aspects of property regime, policy and programmes for Banni region is presented in Table 4.1.

Table 4.1: Policies/Programmes relevant to grassland and subsistence systems in Banni

Policy/Programme Area	**Observation**
Ownership & property rights	Absence of private ownership; Land under Forest Dept. & Revenue Dept.
Administrative initiative	Creation of BDA
Agriculture	Restrictions in doing cultivation
Biodiversity conservation	Absence of efforts to conserve the Banni as an important grassland ecosystem
Fodder development	Development of Grass Plots & Fodder Banks
Conservation of indigenous breeds of livestock	Absence of serious efforts. Even the local breed of buffalo – Kundri- is non-recognised.
Dairy development	Inadequate support
Grazing	Absence of restrictions
Livestock migration	Initially focus was to minimise the out-migration. In times of scarcity, government supports the migrating communities through initiation of various steps. No efforts to minimise in-migration.
Scarcity relief	Supply of fodder at subsidised rate. Opening of reserved forests for grazing. Opening of cattle camps.
MFP Collection	Forest Department collects minor produce like wax, honey and gum with villagers as labour force.
Charcoal Making	Controlled by GSFDC through contracting
Prosopis Control	Policy shift by Forest Department towards removal of the Prosopis
Drinking water supply	Pipelines for water supply to few villages

4.3.4 Ecological Changes

Besides free grazing, some developmental activities also accelerated the process of ecological changes in the region. The plantation of *Prosopis juliflora* is an important landmark in the ecological history of the region. The dispute between Revenue Department and Forest Department over who has the administrative control over Banni, added to the resource management problems in the absence of any grazing regulations.

Damming of some of the rivers flowing from Bhuj ridge towards Banni is also considered by many as a factor contributing to the ecological changes in the region. Prior to damming few rivers, the fresh water flow to Banni used to leach the salinity, besides enriching the soil with the nutrients suitable for grass growth in the region. However, after construction of about 6 medium dams, with a gross storage capacity of 188 MCM, the surface runoff into Banni has declined, reducing the periodic washing away of salts. From ecological point of view, all these may have had an impact on the grassland system.

4.3.5 Prosopis Invasion

The exotic mesquite, *Prosopis juliflora*, was introduced into the region to improve the ecological conditions by enhancing tree cover. The general characteristics of ecogical invasions and of mesquites over grasslands were discussed before. The invasion of Banni by P. juliflora was facilitated by two major factors: firstly, the competitive advantage over the native species and secondly, the dispersal of the seeds of the plant by the livestock. The rapid invasion by *Prosopis* resulted in the drastic reduction of the potential gazing areas, both in terms of extent and species composition. It also reduced the population of other woody and fodder species such as *Acacia nilotica, A. Senegal, Salvadora persica, S. oleoides* and *Prosopis cineraria.* Satellite studies show that between the coverage of *Prosopis juliflora* increased at an unprecedented rate of about 26.7 km^2 per year between 1980 and 1988 (Table 4.2). There is no doubt that the mesquite is invading all the grassland areas.

The saline area also increased at the rate of almost 16 km^2 per annum between 1980 and 1988. Factors such as the damming of north flowing rivers, could be a factor contributing to this. The increased level of salinity in soil has further reduced the potential grassland areas from Banni. Thus all these factors have cumulatively led to the decline in the potential grazing area in Banni grassland and increased pressure on the remaining grassland patches.

Table 4.2: Change in different land use categories in Banni region

Land use type	**Area (km^2) in 1980***	**Area (km^2) in 1988***	**Rate of change (km2/yr)**
Grassland	1010.9	767.9	-30.4
Grass+Prosopis	565.5	567.8	+0.3
Prosopis	378.9	592.8	+26.7
Other landuse	1064.4	662.4	-50.3
Saline area	827.1	955.9	+16.1
TOTAL	**3846.8**	**3846.8**	

*Source: Jadhav et al 1992

4.3.6 People's Perceptions

People's perception of ecological changes was documented through questionnaire survey in sampled villages of Banni. The questionnaire elicited responses on the extent of invasion by *Prosopis juliflora* around human settlements, perceived causes and impacts of the invasion. The responses were quantified using the scores assigned to changes in the abundance and density of grass species.

Regarding the invasion by *Prosopis juliflora*, respondents were asked to rank the invasion in terms of density around their village in 5 categories (0 – no invasion and 4 – high invasion). About 92% of respondents rated invasion 3 and above, this means high to very high invasion of *Prosopis* in terms of density (Table 4.3).

The villagers were also asked to give their opinion on the reasons of increase in the *Prosopis* invasion in Banni. The reasons were listed by the study team based on the group discussion at different places prior to initiate household surveys. The response of 385 respondents was ranked into two weight classes – low (giving score of 1 and 2) and high weight category (giving score of 3 and 4) (Table 4.4). The opinion on the plantation by forest department as one of the reasons of spread was divided among the respondents, although slightly higher percentage of people gave a lower importance to this.

Contrary to this, almost 90% of the respondents blamed it on the government, which did not make any effort to control the spread. The community was not ready to take any blame for its spread. Almost 73% rated lack of community effort as not a very significant cause for the spread, though 100% of them felt that free grazing has helped the fast spread. Restrictions on cutting and charcoal making were given a low score by the respondents. A sizeable proportion of respondents (75%) also felt that land of Banni is suitable for the growth of *Prosopis*.

Table 4.3: Perception analysis of respondents on the invasion by *Prosopis juliflora*

Average ranking	Respondents	% of respondents
2.50	5	1.3
2.75	250	6.5
3.00	74	19.2
3.25	204	53.0
3.50	52	13.5
3.75	23	6.0
4.00	2	0.5
Total	**385**	**100.0**

Table 4.4: Opinion of the villagers on the reasons of Prosopis spread in Banni

Reasons	% Respondents under different weightage category	
	Low	High
Plantation by Forest Department	57.4	42.6
No effort from government to control the spread	10.4	89.6
No effort from community to control the spread	72.7	27.3
Spread of by free grazing livestock	0.3	99.7
Restriction on cutting and charcoal making	62.9	37.1
Land of Banni is suitable or Prosopis growth	25.2	74.8

All the respondents opined that because of high rate of invasion, especially during last 5 years, the grassland has deteriorated in terms of species diversity, area coverage and species density also. Moreover, the decline in the availability of the palatable species has resulted into fodder scarcity, which in turn has affected the milk production potential of the animals. Perception analysis listed about 20 grass species, which are believed to have declined in the region (Table 4.5), both in terms of area coverage and density. Of these, about 6 species recorded higher rate of reduction (>40%), which are also considered as most palatable species for livestock.

Table 4.5: List of grass species showing reduction in Banni, as told by the respondents

Local Name	Scientific name	Frequency (%) of response
Dennai	*Dicanthium annulatum*	88.0
Sann	*Heliotropium bacciferum*	75.3
Chuchani	*Eragrostis minor*	72.5
Khevai	*Sporobolus helvolus*	54.5
Mandhanu	*Digitaria sanguinalis*	52.2
Dhrab	*Desmostachia bipinata*	45.5
Siyarpuchh	*Chloris barbata*	33.8
Sonvel	*Hylandia letebrosa*	30.6
Savani	-	30.1
Dhrabad	-	20.8
Dhraman	*Cenchrus setigerus*	20.3
Kal	*Cypreus rotendus*	20.3
Gandhir	*Paspalum crusgali*	17.9
Lamph	*Aristida hystricula*	13.8
Kurai	-	13.5
Oen	*Cressa cretica*	11.7
Dhamur	*Cyperus rotundus sub sp. dupoperate*	10.1
Khario	*Eragrostis bulbosa*	6.0
Chidya	*Melenocenchrus jequimonti*	4.9
Lular		4.9

4.4 Naliya: Typology-II

The Naliya grassland is formed by a mosaic of large patches of grasslands spread in and around the Lala Bustard Sanctuary in Abdasa Taluka (Fig. 2.2). The prominent grasslands known in the area are grassland of Vingaber, near Naliya Air Force Station and Lala Bustard Sanctuary. These different units of grassland together form a large area of about 160 km^2 of grassland, which is fragmented by other land use such as agriculture, homestead lands, built up areas and woodlands. The woodlots are grown by several government agencies such as Gujarat Energy Development Agency (GEDA) and Forest Department under Narmada Compensatory Afforestation programme. The entire grassland area shows contiguity with the coastal stretch and mudflats towards south.

4.4.1 Physio-Climatic Regime

The entire area is flat with very low elevation. The soil type in the large parts is sandy loam with mix of gravely loam. Towards the coastal area sandy mud flats are quite common. The soil texture of the inland areas is ideal for agriculture cultivation and therefore large parts in and around grasslands are under cultivation. The climate of the Abdasa taluka is not very different from the rest of the district Kachchh. The climatic uncertainty, such as rainfall, exists throughout the district and is therefore in Abdasa taluka also. The average rainfall (based on the long term average of 70 yeas between 1932 and 2001) in the area is recorded around 378 mm (Fig. 4.2). The coefficient of variation (CV) was recorded 78%, much higher than that was recorded for Banni region during the same period. The variation in the rainfall pattern is exhibited in the number of poor rainfall years in the region. Of the total 70 years, 47 years (67%) recorded below average rainfall, corroborating with the fact of high CV in the rainfall pattern. Of these, 47 below average rainfall years, 32 years (68%) were recorded drought years, recording below 75% of the average rainfall. Of these 32 years, 18 years were severe drought years (below 50% of average rainfall) while the rest 14 were moderate drought years (50-75% of average rainfall year).

4.4.2 Flora & Fauna

From floristic point of view, Naliya grassland is biodiversity rich. Vegetation survey conducted by Silori et al (2002) in and around Vingaber grasslands listed about 90 plant species under different habitat categories. Species such as *Aristida mutabilis*, *Cenchrus setigerus*, *Cymbopogon martini* and *Dichanthium annulatum* dominate the grasses. A few species, *Boerhavia* and *Cleome viscosa* and *Boreria articularis,* dominate the other herbaceous flora. *Acacia senegal*, *Acacia nilotica*, *Balanites aegyptica* dominate the upper canopy, although most of these were in recruitment category. *Zizyphus numularia* was the dominant species in the shrub category.

The Naliya grassland is home for several rare and endangered bird and animal species. Among these, the most important one is the critically endangered bird, Great Indian Bustard (*Ardeotis nigirceps*). The grasslands of Lala Bustard Sanctuary (2 km^2) and the adjoining areas offer the suitable habitats for the breeding and feeding for this species. The ecological study carried out by the GUIDE (2001) enumerated a total of about 21 birds in and around the area, which could be the maximum population of this species in this region, although there are other records, which state the number up to about 30 birds. The area is also known for largest breeding congregation of another critically endangered bird, the Lesser Florican (*Sypheotides indica*) and as an important wintering ground for Houbara Bustard (*Chlamydotis undulata*). Thus, from biodiversity point of view this is a unique area where all three species of bustards use the area for feeding and breeding. Apart from these, about 36 species of birds have also been recorded.

Among animal species, Chinkara, Nilgai, Wild boar, Indian Fox, Jackal, Indian Hare, Grey Wolf, and Small Indian Mongoose have been reported from the area. These grasslands are also home for about five species of reptiles including endangered Spiny tailed lizard. The summary of various faunal groups of Naliya grassland is presented in Table 4.6.

Table 4.6: Floral and Faunal richness of Naliya grassland			
Floral Groups	**No. of species**	**Faunal Groups**	**No. of Species**
Grass	14	Reptile	5
Herbs	46	Birds	36
Under Shrub	5	Mammals	8
Shrub	11	**Total**	**49**
Trees	8		
Twiners and climbers	6		
Total	**90**		

4.4.3 Property Management Regime

One third of the Naliya grassland has contiguous patches of grassland interspersed with agricultural fields (GUIDE 2001) and consist of three major clusters around Lala Bustard Sanctuary, Vingaber and India Air Force Station. Most of the grassland tracts are owned by major Government agencies such as the State Revenue Department, the Gujarat State Rural Development Corporation (GSRDC), Gujarat Energy Development Agency (GEDA), the Gujarat State Forest Department (GSFD) and the Gujarat Sheep and Wool Development Agency. Agencies, such as State Forest Department and GEDA have converted grasslands into woodlots as part of the Narmada Compensatory Afforestation Programme and to develop energy plantations.

Except for these woodlots, remaining grasslands are open for free grazing. Recently, there are proposals to transfer the ownership of important grassland areas to the forest department, to help in wildlife conservation. The encroachment of grasslands for agriculture cultivation or the illegal privatisation of the common land is a contentious issue. Such practices are leading to the fragmentation and habitat loss.

4.4.4 People's Perceptions

The household surveys covered 9 villages, covering 174 households. People's perception of ecological changes was recorded by encouraging respondents to assign scores indicating their assessment. The respondents were asked to rank the major grass species according to their status in terms of density for two periods – the year of study and about 15 years back in 1985. According to villagers, 8 grass species (Table 4.7) are frequently found (systematic ecological studies reported 14 grass species).

Table 4.7: Perception of local people on the changes in the abundance of major grass species		
Grass species	**Abundance (%) in 1985**	**Abundance (%) in 2000**
Cymbopogon martini (Kuyad)	24.7	32.2
Dicanthium annulatum (Dennai)	20.9	20.0
Aristida hystricula (Laanp)	18.3	15.7
Cenchrus setigerus (Dhamur)	12.1	9.7
Desmostachia bipinata(Dhrab)	14.4	14.3
Sporobolus helvolus (Khevai)	3.9	2.8
Cynodon dactylon (Chhabar)	4.2	3.7
Dactyloctenium aegypticum (Gandhir)	1.4	1.6
Local names are given in parentheses		

Villagers did not mention any significant change in the abundance level of most species, which was not different from the general perception on the overall changes in the grasslands that emerged during group discussions in the study villages. In people's perception, the abundance of many grasses such as

Dennai, Laanp and Dhamur that are good for livestock declined, while that of less preferred grass such as Kuyad increased.

In villagers view (Table 4.8), woody cover from species such as Desi baval, Khari jar, Khijado and Kerad declined drastically in the last 15 years while *Prosopis juliflora* is increasing, and appears to be slowly invading the grassland.

Table 4.8: Perception of the villagers on the change in the abundance of major woody species

Species	**Abundance (%) in 1985**	**Abundance (%) in 2000**
Desi Baval (*Acacia nilotica*)	43	4
Khari Jar (*Salvadora persica*)	5	1
Khijado (*Prosopis cineraria*)	18	3
Kerad (*Capparis decidua*)	14	9
Boradi (*Zizyphus numularia*)	19	19
Gando Baval (*Prosopis juliflora*)	1	64

As regards faunal species, villagers did not perceive did not show any fall in the abundance of species such as Chinkara (Indian Gazelle), Jackal, Caracal, GIB, Lesser Florican and Common Crane. In their view, there was an increase in the numbers of Wild Boar and Nilgai (Table 4.9).

Table 4.9: Abundance ranking of wild animals as told by the villagers

Species	**Abundance ranking in 1985**	**Abundance ranking in 2000**
Chinkara	4	4
Nilgai	1	5
Wild boar	2	5
Jackal	3	3
Hare	3	2
Wolf	2	1
Hyena	2	1
Caracal	1	1
GIB	1	1
Lesser Florican	1	1
Common Crane	5	5
Abundance ranking: 1- very low; 2- low; 3- moderate, 4- high, 5- very high		

4.5 Conclusion

The data presented in this chapter brings out the differences between two grassland typologies in ecological and socio-economic functions they play. A summary of difference in the important socio-economic and ecological parameters between two typologies is presented in the Table 4.10.

Banni, perhaps the largest common property resource in the country, has undergone significant ecological and socio-economic transformation. Some of these have been responsible for degradation of grassland resources at large scale, which eventually led to the vast changes in the resource regimes of the area. During princely time, the use of Banni grasslands was under a defined management regime by imposing certain grazing regulations on the kinds of animals and the period of grazing. With the disappearance of grazing regulations, the system was transformed into an open access. The introduction of *Prosopis juliflora* during 1960s is an important milestone in the history of Banni. The plantation of *Prosopis juliflora* eased the availability of fuel wood and opened up new economic opportunities from non-timber forest produce. The illegal making of wood charcoal has introduced certain degree of criminal activity into the pastoral community.

Table 4.10: Comparison of Banni and Naliya		
Aspect	**Banni**	**Naliya**
Land-use/ Land Cover	Grasslands, Prosopis thickets. Saline and non-saline areas without grass	Agriculture, grasslands and plantations
Ownership	Forest and Revenue Departments	GDFE, GEDA, DRDA. Sheep & goat breeding Centre; Private & Govt.
Main occupation	Livestock Rearing NTFP based economy, Handicraft	Agriculture; Livestock rearing; wage labour in coastal fishing and salt pans
Major socio-economic changes	Increased expenditure on fodder purchase; Change in livestock composition; Abandonment of some villages; Increased dependency on subsidised Govt. programmes during scarcity	Expansion of Agriculture area, over withdrawal of ground water for agriculture
Important Historical Benchmarks	Princely Rule (before 1947); Plantation of Prosopis (around 1960); Damming of North-flowing rivers (around 1960); Rapid spread of Prosopis; Wood charcoal from Prosopis for the market	Princely Rule (before 1947); Creation of Protected Area (around 1988)
Major ecological changes	Grassland area shrinkage; Grassland quality decline; Invasion of Prosopis. Complete loss of Babul forest; Salinity ingress; Reduced surface run-off and base flow due to damming of rivers.	Tree Plantations; Conversion of grasslands to agriculture; Grassland deterioration; Spread of Prosopis

The local people's perceptions on ecological changes in Naliya supports the apprehension that even in Naliya, *Prosopis juliflora* is slowly spreading. There is also a certain amount of man-animal conflict situation in the region because of the increase in the numbers of wild boars and blue bulls. The area continues to be an important wildlife refuge and appear to support a fairly large numbers of different rare and endangered biodiversity. The promotion of woodlots on grassland is clearly inconsistent with the goals of biodiversity conservation in the area. There is clearly a need for review of the policies, which are without doubt run counter to the biodiversity conservation needs. What is of particular concern is that such activities are promoted by SFD - the very agency, which is expected to play the lead role in wildlife conservation. A summary of major natural resource concerns in the two typologies is presented in Table 4.11.

Table 4.11: Summary of important natural resources and associated issues in two grassland typologies		
Resource	**Banni**	**Naliya**
Soil	High Salinity; Low permeability; Poor Organic matter; Poor soil-moisture regime	Poor soil-moisture regime
Water	Highly saline ground-water at low depth; Little scope of surface water management/ harvest	Over-withdrawal of ground water for Agriculture Inadequate surface water harvesting
Vegetation	High rate of invasion of *Prosopis juliflora;* Reduction in the area of grassland; Decline in grass and other woody species diversity	Dominance of unpalatable grass species; Plantation of some grassland areas with woody trees; Encroachments of grasslands for agriculture
Wild Animals	Loss of habitats of many species	Habitat of highly endangered species (GIB, Lesser Florican, Chinkara); Inadequate area under PA (Lala Bustard Sanctuary – 2 km^2)

It is also evident that the wildlife depends mostly on the grasslands and agricultural fields outside the meagre wildlife preserve (Lala Bustard Sanctuary) and no conservation programme will be successful without active community participation. The critical period for biodiversity conservation is the few months of monsoon in a good rainfall year. And conservation effort will have to be based on active monitoring of the habitat needs of the wildlife during that period and the cooperation of herders to minimise disturbance to areas used by wildlife.

5 Pastoralism: Emerging Trends

Often, discussions on pastoralism tend to be strongly influenced the experiences from Africa and Middle East. The cultural, socio-economic, and even ecological framework of pastoralism in India is quite different, to the extent that categories commonly applied elsewhere are either inappropriate or inadequate (Köhler-Rollefson, 1992). Many regard pastoralism in India more appropriately as an occupational specialisation that represents one of the many economic activities pursued within the village context, at par with farming or trading. In many cases, pastoral castes do not only own livestock, but also look after and pasture the animals belonging to other village members, acting as hired herders.

This chapter is concerned with the pastoral aspects of the socio-economic life in the two typologies: Banni and Naliya. However, the term pastoral is not to be confused with the meanings attached to it in contexts such as that prevail in Africa or Middle East. The discussion for each typology includes a general overview of the demographic and socio-economic parameters associated with the pastoral mode and also specific in-depth details on these parameters derived from the household surveys conducted in the two study regions.

5.1 Banni

5.1.1 Socio-Cultural Background

The people of Banni are traditionally pastoralists, known as Maldharis or Baniyaras, and are famous as keepers and breeders of buffaloes, cattle, sheep, goats, camels and horses since ages. They have made significant contributions to the economy of the region for a long time by producing milk, ghee, meat, wool etc. However, the breeding of sheep, goats, camels and horses is no longer a major practice. Milk production has become the major economic activity now.

The people of Banni belong to three major communities: Muslims, Hindu and Vadha. Among Muslims there are about 18 sub-sects such as Sangar, Haleputra, Raiseputra, Jatt, Sumara, Mutva, Node, Pathan, Hingorja, Bambha, Kurar, Juneja, Bhatti, Khatirs, Sheikh, and Saiyad. These sub sects are largely Sindhi-Muslim and follow Islam with variations at the sub sect level in terms of attire, occupational pattern and socio-cultural rituals and beliefs. For example, Raisepotra are known as excellent cattle breeders by occupation while Khatri Muslims, believed to be migrants from Sindh, work as dyers, carpenters, while their women folk are well known for embroidery work. Among Hindus, Lohana and Meghwals are the main social groups. Meghwals are Harijans (scheduled castes), mainly involved in leather tanning and shoe-making while Lohana are largely engaged in the trade and commerce. Vadhas, the third major social group, also known as Meols, Mevlas or Mes, on the other hand are considered peculiar in the sense that they do not follow either Islam or Hinduism strictly, although their customs and traditions are found to be closer to Islam.

5.1.2 Demography

The village surveys of this study were conducted between September and December 2000, well before the decennial census operations began and the demographic data used in this work are of the Census 1991. Moreover, due to devastation caused by the earthquake of 26 January 2001, Census 2001 was not completed in Kachchh District. According to 1991 census, Banni region has 17 *Juth* (group) *Gram*

Panchayats (Table 5.1). Under these 17 *Juth Panchayats* there are 51 villages (Annexure V). The total population of these 51 villages is around 10,949. The average family size is around 4.5, while the sex ratio is 93(F):100(M). Most of the population (65%) is concentrated in five *Juth Panchayats* viz., Bhitara Mota, Hodka, Bhrindiyara, Gorewali and Luna. The largest *Juth panchayat* – Hodka, with 12 villages within its administration, has a population of 2,297 while the Udhmo has the lowest with only 71 persons. Kharod *Panchayat* is uninhabited. The villages of Banni are traditionally known as '*Jheels*' (lakes) or *Wandhay*, because in olden days Maldharis used to make their hutments around natural depressed water collection areas where rainwater accumulate.

Table 5.1: Population of Banni (1991 Census)

#	Juth Panchayat	Area* (ha)	Households	Male	Female	Population
1	Bhitara	9121.7	184	388	344	732
2	Udhmo	984.2	15	38	33	71
3	Luna	18968.7	198	520	476	996
4	Mithdi	9008.6	116	243	211	454
5	Bhagadio	11754.9	50	191	154	345
6	Gorewali	5238.6	296	768	613	1381
7	Shervo	2284.1	38	87	83	170
8	Bhirandiyara	16609.9	327	878	863	1741
9	Hodka	12680.4	561	1163	1134	2297
10	Bhojardo	22940.4	145	307	302	609
11	Misariyado	3637.3	102	223	219	442
12	Daddhar Nani	2693.9	95	230	223	453
13	Daddhar Moti	3102.5	63	149	147	296
14	Dedhiya	2290.0	38	88	102	190
15	Raiyado	3332.5	101	214	211	425
16	Bardo	20918.8	90	186	161	347
17	Kharod	7870.7	0	0	0	0
	Total	**153,437.3**	**2,419**	**5,673**	**5,276**	**10,949**

**Area excludes parts in Rann of Kachchh*

Of the total population, about 19.4% were in the age group of 0-6 years. The literacy rate in the region for the eligible population (above 6 years) was 16.6%, which is very low as compared to the literacy rate for the whole of the district (52.8%). Of the total eligible males, about 26.5% were literate against 64.3% for the district, while among females this percentage was 5.6 as against the district average of 40.9%.

Between 1961 and 1991, the population of Banni region increased by about 23%, which is much less than that recorded for the district Kachchh (81.2%) during the same period. The decadal growth showed successive increase except during last decade between 1981 and 1991. Between 1971 and 1981 the growth in the population has been quite significant while in the following decade, the population declined by about 24% (Table 5.2). The decline in the population between 1981 and 1991 was possibly due to out migration of the people from the area in search of livelihood after three consecutive drought years between 1985 and 1987.

Table 5.2: Demographic Trends in Banni

Year	Population	% Growth
1961	8,885	-
1971	9,540	+7
1981	14,494	+52
1991	10,949	-24

Source: District census handbooks

5.1.3 Demography of the Villages Surveyed

For an in depth understanding of the demographic and socio-economic patterns, we sampled a total of 387 households, representing the whole of Banni. The demographic summary of these households is presented in Table 5.3. The mean age of the respondent was found to be about 39.4 yrs; while about 15% respondent were over 50 years of age. The average family size is 6.7. The average sex ratio was 89 females for every 100 males. The literacy rate of the sample population works out to be 10%, though it was higher in some villages such as Mithdi and Panawadi. Women's literacy is abysmally low at 3% in the sampled households and most of the literate women belong to two villages.

Table 5.3: Demographic details of the sampled villages based on household survey

Village	Total Popu. (1991)	No. of Sample House-holds	Mean Age of Respo-ndent	Avg. Family Size	Sex Ratio (Females per 100 Males)	% Literacy		
						Overall	Male	Female
Hodako	634	96	41.6	7.1	88	15.3	28.3	0.6
Bhojardo[9]	635	51	37.9	5.8	79	1.7	3.0	0.0
Mithidi	454	50	36.9	6.2	86	20.6	29.3	10.4
Daddar Nani	453	43	37.8	7.6	106	9.9	20.4	0.0
Thikariyado	167	42	38.5	5.1	95	8.0	15.6	0.0
Bhitara Mota	140	32	43.9	8.0	80	9.6	17.3	0.0
Dedhia Nani	190	27	41.0	5.3	103	3.4	5.6	1.4
Panwadi	102	14	36.7	9.5	77	46.6	61.3	27.6
Burkul	114	11	41.2	8.6	111	0.0	0.0	0.0
Madan	119	9	39.7	8.8	97	11.9	23.3	0.0
Dedia Mota	10	9	37.0	5.2	68	4.3	7.1	0.0
Udai	15	3	33.0	11.3	100	0.0	0.0	0.0
Total	**3033**	**387**	**39.4**	**6.7**	**89**	**10.1**	**16.3**	**3.1**

5.1.4 Livestock Sector

The State Animal Husbandry Department conducts livestock census approximately every five years. According to 1997 livestock census, total population of Banni was 30214 animals (Table 5.4) (Dept. of Animal Husbandry, 2000). Buffaloes contributed maximum to the total population (70%), followed by 18% cattle and about 11% sheep and goats together. Camels, horses, mules and donkeys were other major animals. About 43% of the total livestock is in three *Juth Panchayats*, viz., Misriyado, Bardo and Bhojardo. In terms of Adult Cattle Units[10] (ACU), the total livestock is equivalent to around 35,888 ACU, excluding horses, mules and donkeys. Average livestock holding per family comes to around 12 animals (numbers).

Table 5.4: Livestock population of Banni according to 1997 census

Village Panchayat	Cattle	Buffalo	Goat	Sheep	Camel	Horses	Mules & donkeys	Total*
Luna	170	1880	45	10	15	13	12	2145
Bhitara Mota	0	228	20	9	0	0	9	266
Bhagadio	86	1540	50	0	0	0	0	1676
Mithdi	190	281	0	0	0	0	12	483
Udhmo	1	186	6	7	2	0	12	214
Shervo	50	1530	0	0	0	0	0	1580

[9] The Zarmariwandh is included in Bhojardo as a distant hamlet.

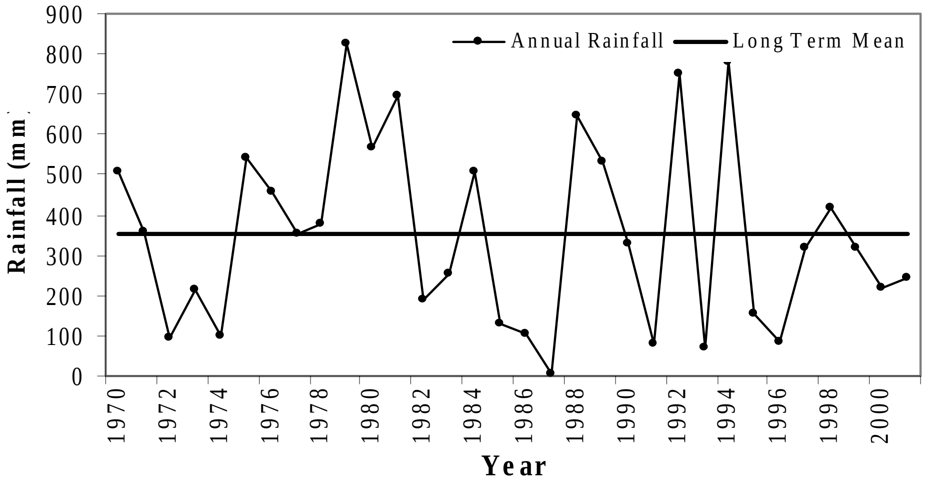
[10] Adult Cattle Unit (ACU): Numbers of different types of livestock are converted into a uniform number – ACU, based on the biomass requirement, which is determined on the basis of body weight of animal. The conversion units are: One Adult Cattle = One ACU; One buffalo = 1.4 ACU; One sheep or goat = 0.25 ACU, One Camel = 1.4 ACU.

Table 5.4: Livestock population of Banni according to 1997 census								
Village Panchayat	**Cattle**	**Buffalo**	**Goat**	**Sheep**	**Camel**	**Horses**	**Mules & donkeys**	**Total***
Gorewali	25	966	111	856	0	0	0	1958
Daddhar Moti	713	1463	119	39	2	11	0	2347
Daddhar Nani	127	786	64	379	0	24	0	1380
Hodka	150	1750	0	0	0	0	0	2000
Dedhiya	121	1076	29	41	0	32	0	1299
Bhirandiyara	21	400	22	7	7	4	2	463
Misariyado	3057	653	186	269	0	29	0	4194
Bhojardo	391	2194	123	37	4	79	42	2870
Kharod	39	355	0	0	0	0	0	394
Bardo	200	5044	537	225	0	0	0	6006
Raiyada	187	736	0	0	0	16	0	939
Total	**5528**	**21068**	**1412**	**1879**	**30**	**208**	**89**	**30214**
** Excludes population of other livestock such as dogs, pigs and rabbits*								

The changes in the livestock composition provide a better understanding of the macro-level pattern of livestock rearing in the region. For example, though the overall growth was about 17 percent between 1977 and 1997, the current population is far less than that in 1982 (Table 5.5), reflecting the cyclical peaks, characteristics of highly arid regions. These demographic fluctuations are caused largely by extreme variations in the rainfall.

Table 5.5: Livestock Census in Banni						
Year	**Cattle**	**Buffalo**	**Sheep**	**Goat**	**Others**	**Total**
1957	24000		11000		NA	35000
1977	6295	8769	5173	4379	919	25535
1982	9625	22174	12555	3957	1125	49436
1988	6461	13119	2522	2352	302	24756
1992	6058	16774	1399	1006	808	26045
1997	5489	20713	1879	1412	327	29820
% (1997)	18.4	69.5	6.3	4.7	1.1	100.0

Fig. 5.1: Rainfall Pattern of Banni



The effect of rainfall in controlling the livestock population in arid pastoral regions is well documented. In the present case, inventory of 1977 could be considered as benchmark population. Three consecutive droughts between 1972 and 1974 had led to large decline in the livestock population. Between 1977 and 1982, the rainfall was above the long-term annual average of about 353 mm (Fig. 5.1), resulting in a near doubling of the livestock. However, owing to three consecutive droughts in the following years between 1985 and 1987, the livestock population was reduced to half of the 1982 population. Interestingly, livestock population started recovering in the years after 1987, but the growth was not very rapid. This could probably be due to the high variability in the rainfall pattern. The 3-year moving average of rainfall, clearly show that good rainfall conditions prevailed between 1977 and 1984, which was followed successive dry years till 1989. The fluctuation in the livestock population clearly follows the rainfall pattern with high level of mortality during the drought years[11].

Herd Structure

Another significant feature is the change in livestock composition with a pronounced increase in the number of buffaloes and a decline in the population of cattle, sheep and goats (Table 5.6). Among the small ruminants, the decline in population of sheep is very striking. A broad conclusion that can be drawn from these shifts is that at present milk production has emerged as the major economic activity and this change in livestock composition may have its ramifications on the nomadism of these herders.

Table 5.6: Changing livestock species ratios in Banni

Year	*Cattle : Buffalo : Goat & Sheep*
1977	72 : 100 : 109
1982	43 : 100 : 74
1988	49 : 100 : 37
1992	36 : 100 : 14
1997	27 : 100 : 16

The 5-yearly census data reflects the overall response of the livestock owners of the Banni in maintaining the numbers and species composition. The analysis of household survey revealed that out of total 5,338 livestock, about 80% were buffalos, while the representation of cattle and sheep/goats was only about 6% and 14%, respectively. In addition, total number of herds[12] and mean herd size indicated that about 77% households possess buffaloes with a mean herd size of about 15 animals. However, these values are much less in case of cattle and sheep/goat (Table 5.7). These are consistent with the trend towards an increased role for buffaloes in the livestock sector for milk production.

Table 5.7: Herds (N = 387) and herd size for different livestock species in Banni (1999)

Herd Size	**Cattle***		**Buffalo***		**Sheep & Goat**	
	No. of Herds	**Mean Herd Size**	**No. of Herds**	**Mean Herd Size**	**No. of Herds**	**Mean Herd Size**
1 to 5	42	2.7	92	3.1	59	2.7
6 to 10	10	7.6	67	8.1	11	7.6
11 to 25	8	16.9	89	16.9	7	16.1
26 to 50	2	34.5	39	37.1	4	45.0
51 to 100	0	0.0	7	75.3	4	85.0
> 100	0	0.0	2	127.5	1	150.0
Overall	**62 (16.0)**	**6.4**	**296 (76.5)**	**15.4**	**86 (22.2)**	**11.9**

* Cattle and Buffalo include both the adult and young stocks
Value in parenthesis is the percentage of total herds.

[11] The data on the livestock mortality, especially during the poor rainfall years is not available to substantiate the facts.

[12] In the data, each household with different livestock species is considered as a separate herd. Therefore, number of herds is equivalent to the number of households. All the herd related analysis was done on the 1999 data.

Based on the composition of livestock, the households were grouped into six types (Table 5.8). It can be seen that only 15.6% households keep mixed livestock herds. Obviously, buffaloes are represented in three groups. About 14.2% of households were not herders.

Table 5.8: Livestock group types in Banni

Herd Type	No. of Herds	% of Total
Cattle	19	4.9
Buffalo	236	61.0
Cattle + Buffalo	42	10.9
Buffalo + Sheep & Goat	18	4.7
Sheep & Goat	17	4.4
Without Livestock	55	14.2
Total	**387**	**100.0**

Stock Balance

In a particular year, the livestock balance in the region is the sum of the stock of previous year, additions (new born and purchases) and outflows (death and sale). We looked at the livestock balance with opening and closing balances for the year 1999 and 2000, respectively, for each household (Table 5.9). This discussion seeks to provide some indicative values and not definite values. The first point to note is that there is an overall decline in the stock of animals during the survey period, mainly due to large number of deaths caused by drought conditions[13]. The losses in buffaloes herds was much less (6.5%) compared to that for cattle (25%). Small ruminants also had high turnover.

Table 5.9: Balance Sheet of Livestock Population in Banni

Animal Type	Opening Balance (1999)*	1999-2000				Closing Balance (2000)	% of Opening Balance
		Deduction		Addition			
		Death	Sale	New Born	Purchase		
Cattle	394	161	32	58	37	296	75.1
Buffalo	4562	886	196	760	25	4265	93.5
Sheep	669	225	66	83	11	472	70.6
Goat	327	76	44	41	13	261	79.8
Overall	**5952**	**1348**	**338**	**942**	**86**	**5294**	**88.9**
* Numbers include both adult and young ones.							

Considering the importance of buffaloes and cattle in the socio-economic system, further disaggregated analyses were done to understand the roles of these animals and the overall understanding of pastoralism in Banni. One of the most important issues in the traditional pastoralism is the effect of herd size on the overall dynamics in terms of the number of animals. In order to assess the dynamics of the buffalo and cattle herds, all the herds were sub-divided into smaller groups – five for the buffaloes and three for cattle- based on their opening herd stock. The balance sheet for the all the groups of buffalo and cattle is presented in Table 5.10.

The results show that the spread of mean herd sizes across the groups are large enough suggesting that the effect of herd size, if any, should be apparent. The effects of herd size were evaluated in terms of 'turnover' and also in terms of behaviour of individual additive and deductive parameters of turnovers. Stock turnover were also analysed at three different levels: the entire herd and, adult and young animals separately. The overall decline in the stock of animals is in conformity with the trends seen in the quinquennial livestock census. In a sense, the stock turnovers appear to be the ebb of the population cycle. These trends are characteristic of pastoral systems in arid/semi-arid zones.

[13] In general (or normal years), birth rate should be more than the mortality rate. However, the sample data does not reflect a normal condition but a representative of regular phenomenon of drought, and as a result, the animal mortality is very high.

Table 5.10: Balance sheet of buffalo and cattle herds across herd size classes										
Parameters	**Buffalo Herd Size**						**Cattle Herd Size**			
	1-5	**6-10**	**11-15**	**16-25**	**>25**	**All**	**1-2**	**3-6**	**7-39**	**All**
Total Herds	92	67	40	49	48	296	23	22	17	62
Mean Herd Size	3.1	8.1	12.8	20.3	46.5	15.4	1.61	4.32	15.41	6.35
Opening Stock	286	542	511	993	2230	4562	37	95	262	394
Adult	208	390	384	750	1741	3473	30	73	191	294
Young	78	152	127	243	489	1089	7	22	71	100
Birth	67	107	96	174	316	760	9	21	28	58
Death	73	148	111	195	359	886	14	34	113	161
Adult	50	104	77	110	241	582	12	24	85	121
Young	23	44	34	85	118	304	2	10	28	40
Purchase	5	3	8	4	5	25	1	0	36[14]	37
Adult	5	3	8	2	3	21	1	0	6	7
Young	0	0	0	2	2	4	0	0	30	30
Sale	21	32	32	39	72	196	0	8	24	32
Adult	18	29	28	35	72	182	0	5	0	5
Young	3	3	4	4	0	14	0	3	24	27
Closing Stock	264	472	472	937	2120	4265	33	74	189	296
% Total Stock Turnover	-7.7	-12.9	-7.6	-5.6	-4.9	-6.5	-10.8	-22.1	-27.9	-24.9
% Adult Stock Turnover	-30.3	-33.3	-25.3	-19.1	-17.8	-21.4	-36.7	-39.7	-41.4	-40.5
% Young Stock Turnover	-32.3	-30.9	-29.9	-35.8	-23.7	-28.8	-28.6	-59.1	-31.0	-37.0

For both the species, the loss of animals in terms of absolute numbers increase with the increase in herd size. However, in relative terms, the stock turnover showed opposite tendencies in the two livestock types. In case of buffalo, the relative turnover values show a decreasing trend with the increasing herd size, while the opposite trend could be seen for the cattle (Table 5.10). In terms of absolute numbers, buffalo had higher decline than the cattle. This is obvious since buffaloes are significantly more in proportion than the cattle. However, in relative terms, the cattle had higher negative turnover (about 25%) than the buffaloes (6.5%). The high percentage of cattle death (about 41%) is the most crucial factor contributing to their high negative turnover. This is, however, in contrast with the general perception that the local breed of cattle is better adapted to extreme climatic conditions. It appears that buffaloes, which are also a local breed and adapted to the area, attract good maintenance by the owners due to their higher economic values.

Within the species, the relative turnover rates were different for adult and young stocks. In case of buffalo, there was comparatively higher negative turnover for young animals (28.8%) than the adult ones (21.4%)[15]. However, in case of cattle, the adult stocks had higher negative turnover (40.5%) than the young stocks (37%). This differential behaviour can be explained by and related to the economic values of different animal types. The animal sale data clearly indicates that more adult buffaloes and young cattle were sold from the region. Since, the young buffaloes and adult cattle are associated with poor market value, their maintenance may be ignored by the owners, making them more vulnerable to the harsh conditions and resulting into higher turnovers.

Among the different age groups of buffalo stocks, the relative proportion of deaths was higher among the young (27.9%) than the adults (16.8%). The sale of adult buffaloes was four times more (5.2%) than of the young (1.3%). The proportion of sale, death and birth in buffalo declined with the increase

[14] In the case of cattle purchase and sale, only one or two families reported the major transactions. In fact, these families reported that they are the traders of the cattle, especially the young cattle. They collect these animals from different Maldhari families (even outside of Banni) and sell them later. During the questionnaire survey, however, they reported these animals as their own.

[15] In turnover estimations of adult and young stocks, only three parameters were used- the death, the sale and the purchase. The new born animals were included in the overall turnover estimation.

in the herd size (Table 5.11). In case of cattle, however, the proportion of death was almost equal among the adult and young. The sale of young cattle was relatively more than that of adults.

The above findings indicate that in the two species, the effects of herd size vary. While, in case of buffalo, it does not support the general perception that turnovers will increase with the larger herd size. Rather, it tries to point out that the smaller herds of buffalo are more dynamic than the larger herds. However, among the cattle, the larger herds are more dynamic than the smaller ones.

Table 5.11: Response of different herds parameters (%) across herd size

Parameters*	Buffalo Herd Size						Cattle Herd Size			
	1-5	6-10	11-15	16-25	>25	All	1-2	3-6	7-39	All
Birth	32.2	27.4	25.0	23.2	18.2	21.9	30.0	28.8	14.7	19.7
Adult Death	24.0	26.7	20.1	14.7	13.8	16.8	40.0	32.9	44.5	41.2
Adult Sale	8.7	7.4	7.3	4.7	4.1	5.2	0.0	6.8	0.0	1.7
Young Death	29.5	28.9	26.8	35.0	24.1	27.9	28.6	45.5	39.4	40.0
Young Sale	3.8	2.0	3.1	1.6	0.0	1.3	0.0	13.6	33.8	27.0

***** Parameters like birth, adult death and adult sale are estimated as a percentage of the adult animals; The deaths and sales of young ones are estimated as the % of total young. Purchase of new animals are not presented due to their insignificant numbers

The offtake, as discussed before, is an important characteristic of pastoralism. However, animal sales data reported in the survey is rather low[16], but in excess of purchase. In percentage terms, the lowest off take was in the case of Buffalo (4.3%) followed by Cattle (7.8%), Goat (9.9%) and Sheep (13.5%). The analysis also revealed that the pattern of sale varied in adult and young animals of different species. Table 5.12 provides the frequency of sales of different livestock types. In case of cattle about 12% owners of young animals reported sale, while it was about 25% in the case adult buffalo. The animal sale was mainly in young cattle and adult buffaloes.

Table 5.12: Frequency of livestock sale

Animal Type	Families	Reported Sale	%
Adult Cattle	61	1	1.6
Young Cattle	34	4	11.8
Adult Buffalo	293	74	25.3
Young Buffalo	227	5	2.2
Goat	76	8	10.5
Sheep	31	7	22.5

5.1.5 Migration – The Drought Coping Strategy

Nomadic and transhumant pastoralism is considered by many as an efficient form of land use for arid and semi-arid lands, where crop production is very risky due to high climatic variability (Kilby 1993, Scoones 1995). In economic terms, such migrations are supposed to be an effective tool to reduce risks. Maldharis of Banni, too, are known for their seasonal migration to different parts of Kachchh and, in very severe drought conditions, they resort to long distance migration to different parts of the State. There are many traditional routes of migration for herds belonging to different villages or different community groups. One of the traditional routes of migration is the Banni-Haji Pir-Lakhapat- Naliya- Mandvi- Mundra.

Other than migration, the Banni herders resort to other means to minimise the losses in their stock assets (Table 5.13). One major strategy is to remain dependent on the government run cattle-camps, where fodder is provided at subsidised rates; while some also work in the state sponsored scarcity relief works. Thus the government run programmes play a great role as drought coping strategy for

[16] The low offtake reported during the period of this survey was possibly due to the drought like conditions.

the Maldharis of Banni in particular and for majority of the livestock owners and landless labourers in the whole of the district Kachchh. Few families also resorted to the loans and sale of livestock assets to counter the adverse climatic conditions.

Table 5.13: Pastoralists' strategies against drought (n=387)		
Strategies	**n**	**%**
Selling of Livestock	48	12.40
Sending of livestock to Panjrapols	0	0.00
Sending of livestock to Cattle Camps	207	53.49
Sale of Ornaments	11	2.84
Taking loan	70	18.09
Migrated for longer duration	47	12.14
Worked in Scarcity Relief Programs	169	43.67

Although, the present study did not focus on the issues of migration amongst the pastoralists of Banni, yet it did bring out many interesting facts. It is important to mention here that the 'migration' in the present context has included mainly the long distance movement (generally out of Kachchh). During the survey, out of total 332 livestock owning families, 149 families (i.e. about 45%) reported migration with livestock as a drought coping measure. The number of non-migrating families in the recent past (before five years) has been increasing (Table 5.14). This too indicates that there may be a slow process of sedentarization among the otherwise nomadic Banni pastoralists.

Table 5.14: Frequency of migration across time		
Last Migration	**No. of Families**	**%**
20 Yrs Back	2	1.3
15 Yrs Back	3	2.0
10 Yrs Back	6	4.0
5 Yrs. Back	32	21.5
Migrated Recently (after 1995)	106	71.1
Total	**149**	**100.0**

Although, a detailed study is needed to examine the veracity of this, the following factors may possibly explain this pattern: (a) Of late, the state government has made serious efforts in providing two basic needs for livestock: water and fodder supply, through pipelines and cattle camps respectively, reducing the risks to a certain level (b) Availability of other alternative economic activities, labour in the scarcity relief work, on nearby industrial units or, more commonly, the economic earnings from *Prosopis juliflora*[17]; (c) Socio-political and land-use changes in the traditional migration routes, causing tension between the migratory Maldharis and the local people. Another factor could be the changing livestock herd composition in favour of buffalo, which is not as sturdy as cattle to cope with long distance migrations. This is further substantiated by evidence that the families with buffalo herds resorted less to migration than the families with cattle herds (Table 5.15).

Table 5.15: Migration pattern across herd types in Banni			
Herd Type	**Families**	**Migratory Families**	**%**
Cattle	19	10	52.6
Buffalo	236	105	44.5
Cattle + Buffalo	42	24	57.1
Buffalo+Sheep/ Goat	18	8	44.4
Sheep & Goat	17	2	11.8
Overall	**332**	**149**	**44.9**

Furthermore, it is generally hypothesised that one of the important determinant of migration is the size of the livestock herd. This study provides a numerical confirmation to this hypothesis. ANOVA revealed that both in terms of ACU or absolute numbers, mean herd size is significantly higher in the

[17] The economic role of *Prosopis juliflora* will be discussed in detail in the following chapters.

migratory groups (Table 5.16). This indicates that under the resource scarcity period, especially during droughts, the smaller herds can survive with the limited available resources, while with the larger herds, which are difficult to maintain in good condition, they are forced to migrate.

Table 5.16: Migration response vis-à-vis livestock herd size			
Livestock parameter	**Mean Herd Size**		**F Value**
	Migratory (after 1999)	**Non-migratory**	
Total ACU	34.7 (31)	14.2 (99)	19.0*
Number of Buffaloes	28.2 (30)	11.7 (94)	19.7*
Cattle (in ACU)	7.4 (7)	2.6 (16)	6.9**
Value in parenthesis is the sample size. * and ** indicate p>0.001 and p>0.05, respectively.			

5.1.6 Occupations and Sub-Occupations

The survey revealed that livestock rearing is the most dominant occupation type in Banni engaging about 65% families; though only about 52% of the families confirmed this as their main occupation (Table 5.17). Labour is the second most dominant occupation type, which includes both farm labour and labour in *Prosopis juliflora* based charcoal making. Being a non-agricultural region, the farm labour opportunities in the Banni are very restricted, and therefore, major labour works are associated with the charcoal making from *Prosopis juliflora*[18]. Table also highlights that while grassland dependent livestock sector is the most dominant form of occupation, in Banni the dependency of families on *Prosopis juliflora* is also very significant as over 56% families had their occupational link with *Prosopis juliflora* (through charcoal making and labour associated with charcoal making). In addition, the *Prosopis juliflora*, unlike livestock sector, is not affected from stochastic climatic events and thus has accessibility to the larger population for the longer period. The handicrafts, especially the embroidery and leather works, are the other significant occupation category in Banni.

Table 5.17: Main and sub-occupation pattern in Banni				
Occupation Category	**Number of Families**			**% of Total 381 families**
	Main Occupation	**Sub-Occupation**	**Total**	
Livestock	198	51	249	65.4
Charcoal	34	15	49	12.9
Labour	85	80	165	43.3
Handicraft	33	7	40	10.5
Service	10	3	13	3.4
Others	21	19	40	10.5

The above discussion highlights four major occupation types in Banni: livestock rearing, charcoal making, labour and handicrafts. Interestingly, these occupations play different roles and are of varied importance to different livestock owning families (Table 5.18). All the buffalo owning groups focus on livestock rearing as their main occupation with limited diversification to other occupation types. On the contrary, about 69% of cattle owning families reported charcoal making and labour as their main occupation. Similarly, no owners of small ruminants reported the livestock rearing as their main occupation, rather about 69% families considered labour and handicraft as their main occupations. In a broader sense, thus the families without livestock herds and that of cattle or sheep/goat keeping families have almost similar occupation types.

[18] The charcoal making from *Prosopis juliflora* is an illegal activity under Forest Conservation Act, especially in the context of Banni which is legally under Protected Forest (PF) category.

Table 5.18: Frequency (%) of families with different occupations vis-à-vis herd types							
Herd Types	**n**	**Main Occupation Types**					
		Livestock	**Charcoal**	**Service**	**Labour**	**Handicraft**	**Others**
Cattle	19	21.1	21.1	0.0	47.4	5.3	5.3
Buffalo	231	64.5	7.4	2.2	13.9	7.8	4.3
Cattle+Buffalo	42	76.2	2.4	2.4	11.9	4.8	2.4
Buffalo+Sheep & Goat	18	61.1	5.6	5.6	11.1	11.1	5.6
Sheep & Goat	16	0.0	6.3	12.5	50.0	18.8	12.5
Without Livestock	52	0.0	19.2	1.9	55.8	15.4	7.7
Total	**378**	**51.9**	**9.0**	**2.6**	**22.5**	**9.0**	**5.0**

5.2 Naliya

The Naliya typology is quite different from the Banni typology in all respects. Though the pasture land in the region also has similar *de facto* status as that of Banni in terms of property regime, certain issues like the demographic pattern, socio-economic setup, income opportunities, socio-economic and ecological roles of grasslands and associated issues are quite different. The invasion by *Prosopis juliflora* is not a major problem here. Agriculture is the major economic activity.

5.2.1 Socio-Cultural Background

From socio-cultural point of view, the Naliya region is more diverse as compared to Banni region. It is composed of a mixed group of agriculturists, Maldharis, fishermen, traders and marginal labourers in agriculture, salt pans, coastal fishing, construction and few other forestry activities. There are about 13 villages distributed in and around Naliya grassland areas. The larger section of the population has agriculture as their major source of income, which is dominated by Darbar and Muslim communities. Although few other communities such as Jains, Harijans and tribals also hold agricultural land, their proportion is relatively small, both in terms of number of land holding families and per unit holding. Of late, few families of Punjabis have also settled in the area and are engaged in large scale irrigated agriculture cultivation, mainly dependent on the ground water. Animal husbandry is the second major source of income to the local residents, while some of the villagers of Jakhau and Budiya, the coastal villages, earn their livings through fishing and working as labourers in salt pans.

5.2.2 Demography

According to 1991 census, there are a total of about 2200 families with a population of around 11049 (Table 5.19). The average family size comes to around 5. Villages like, Lala, Budiya and Jakhau are dominated by Muslims, involved both in agriculture and animal husbandry (agro-pastoral communities) while Vingaber, Prajau and Jassapar are dominated by Darbar (Rajput) community, mainly involved in agriculture. Agrarian communities also dominate other villages located near Naliya Air Force station and proportion of Maldharis in these villages is low. The sex ratio in this region is around 84(F):100(M).

Table 5.19: Population (Census 1991) of the villages around Naliya grassland					
Village	**Area (ha)**	**Families**	**Males**	**Females**	**Total**
Bhachunda	2731.57	88	202	252	454
Bhanada	3035.33	716	2085	1130	3215
Budiya	1029.8	27	102	83	185
Jakhau	13014.48	664	1667	1702	3369
Jassapar	746.93	123	275	323	598
Kala talav	1019.44	89	258	244	502
Kukadau	932.47	48	124	119	243
Kunathiya	1018.59	50	133	130	263
Lala	601.62	115	388	318	706
Parjau	3269.51	42	101	101	202
Raidhanpar	126.04	51	177	144	321
Vadapaddhar	1963.96	145	363	359	722
Vingaber	1603.37	42	135	134	269
Total	**31093.11**	**2200**	**6010**	**5039**	**11049**

5.2.3 Demography of the Villages Surveyed

For detailed understanding of the latest demographic pattern and socio-cultural milieu, we sampled a total of about 174 households from 9 villages. The method of the household sampling has already been discussed in the methodology chapter. The sampled households belonged to about 14 caste and communities, majority of them being Muslim communities (42%) followed by Darbar, Hindu Rajput (22%) and 12% to the Scheduled caste (Harijan) families. About 6% of the surveyed families belonged to Koli community, a Scheduled Tribe (Table 5.20). Three families of Sikhs were also interviewed, who are newly settled in the region, as part of a government policy. Among other categories, few families of Lohana (traders), Thakur, Darji (tailor), Bava (traditionally temple priest) and Rajput were included.

Table 5.20: Major communities of the Naliya	
Community	**No. of families**
Muslim	73 (42)
Harijan	21 (12)
Darbar	39 (22)
Jain	10 (6)
Koli	11 (6)
Bhanushali	5 (3)
Sikh	3 (2)
Others	12 (7)
Total	**174**
Values in parentheses refer to the % of total	

The demographic details emerging from the survey are presented in Table 5.21. The total population of the surveyed households is around 1000, with a sex ratio of 97 females per 100 males. The average family size in all the sampled households was close to 6, with 3 villages, *viz*, Lala (8.2), Raidhanpar (6.6) and Vingaber (6.1) having higher average family size in the sampled households. Vadapaddhar had smaller size of households (4.7). Across communities the average family size was higher among Muslims (6.7) and Sikhs (6.3).

Table 5.21: Demographic details of the sampled villages						
Village	**Total families***	**No. of surveyed families**	**Total Population**	**Total Male**	**Total Female**	**Average Family size**
Budiya	47	11	58	26	32	5.3
Kukdau	63	16	85	43	42	5.3
Lala	113	26	213	116	97	8.2
Vadapaddar	154	36	170	88	82	4.7
Jasapar	56	16	83	41	42	5.2
Parjau	98	25	129	60	69	5.2
Kunathiya	58	13	71	35	36	5.5
Raidhanpar	96	17	113	58	55	6.6
Vengaber	61	14	85	44	41	6.1
Total	**746**	**174**	**1007**	**511**	**496**	**5.8**
*Based on the house listing done in year 2000						

The literacy rate in the sampled villages is extremely low. A mere 32% of the total population is literate. The literacy rate among males was around 45% while among females, it was as low as 19% (Table 5.22). Nevertheless, these are much higher to that in Banni region. Among the villages surveyed, highest literacy was in Prajau (49%) followed by Vadapaddhar (45%), while Raidhanpar was the least literate, with only 2% literacy among females. Across communities, the literacy rate was substantially high among Brahmins (82%), Jains (80%) and Bhanushali (59%). It was very low among tribals (12.5%), Muslims (20%) and Harijans - Scheduled Castes (31%).

Table 5.22: Literacy rate among sampled population				
Village	**Total Population**	**% Literacy**		
		Total	**Male**	**Female**
Budiya	58	29	38	22
Kukdau	85	32	47	17
Lala	213	24	41	4
Vadapaddar	170	45	58	32
Jasapar	83	27	37	17
Parjau	129	49	58	41
Kunathiya	71	28	43	14
Raidhanpar	113	17	31	2
Vengaber	85	28	39	17
Total	**1007**	**32**	**45**	**19**

5.2.4 Occupation Pattern

The villagers of the sampled households earn their living through a variety of occupations such as agriculture, animal husbandry and daily wage labour in the agriculture fields, construction activities and other smaller activities (Table 5.23). Agriculture sector was reported to be the main source of income for the villagers, in which about 84% families were engaged for their earnings as main occupation (56%) and sub occupation (28%). Daily wage labour in agriculture fields and other construction activities was another important income sector in which 16% families were involved primarily, while for 44% families it was a secondary source of income. Small number of families also earned their living through fishing, while animal husbandry was reported by only 6% families as main occupation and 11% families as subsidiary occupation. Other income sources include earnings through carpentry, tailoring and petty shops, which villagers do not consider a consistent source of income, though 10% of the total sampled households mentioned these activities as their primary source of income.

Table 5.23: Occupation pattern in the sampled villages		
Occupation categories	**No. of families**	
	Main occupation	**Sub occupation**
Animal Husbandry	10 (6)	9 (11)
Fishing	9 (5)	1 (1)
Agriculture	98 (56)	24 (28)
Labour	28 (16)	37 (44)
Service	11 (6)	8 (9)
Other works	18 (10)	6 (7)
Total	**174**	**85**
Values in parentheses are % of the total		

5.2.5 Land Ownership and Agriculture

Of the total 174 sampled families, 140 families (80%) were involved in agriculture. It is important to indicate here that, in the household survey, the land owned by the villagers belonged to three different types as far as ownership is concerned. Besides own land, villagers also cultivated *arjiwali* land, which is at present under cultivation but the ownership of the land has not been awarded to the cultivator and application (*arji*) for the ownership is pending with the local office of the Revenue Department[19]. The third type belonged to those landless families, who are cultivating land belonging to others under sharecropping arrangement. The number of such families was only 5. Rest of the 135 families owned 2959 acres of land or an average of nearly 22 acres per household. Based on the size of land holdings, the land holders were divided into 5 categories, as cited in Table 5.24. The proportion of the semi-medium to large land holders was higher than the lower land holding groups.

Table 5.24: Land ownership pattern across farmers' category			
Land holding categories	**No. of farmers**	**Land Holding (in Acre)**	
		Total	**Average**
Marginal farmer (1-5 acres)	11	44	4
Small farmers (6-10 acres)	28	254	9
Semi-medium farmers (11-20 acre)	36	582	16
Medium farmers (21-40 acres)	45	1274	28
Large farmers (>40 acres)	15	805	54
Total	**135**	**2959**	**22**

We also attempted to document the trends in the land ownership pattern across different types of the ownership. Interestingly, the private ownership across all categories showed significant increase (Table 5.25). This indicates that the villagers encroach upon the grassland converting them into private farm land and apply for regularization. The increase in the total own land and increase in the *arjiwali* land point towards such trends. Moreover, the area under cultivation also increased significantly as also the area under irrigation, indicating increased withdrawal of groundwater for irrigation in the absence of any surface water source.

Table 5.25: Changes in Land Holding Categories in Naliya			
Land Type	**Land Holding (in Acre)**		
	1995	**2000**	**Increase**
Total own land	1155	1934	779
Total *arjiwali* land	340	1025	685
Cultivated land	104	2313	2209
Irrigated area	0.5	407	406.5

[19] This could also be interpreted as encroached land, since the land is being used privately while the ownership remains with the government.

Of the total agriculture land, 78% was under cultivation while the rest was left uncultivated. Of the total cultivated area about 18% was irrigated by ground water, while the rest was under rain-fed agriculture. The proportion of irrigated area was substantially high in Lala, Vadapaddhar, Vingaber and Prajau villages, which together account for about 96% of the total irrigated area. All these villages are distributed around grasslands of Lala sanctuary and Vingaber grasslands, which are important areas from the biodiversity conservation point of view as mentioned in Chapter 4. The proportion of farmers with irrigation facility was substantially high among medium (49%) and large farmers (73%). Across communities, all the sampled families of Bhanushali and Sikh community owned agricultural land (Table 5.26) while the proportion of land owning families was substantially high among other communities such as Harijan, Darbar, Koli and Jain.

Table 5.26: Land ownership across different communities

Community	No. of sampled households	No. of land holding families	Total area occupied (Acre)	Average holding/ Family (Acre)
Muslim	73	49 (67)	1065	22
Harijan	21	19 (90)	361	19
Darbar	39	37 (95)	894	24
Jain	10	8 (80)	151	19
Koli	11	10 (91)	179	18
Bhanushali	5	5 (100)	182	36
Others	12	4 (33)	42	11
Sikh	3	3 (100)	85	28
Total	**174**	**135 (78)**	**2959**	**22**

Values in parentheses refer to the percentage of total sampled households

5.2.6 Livestock Sector

Animal husbandry was the second most income generating activity after agriculture among the residents of Naliya region. The 1997 livestock census enumerated a total of 12461 livestock from 13 villages, distributed in and around the Naliya grassland (Table 5.27). About 34% of the total livestock of Naliya consists of cattle, while buffaloes constitute 6%. The rest of the population is sheep (12%) and goats (48%). The livestock in the region mainly cater to the domestic needs and less to the market. During the summer season, the herders from Banni often migrate to Naliya with their livestock. Out migration is almost non-existent among the livestock owners of Naliya.

Table 5.27: Livestock population of the villages of Naliya grassland (1997)

Village	Cows	Buffalo	Sheep	Goat	Total
Bhachunda	186	4	40	558	788
Bhanada	627	384	232	546	1789
Budiya	145	17	17	111	290
Jakhau	604	52	86	401	1143
Jassapar	111	13	9	88	221
Kala talav	468	0	514	1462	2444
Kukdau	135	19	30	138	322
Kunathiya	320	0	157	404	881
Lala	646	71	97	1158	1972
Prajau	389	118	23	97	627
Raidhanpar	163	0	240	678	1081
Vadapaddhar	324	13	0	0	337
Vingaber	149	12	38	367	566
Total	**4267**	**703**	**1483**	**6008**	**12461**

Herd composition

The results presented in this section are based on the survey conducted in 174 households. Of the total sampled households, 87% owned a total of about 4371 livestock. Of the total livestock, 79% consisted of sheep and goats, followed by 17% of cattle including cows and bullocks, while buffaloes were only 4% to the total livestock population (Table 5.28). These figures of different livestock species from the sampled households are the reflections of the overall population of the entire region. It was found that of the total cows and buffaloes 56% and 36% respectively were milking at the time of household survey. Some of the goat milk is also consumed.

Table 5.28: Livestock population and composition of the sampled households

Villages	Cattle	Bull	Buffalo	Sheep	Goat	Total livestock
Budiya	49	13	3	143	76	284
Kukdau	59	23	25	91	17	215
Lala	94	33	20	1077	291	1515
Vadapaddar	83	19	56	209	183	550
Jasapar	41	16	7	48	45	157
Parjau	82	22	24	2	7	137
Kunathiya	61	19	14	96	191	381
Raidhanpar	65	23	0	481	293	862
Vingaber	45	16	4	79	126	270
Total (%)	**579 (13)**	**184 (4)**	**153 (4)**	**2226 (51)**	**1229 (28)**	**4371**

Livestock Ownership Pattern

The percentage of livestock owning families was substantially high (87%) in all the sampled villages except, Budiya village, where only 64% of the total sampled families owned livestock. The average livestock holding per family was around 29 animals per family, which is more than the double that recorded for Banni region. This is mainly due to the higher proportion of sheep and goats in total population. Across sampled villages, the average holding was higher in Lala (66), Raidhanpar (54) and Budiya (41) villages, while it was less in Prajau village (6) (Table 5.29).

Table 5.29: Livestock ownership pattern of the sampled households

Villages	Families	Livestock Owing Families	Average Livestock Holding per Family
Budiya	11	7(64)	41
Kukdau	16	15 (94)	14
Lala	26	23 (88)	66
Vadapaddar	36	30 (83)	18
Jasapar	16	12 (75)	13
Parjau	25	22 (88)	6
Kunathiya	13	12 (92)	32
Raidhanpar	17	16 (94)	54
Vingaber	14	14 (100)	19
Total	**174**	**151 (87)**	**29**

Value in parenthesis is the percentage of total families in the village

The ownership pattern across communities revealed that average holding of livestock was the highest with Muslims who owned about 79% of the total livestock followed by 14% with upper caste Darbar community and 3% by Harijans. Rest 5% of the total livestock population was owned by other communities (Table 5.30). The higher proportion of livestock among the Muslim community can be explained by the fact that Muslims in this region are the traditional livestock rearing communities who have recently been initiated to agriculture.

Table 5.30: Livestock ownership pattern across communities		
Community	**Total Livestock**	**% of Total Livestock**
Muslim	3442	78.7
Harijan	130	3.0
Darbar	608	13.9
Jain	42	1.0
Koli	30	0.7
Bhanushali	39	0.9
Sikh	27	0.6
Other	53	1.2
Total	**4371**	**100.0**

Of the total 150 livestock owning families, 46 had only cattle, while 18 had only sheep and goats. Rest owned mixed herds, but in the mixed herds, the proportion of sheep and goats was rather high (Table 5.31). Analysis of livestock ownership data across land holding categories did not reveal any definite pattern as far as average holding is concerned, though in the higher land holding group, the average livestock holding per family was higher (Table 5.32), while it was less with the landless group. However, it may be noted that across different land holding categories, the ownership of the sheep and goat was quite uniform contributing between 73 and 80% to the total population owned. Buffaloes contributed less than 3% to the total population except among medium farmers, who had about 9% buffaloes in their total livestock population.

Table 5.31: Livestock herd wise ownership pattern					
Livestock Group	**Households**	**Livestock**	**Cattle (%)**	**Buffalo (%)**	**Sheep/ Goat (%)**
Cattle	46	152	100	0	0
Cattle+buffalo	15	171	40	60	0
Cattle+sheep/goat	56	2630	10	0	90
Cattle+buffalo+sheep/goat	15	1134	9	5	86
Sheep/goat	18	97	0	0	100
Total	**150**	**4184**	**14**	**4**	**83**

Small ruminant milk production is more of a subsistence product in Naliya and not very profitable (Cincotta and Pangare, 1993), as in other areas (Ahuja and Rathore,1987) However, in many agro-pastoral systems, the small ruminants help in bringing about a net export of nitrogen from the common sources onto cropland (Powell and Williams 1992). The pattern of livestock holdings across different land ownership families suggests that the large landholders are able to maintain the large herds because of the supplement fodder available in the form of agricultural residue, apart from the fodder available from the surrounding grasslands.

Table 5.32: Livestock holding across different land holding families			
Land holding categories	**Total Families**	**Livestock Owning Families**	**Avg. Livestock Holding**
Landless	39	26	14
Marginal	11	8	26
Small	28	26	18
Semi-medium	36	33	23
Medium	45	43	36
Large	15	15	67
Total	**174**	**151**	**29**

Migration

The household survey did not reveal any history of out-migration with livestock in search of fodder. Given the size of livestock holdings and the fact that the basis of the economy is not livestock, this is not surprising. Moreover, the larger herds maintained by richer farmers are able to depend partially on the fallows and agricultural residues.

5.3 Summing Up

This chapter brings out the distinction between two typologies in terms of the demogaphic composition, socio-economic structure, cultural and pastoral practices. From socio-cultural point of view, Banni has been traditionally known for the Maldhari pastoral communities, mainly Muslims, whereas, Naliya is a diverse region with mix of several communities involved in different occupations including agriculture, livestock rearing, fishing, labour in salt pans and other kinds of labour activities. The social infrastructure is very poor in Banni. The larger porportion of buffaloes in the livestock population signifies their contribution in the milk based economy of the region. Contrary to this, the lower proportion of buffaloes and higher proportion of sheep and goat in Naliya region indicates that livestock are mainly reared for meeting the household demand of milk and milk products and the economy of the region is largely based on the agriculture, coastal fishing and labour activities in different sectors. However, the economy of the animal husbandry revolves around the grasslands, but the level of dependency and use pattern of grassland resources varies between both typologies. The scarcity of the fodder resources in Banni during drought periods force the local people to migrate with their livestock to differernt parts of the district and sometime even outside the district also. On the contrary, in case of Naliya the availability of supplemental fodder in the form of agricutlure residue from cultivated areas is able to meet the fodder needs of the rather low number of livestock during lean period.

6 Resource Economics - A Disaggregated Analysis

6.1 Background

Livestock-based economy that depends almost completely on grasslands is the second most prominent subsistence system in Kachchh. In addition to exclusively pastoral households, who occasionally migrate to cope with drought conditions, almost every agricultural household also maintains some level of livestock. These livestock are an important component of the rural economy. Milk and milk products are either sold to the local markets or used for own consumption. The milk production potential of the district was estimated at about 0.3 million litres per day in 1992. The annual coarse wool production from the district is about 5 million kg.

Central to this economic sector is the existence of large pasturelands on which livestock are able to graze freely. During drought periods the state government steps in to provide fodder and scarcity relief. The State Forest Department collects about 0.92 million kg of grass per year from *Rakhals*, which are stocked and sold to villagers only during the scarcity periods as part of the relief measures. Despite the direct enormous economic significance of the grassland, there has been very little documentation on the resource economics of this sector.

As discussed earlier, this study is concerned with the resource economics of the grassland-savannah system and not with the village pastures, which are relatively smaller common property land resource owned and controlled by the village community through its formal or informal institutions. In contrast, the large grassland-savannah systems are owned and controlled by the state government (revenue or forest department) or its agencies. Some of these are, in the strict legal sense, under well-defined property ownership and management regimes. Small part of Naliya is a protected area managed by the State Forest Department for wildlife conservation and almost the entire Banni is classified as Protected Forest under the Forest Conservation Act. Not withstanding the *de jure* status, nearly all of these grasslands are, *de facto*, open access pastures without any institutional arrangements for their management as common property resources.

The economic data analysed in this chapter has to be viewed against this backdrop, wherein the source of the major input for the livestock-based economy – fodder – is the open access grasslands. In Typology-I (Banni), the woody invasion of grassland, has given rise to an additional economic opportunity based on another renewable resource, while reducing the incomes from grass. While agriculture is non-existent in Banni, it is the mainstay of the agro-pastoral economy in Typology-II (Naliya). An exhaustive disaggregated analysis of the resource economics is attempted here using the primary data collected through surveys in the two typologies.

6.2 Banni

The main feature of Banni region is the dominance of pastoral economy, even today, and the near complete absence of agriculture. Akin to studies on agricultural systems, the first step towards disaggregating incomes on the basis of its sources is to partition the various incomes into two broad classes:

a) Livestock-Based Incomes (LBI) and
b) Non-Livestock Based Incomes (NLBI)

All the twelve major income streams recorded from the region (Table 6.1) can be assigned to these two general categories for studies focussed on the resource from which the incomes emanate. The categories such as farm and non-farm incomes are of little utility in this case. It is apparent that the major incomes streams have its origins in the two key renewable resources of the region: grassland and woody species.

Table 6.1: Major income sources in Banni	
Income Streams	**Income Class**
1. Milk Sale	***Livestock (Grassland) Based Income (LBI)***
2. Ghee Sale	
3. Animal Sale	
4. Other Livestock products (dung and wool)	
5. Charcoal	***Non-Livestock Based Income (NLBI)***
6. NTFP	
7. Labour	
8. Handicraft	
9. Upkeep of outsider's livestock[20]	
10. Agriculture[21]	
11. Remittance (Service)	
12. Other subsidiary sources (artisans, shops etc.)	

LBI includes the income from milk and milk products, sale of animals and sale of other animal products like dung and wool. NLBI consists of incomes from NTFP collection, charcoal making, as well as incomes from handicrafts, wage labour, remittances from outside, miscellaneous sources and a category "upkeep of outsider's livestock", which calls for some explanation as to why it is included in NLBI. The livestock upkeep is the earnings in the form of charges for upkeep of unproductive livestock brought into the region from outside. We have included this in NLBI to demarcate it from the incomes derived from own livestock and because the earnings are not very different from wage labour. Almost all of the NTFP in Banni – mostly gum, honey, pods, etc. – is associated with *Prosopis juliflora*.

Consultations with the local people and other persons knowledgeable about the Banni region, confirmed that with the changing resource picture along with the overall development and market linkages, there are changes in economic patterns of Maldharis (herders) through diversification in income generating activities. These observations are summarised in Table 6.2.

Table 6.2: Qualitative changes in pattern of income generation in Banni

Period	Sources of Income					
	Livestock Sale	**Ghee**	**Milk**	**Labour**	**Handicraft**	***P. juliflora* Cover**
Pre-independence	High	High	Low	Low	Low	Nil
Post independence & prior to woody invasion	High	High	Medium	Medium	Medium	Nil
Current	Medium	Low	High	High	Medium	High

6.2.1 Income Diversification

In the present study, income analysis has been done mainly on the Gross Annual Household Income[22] (GAHI) and the data set used for income analysis relates to 251 out of the 387 survey schedules, since

[20] It is described in many earlier reports that dry cattle and buffaloes from outside Banni are taken care of by people from Banni for a fee for short periods and returned to the owners. The only earning is the charges levied for the safekeeping. These free grazing animals do add to the grazing pressure. However, the earnings are more like wage labour.
[21] Agriculture in Banni is not possible due to unsuitable soil- water condition. However, a few maldharis families reported that they are engaged in share-cropping outside Banni region.
[22] The net household income was not possible to compute, as the different production costs for each production system were not available at household level.

only this sub-set had reported consistent income related data. The remaining schedules had incomplete data on many income related queries. Subject to caveats mentioned in Chapter 2 on methodology, the definition of GAHI applied to the Banni region is given below:

Milk Sale	Cash received through sale of milk as per actual prices reported by the respondent, which depends on whether it is of cow or buffalo. It also vary to a degree depending on the remoteness of the village
Ghee & Mawa Sale	Cash received through sale of ghee (made from unsold milk or cream of skimmed milk sold) and of mawa (a from of milk-cake) used in making milk-based sweets
Animal Sale	Cash realised through the sale of animals (young & adult). The sale of cows and buffalo is as milch animal; of bulls as draught animal and of goat/sheep for slaughter
Other livestock Products (dung and wool)	Cash receipts from the sale of dung and wool. Since there is no agriculture within the region, the dung is sold to agricultural farms outside; The coarse wool produced is also sold and not used within the region.
Charcoal	The income reported is the net earnings from the wood charcoal making activity
NTFP	Earnings from various non-timber forest produce such as honey, wax, gum and pod of the mesquite
Labour	All kinds of wages earnings from casual work within and in the adjoining areas
Handicrafts	Earnings reported from the home-based handicrafts, in which women's contribution is very high
Upkeep of outsider's livestock	Fees charged for keeping free grazing non-lactating livestock of non-residents
Agriculture	Incomes from all kinds of crop production mainly on farmland outside the region
Remittances	Includes all forms of money received by the household as pensions or from relatives living outside the region
Other subsidiary sources (artisans, shops etc.)	These include various forms of income generated from small enterprises, work as artisans, trade or business

The study reveals that, the mean GAHI is Rs. 68,175 with a SD of Rs 77,410 and ranges between Rs 900 and Rs. 677,800. The distribution of GAHI is positively skewed with more families in the lower income groups (Fig. 6.1).

As discussed earlier, the overall GAHI can be decomposed to several sub-components of livestock and non-livestock based income streams (Table 6.3). In terms of frequency of report at household level, the milk sale, NTFP, Charcoal, and sale of animal are the most wide spread income generating activities in Banni indicating the dependency of larger population on these sources. However, in terms of average annual income under each source and their relative contribution in the total economy of the Banni, selling of milk emerged as the major economy in the region followed by charcoal making from Prosopis juliflora. A simple analysis of the table also revealed that livestock based incomes are driving the entire economy of the Banni with about 70% share, while with about 19% share of income from *Prosopis juliflora* are crucial in supporting the economy of this drought prone region.

The last column in Table 6.3 is the income extrapolated for the whole of Banni on the basis of demographic data of 1991 census. The extrapolation is made by assuming that income streams are distributed according to survey data. We have assumed that the proportion of households according to the income source is as in column (5) and derive the total income (column 7) using the mean GAHI in column (6). This leads to the conclusion that the livestock sector contributes about Rs. 120 million, while the non-livestock sector contributes about Rs. 51 million of which nearly Rs. 29 million (57%) comes from the woody resource.

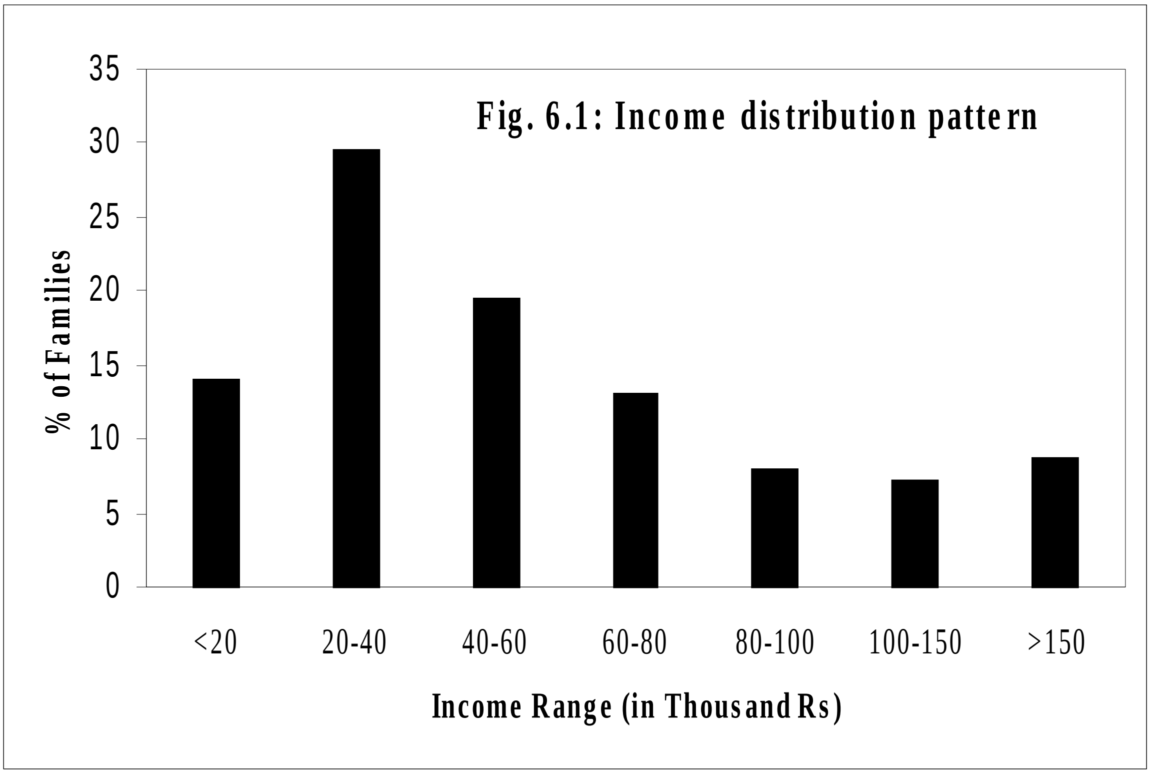


Table 6.3: Income from different sources in Banni						
Income Source	**Gross Income (Million Rs.)**	**Contribution (%) to total income**	**House-holds***	**% of total House-holds**	**Mean GAHI (Rs.)**	**Extrapolated Income for Banni (Million Rs.)**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
LBI	**12.003**	**70.1**	**210**	**83.6**	**57150**	**119.443**
Milk Sale	10.854	63.4	200	79.7	54541	108.130
Ghee & Mawa	0.115	0.7	17	6.8	6752	1.148
Animal Sale	0.888	5.2	61	24.3	14559	8.844
Other Livestock products (Dung and Wool)	0.145	0.8	74	29.5	1937	1.445
NLBI	**5.110**	**29.9**	**217**	**86.5**	**23550**	**50.928**
Charcoal	2.088	12.2	91	36.3	22946	20.824
NTFP	0.710	4.1	145	57.8	4894	7.072
Labour	0.512	3.0	37	14.7	13843	5.087
Handicraft	0.853	5.0	46	18.3	18542	8.483
Agriculture	0.070	0.4	6	2.4	11667	0.700
Service	0.321	1.9	14	5.6	22903	3.206
Other sources – artisan, business, trade, etc.	0.557	3.3	22	8.8	24545	5.569
Totals	**17.112**	**100.0**	**251**	**100.0**	**68175**	**170.438**

***** There are, in general, multiple overlapping income streams for each household and therefore the percentages in column (5) will not sum to 100

Table 6.3 shows that there are two types of income sources in Banni- the livestock based income (LBI) and non-livestock based income (NLBI) and, as noted earlier, the distribution of total income is highly skewed (Fig. 6.1). The disaggregation of households into five income classes reveals interesting patterns in the income contribution from the two sources. The richer households derive more from LBI, while the NLBI forms a major part of the incomes of the poor (Table 6.4). Alternatively, in terms of resource dependency, therefore, the poorer families have greater reliance on NLBI sources and in particular *Prosopis juliflora*, while there is substantial dependence of the richer families on the grassland based livestock sector. Undoubtedly, the assets in the form of livestock holdings are an important determinant of such differences.

Table 6.4: Gross Annual Household Income from livestock and non-livestock sources across income groups

Income Group	No. of Families	Mean (Rs.)	LBI (%)	NLBI (%)
Low (upto 25000)	50	15343	39.6	60.4
Lower Middle (25001-50000)	86	36125	55.1	44.9
Middle (50001-75000)	50	61348	57.1	42.9
Upper Middle (75001-100000)	25	85879	71.6	28.4
High (above 100000)	40	200503	83.5	16.5

6.2.2 Milk Based Income

A wide range of factors determines the MBI, the most dominant component of LBI. The potential of the breed, that is genetically governed, is modified primarily by the state of nutritional support. Stress factors such as work and diseases reduce the milk yields. Supplementary nutrition may increase milk production. The total milk production from same unit of animals varies from one household to another, reflecting the variations in maintenance inputs.

As expected, for all the animal types we recorded a positive relationship between total LBI and the herd size. The data on milk output per ACU show that although there is enormous scatter spanning a very large range, the mean output in each herd size class tends to fall as the herd size increases. In order to analyse the pattern of LBI per livestock unit, we grouped the buffalo herds into 15 size classes and computed the mean MBI in each herd size class. It is evident that larger the herd size, lower the average MBI per ACU (Table 6.5).

Table 6.5: The variation in mean milk-based income (MBI) across different mean buffalo herd size

Mean Herd Size (ACU)	Mean MBI (Rs.)	MBI per ACU (Rs.)	CV (%) of MBI per ACU
2.5	14682	6015	51
4.0	16274	4215	80
6.5	31716	5002	41
9.0	26659	2951	65
11.1	27326	2470	54
13.2	19990	1496	69
15.1	31223	2057	72
18.0	44160	2440	116
19.5	30083	1545	66
22.7	51625	2294	59
25.5	32366	1271	54
28.9	44400	1543	53
34.1	87784	2608	80
48.7	87595	1770	54
90.5	259800	2871	75

Above table also highlights the large variation in the annual MBI per ACU both within and among different groups. The major factor controlling this variation could be the differences in the maintenance effort and input per household. The relationship was modelled using a simple power function i.e. $y = ax^b$, where $a > 0$ and $b < 0$. The regression equation for MBI per ACU (Y) as a function of herd size (X) is:

$$Y(X) = aX^b$$

For the data subset for the buffalo herds, the estimated parameters are: a = 5762.4 and b = -0.3103 with correlation coefficient, $R^2 = 0.4039$. The plots of the data and regression equation are given in Fig. 6.2. The property of curve draws many other interesting points about the pastoral system of Banni.

The curve highlights the crucial part of herd size in the milk production system. By adding a small number of buffalo into already a large herd (effectively low percentage increase) makes a little difference in milk production per ACU; however, addition of even a few animals into a small herd (effectively high percentage increase), significantly reduced the per buffalo milk production (Table 6.6). It is important to mention here that in the Banni, where the purchase of new animals is quite low, increase in herd size is mainly controlled by the reproduction, which is largely dependent upon the rainfall. In the case of small herds, the herders have to put in high maintenance effort per animal to increaser the total output.

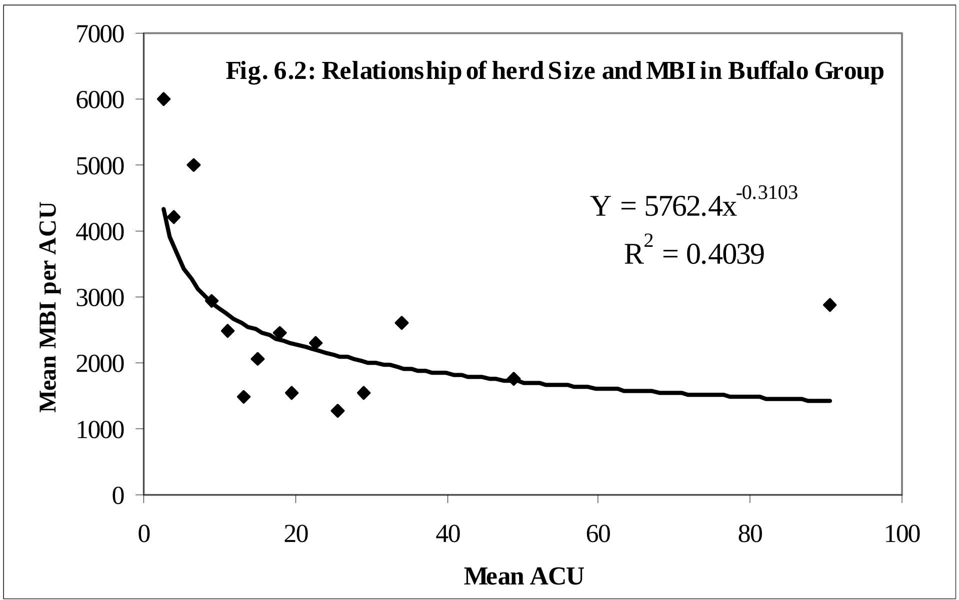


Table 6.6: Relation between MBI/ACU and herd size (estimated from power function)	
% Increase in Herd Size	**% Decline in MBI per ACU**
1	0.3
2	0.6
5	1.5
10	2.9
20	5.5
30	7.8
50	11.8
75	15.9
100	19.4

6.2.3 Economy of Scale

From the herder's point of view, the total milk output per herd is, perhaps, more important even at the cost of decreasing marginal output per animal as the herd size increases. Also, it may be recalled that stocking behaviour usually attributed to pastoral economy requires increases in herd sizes both for asset accumulation and as a risk management strategy. The falling incremental returns per ACU with increasing herd size raise doubts on how the economy of scale principle operates in this production system. However, it would be premature to do so. Firstly, until now, we are discussing gross returns based on milk output per ACU, across herd sizes, when herds consist of a mix of milch and non-milch animals. The milch to non-milch ratio varies much and tends to be low in the larger herds. Secondly, the output per animal would depend on the maintenance inputs over and above the fodder consumed from the open access resource. Thirdly, both for economic and cultural reasons, it is also necessary to increase the herd size owned in order to increase wealth, augment productive capital, and to earn incomes by sale of animals as well, which can be done more profitably when such a sale does not affect the gross milk output of the herd. Another factor is that with larger herds, there is greater flexibility in determining the total output by deciding on how many animals to be maintained for milk production, based on the various considerations including market conditions and rainfall.

Among the different aspects that have a bearing in determining the declining power law function for milk-based income per animal across herd size, only on the maintenance cost per animal do we have some data to undertake an analysis. The obvious question is whether the maintenance cost per animal also exhibits a similar, i.e., declining, power law behaviour. To pursue this reasoning, we examined a data subset on buffalo herds, which has meaningful data on the maintenance costs. The maintenance inputs were estimated from a sub-population of 31 households (Table 6.7). The annual mean livestock maintenance cost (LMC), i.e., paid-cost was found to be Rs.1,118 per ACU with a standard deviation of about Rs. 659. There was considerable variation in the maintenance costs, which in turn affect the milk output of the herd.

Table 6.7: Variation in LMC across buffalo herd size

Mean Herd Size (ACU)	Mean LMC
3.4	1530.4
8.8	1347.7
14.2	996.9
17.6	929.9
24.0	987.8
32.8	1077.1
41.6	417.5
51.0	1388.7

A regression analysis similar to that undertaken for establishing the relationship between MBI per ACU and herd size, was carried out with LMC, resulting in a declining power function (Fig. 6.3). The cost function obtained is:

$$C(X) = cX^d$$

The estimated parameters are: c = 1980.8 and d = -0.2281 with correlation coefficient, $R^2 = 0.2525$.
It may be more meaningful to examine economy of scale by studying the net returns per unit maintenance cost, rather than per animal unit (ACU). We can compute the Net Returns per unit Cost using the regression equations for gross MBI per ACU and maintenance cost (LMC) per ACU. The resulting equation is:

u = (Gross MBI per ACU – LMC per ACU)/(LMC per ACU)

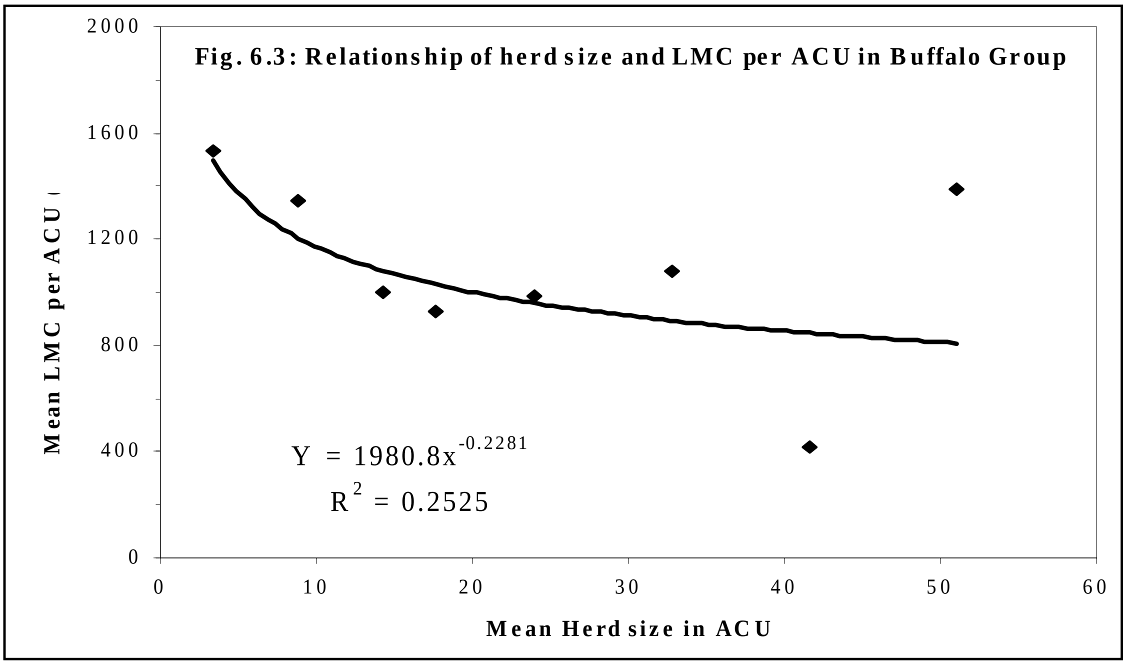
i.e.,

u = (Gross MBI per ACU)/(LMC per ACU) – 1

This leads to another power law function:

u = qX^p, where X is the herd size; q = 2.91; p = -0.0822.

The constants are computed by substituting those estimated in the two regressions.



The net return, u, per unit maintenance cost is still a declining power law function, albeit falling very slowly (exponent of –0.0822 as compared to –0.3103 for gross returns) with herd size. The maintenance cost function is based on a very limited dataset and it is quite likely that this data set is not truly representative. It has also been pointed out elsewhere in this study that the paid-out expenditure has not been easily forthcoming and one is never very sure of the accuracy of this data. Nevertheless, if we continue with the discussion on the question of economy of scale, it can be concluded that only with a better understanding of the actual livestock maintenance costs incurred can we make a definitive statement on the question of economy of scale. Even with the use of a limited dataset the inversion of economy of scale has reduced considerably and has moved closer towards being scale neutral (the exponent, though negative, is now closer to zero).

It would appear that even with better data, the kind of economy of scale that one normally encounters in production systems may not hold in the open access resource based production system of Banni. Another point, which may have to be considered is that net additions to the herd needs to be accounted for as part of the gross livestock-based income as growth in value, as has been done in some studies (cf. Adams, 1996). In conclusion, it may be said that the anomaly in economy of scale seems to be rooted in the 'zero-cost' open access resources.

6.2.4 Returns per Animal and Open Access Resource

The milk based income (MBI) per animal (MBIPA) turns out to be a slowly declining function of herd size that follows a power law function ($Y = aX^b$, where a, b are constants; a>0 and b<0) and the total return would be X*Y. In other words, the utility per animal decline with the addition of one animal, if the asset value of an additional animal is not considered.

Consider a situation where the grazing resources are unlimited and the animal to feed upon are less in number (i.e. number of stock is well below the grazing potential of the area), and all other factors affecting the production of milk (e.g. the animal health, water availability etc.) are constant for all the animals. Under such condition, it is assumed that the values of milk production per animal will record small dispersion around the mean and not affected by the herd size. However, in contrast, in a system where the fodder resources are limited and used by large number of livestock (i.e. number of stock is above the grazing potential of the area) and the limited resources are foraged upon competitively. Under such conditions, therefore, the milk production function is largely dependent upon the external inputs in the form of maintenance cost of the herd. It is expected, therefore, that the milk production per animal will record larger dispersion around the mean and affected by the herd size- a state quite opposite to the first situation.

Ceteris paribus, when all animals have equal access to the graze, milk output per animal would depend on the differentials in the efforts invested per animal by the household or the true maintenance cost per ACU in each herd. This cost is likely to be a function of herd size. The herd size is a intricate variable that depends on cultural factors as well, since herd size is an indicator of social status, and the risk management strategy of the household. Crucially, an important factor associated with herd size is the ratio of milch animals to the total herd size. The ratio tends to fall with herd size and when we compute the mean returns per ACU, the larger herd sizes invariably include a larger proportion of non-milch animals. The asymptotically decreasing power-law function representing output per ACU and herd-size appear to be fairly consistent with what one should expect in an open access system with high uncertainties, although it would appear, *prima facie*, to militate against economy of scale considerations.

Under a free grazing system, where the resources are available at zero cost, herders would naturally tend to increase livestock assets and thus convert the common property resource to a private resource (or asset) and through that improve their income. Hardin (1968) in his famous writing linked such conditions to the ‘tragedy of commons’. Theoretically, when people have open access rights to a resource, the private benefit (e.g. herd increase) of grazing cattle on a common pasture exceeds private costs. This is because all people using the pasture incur some of the cost, but the benefits accrue only to individual. Thus open-access resources tend to be ‘over-grazed’ in the sense that each person is encouraged to keep more animals, as they expect to gain more than they lose. Result from this study (Fig. 6.2) in combination with the conceptual model for common property resources explains the herder’s preference for herd expansion in Banni.

The nature of this function implies that a strategy to maximise returns from grassland resources would be for each herder to go for larger herd size, which will yield greater incomes, even though the return per animal may decline with herd size. This is consistent with conditions of open access involving zero costs for resource use where the only way to extract the maximum is to have larger herds to graze, unlike a stall fed condition where the strategy could be to maximise yields per animal in a herd. It may also be noted that the owning larger herd amounts to possessing greater wealth as well as larger productive assets. The herd expansion or asset creation strategy is achieved by the conversion of the common or open resource into a private movable property under conditions where herders have no claim to private property in land. It need not be a surprise if the strategy to extract the maximum of freely available open access resource to increase assets produces anomalies in economic behaviour such as near absence of the economy of scale.

6.2.5 *Disaggregating by Herd Types*

In order to understand different patterns of resource related economics, the income data were disaggregated at different levels. Pattern of income generation recorded different degree of dependency across herd types. On an average, there is significantly high annual income to the families with livestock than those without livestock (Table 6.8). Among the livestock owning families, those families who keep buffaloes generate higher incomes. The families that support the cattle or sheep/goat herds have significantly low average income, although the poor sample size for these warns about the interpretation of these data. In a sense among all the maldharis families, these two categories can be considered as economically weaker groups. It was already established that poorer families has higher share of income from non-livestock based sources (see Table 6.4). That those groups which own only cattle or sheep/goat, have major dependency on the NLBI, while buffalo owning families has major income share from livestock based sources. However, in terms of total income all the groups are earning large NLBI, this is despite the fact that charcoal making (the most dominant element in NLBI) is an illegal activity in Banni.

The discussions in above sections clearly bring out the fact that milk still controls the economy of the region. However, it is believed that there is significant difference in the milk economy of the cattle and buffalo. Based on the available data collected during this study, an attempt has been made here to weigh up the above assumption in the context of Banni. Simple arithmetic computation revealed that with the similar units of adult animal holdings, a buffalo herder would be able to generate considerably more (74%) net income than a cattle herder (Table 6.9). Such economic differentiation is, unequivocally, a major driving force in changing the herd composition in favour of buffalo.

Table 6.8: Pattern of average annual income from different sources across herd type

Parameters	Herd Types						
	Cattle	Buffalo	Cattle+ Buffalo	Buffalo+ Sheep/ Goat	Sheep/ Goat	Total With Livestock	Without Livestock
No. of Families	5	153	33	15	4	210	41
Avg. ACU	7.3	21.7	27.3	23.9	12.5	22.2	0
MBI	9510	50929	79700	33250	0	52231	0
Animal Sale	0	3414	3710	15950	1000	4229	0
Other LBI	0	618	1061	869	589	690	0
TLBI	**9510**	**54961**	**84471**	**50069**	**1589**	**57150**	**0**
Charcoal	10040	5055	11353	11720	42000	7343	13320
NTFP	1518	2475	2933	3860	3225	2638	3800
Labour	840	2386	3633	600	0	2372	344
Handicraft	0	2698	5442	3120	150	3047	5198
Other	12000	2253	3830	23149	0	4183	1600
TNLBI	**24398**	**14867**	**27192**	**42449**	**45375**	**19582**	**24262**
TINC	**33908**	**69828**	**111663**	**92518**	**46964**	**76732**	**24262**
% Share of LBI	28.0	78.7	75.6	54.1	3.4	74.5	0.0
% Share of NLBI	72.0	21.3	24.4	45.9	96.6	25.5	100.0

Table 6.9: Comparative economy of milk

Parameters	Cattle	Buffalo
Total Animal Enumerated#	206 (134 adult + 72 young)	3699 (2823 adult + 876 young)
Total Milking animals#	39 (29% of total adult)	693 (25% of total adult)
Annual milk production per milking animal#	1130 litre	1740 litre
Average selling price of milk per lit#	Rs.8/-	Rs.11/-
Gross Annual Income per milking animal#	Rs.9,050/-	Rs.19,150/-
Maintenance cost*	Rs.1,350/- @15% of gross income	Rs.5,750/- @30% of gross income
Net annual income per milking animal	Rs.7,700/-	Rs.13,400/-

The values are derived based on the survey data
* Rates of maintenance cost were considered after the discussion with the maldharis

6.2.6 *Determinants of Migration*

It is often argued that the nomadic pastoralists keep too many animals, far above what the grazing land resources are capable of supporting. Large herds are then unable to survive drought induced periods of low forage production. On the contrary, the maldharis believe that large number of stocks is critically essential to get through the drought years. Migration is one of the many critical herd management strategies pastoralists adopt against the drought or scarcity conditions. Therefore, the process of migration is closely related to the condition of the resource. However, this drought coping strategy used by nomadic pastoralists is highly variable and much depends upon socio-economical-cultural and ecological conditionality. On the face of it, the entire concept of nomadic pastoralism may be considered as a means of coping with and exploiting highly variable resources through maintaining mixed herds and by their geographical mobility (or migrations).

In order to cope with the varying rainfall and forage distribution, pastoralists and their stock must possess a high degree of mobility. It has been stated earlier that during the study period about 45% families had reported migration. However, it is a point to ponder that given the similar resource status (like rainfall, fodder and *Prosopis juliflora*) for the entire population, what are the factors forcing one family to opt to migrate and another to stay back? On the face of it, it seems that capacity of a pastoralist to maintain the stock is the main factor in determining the decision of migration, which in turn is controlled by the livestock herd size and income pattern from different sources.

A family without livestock need not to migrate during the scarcity period, as no other major economic activities in Banni are affected by poor rainfall conditions. In case of pastoralism, number of livestock is the asset, which is the primary means of earning livelihood. However, during the drought years, due to insufficient quantity of fodder in regular grazing areas, the animals are exposed to high vulnerability. A pastoralist household, thus find it very difficult to maintain the stock, especially the large stocks, resulting into the migration to other fodder rich areas, including the vicinity of good agriculture areas. The results presented earlier have already confirmed that migratory groups are possessing significantly larger herds of animals than those who did not migrate (see Table 5.16). Disaggregation of different income sources confirms significant variation in total income, LBI and NLBI between the migrant and non-migrant families (Table 6.10). It is interesting to note here that both total NLBI and its major constituent- the PJBI are significantly different in the migrant and non-migrant groups. Although, the PJBI in both the groups contributes about 50% of total NLBI, in terms of actual income, it is significantly higher in non-migrant group.

Table 6.10: Pattern of income (Rs.) in the migrant and non-migrant families

Income Sources	Migrant (n=31)	Non-migrant (n=99)	F Value
Total Income	**101327**	**62071**	**8.0***
Milk Based	85395	34897	16.4*
Other Livestock Products	1242	345	10.6*
Livestock Sale	2980	2716	0.02
LBI	**89617**	**37958**	**16.3***
PJBI (Charcoal+NTFP)	6068	12219	3.3+
OTHI	5642	11893	2.2
NLBI	**11710**	**24113**	**5.8****

* for p>0.001; ** for p>0.05 and + for p = 0.07

In the present context, it is also important to know the key variables that control the probability of a herd to either migrate, or not. For this, we test the probability of a group to migrate using logistic regression model. In a simplistic term, we postulate that the individual decision to migrate depends largely upon the interaction among the livestock assets (ACU) and two major economic variables- the economic value realised through the asset i.e. LBI; and other alternative sources of income i.e. NLBI. The above can also be depicted as:

Probability of Migration= f (ACU, LBI, NLBI)

The result of logistic model is presented in Table 6.11. It is found that herd-size (ACU) exhibits a positive and NLBI a negative significant impact on probability of migration. LBI, on the other hand has a positive but insignificant impact on migration. The coefficient values of total ACU and NLBI highlighted that while alternative income pulls down the probability of migration, the stock size is the main determinant in making decision about migration. This confirms the general observation that under scarcity conditions, maintenance of larger herd becomes difficult within the region, and as a risk minimization strategy pastoralist migrates to other areas to reduce livestock mortality. The role of collateral incomes from those sources that are free from the effect of drought (i.e. NLBI) could, however, be significant in reducing the migration. The fact that PJBI is relatively high in the non-migrant groups further strengthens this inference. Clearly, in the case of Banni, there is a possibility of reducing the effect of drought-driven migration by finding ways to enhance NLBI and in particular by ecologically sound management of economic activities based on *Prosopis juliflora*.

Table 6.11: Result of logistic regression for migration probability

Parameters	Coefficients	Standard Error
N	130	
Constant	-1.5527	0.417
Total LBI	0.0000043	6.005E-6
Total NLBI	-0.000029*	1.456E-5
Total ACU	0.0314**	0.0185
Chi Sq	23.2	
Log likelihood Ratio	119.6	

* for p = 0.04 and ** for p = 0.09

6.2.7 Decomposition of Unequal Resource Dependence

Discussion in above sections clearly establishes the economic role of two natural resource based production systems of Banni- the grasslands and the *Prosopis juliflora*, in generating livelihood to the local maldharis. While, economists have increasingly concerned with the long and short-term determinant of income distribution, the natural resources are undisputedly emerged as one of the key determinants, both in the short and long run. Analysis of income highlights that there are significant differences in overall income at various disaggregated levels. However, those analyses do not provide any clue about the distribution of income within the groups. In this context it is also very important to know the role of various sources of income in determining the overall income pattern. Clearly, this can be attempted by analysing various measures of 'income inequality'. In an effort to analyse the income inequality in Banni pastoralism, we used three methods, commonly used by economists- the Lorenz curve, the Gini coefficient and Coefficient of Variance. The purpose of this exercise is therefore to measure and identify the principal determinants of variation in the income at disaggregated levels.

The total income in the Banni sub-region clearly highlights a large disparity in their distribution. To demonstrate this we have divided the population into different equal sized groups (quintiles) in order of poorest to richest. For each quintile we record the income share earned by that quintile of the population (Fig. 6.4). The total income for all the families (with and without livestock) revealed that out of total income in Banni, more than 50% income is rested with the richest quintile, while less than 5% income is rested with the poorest quintile.

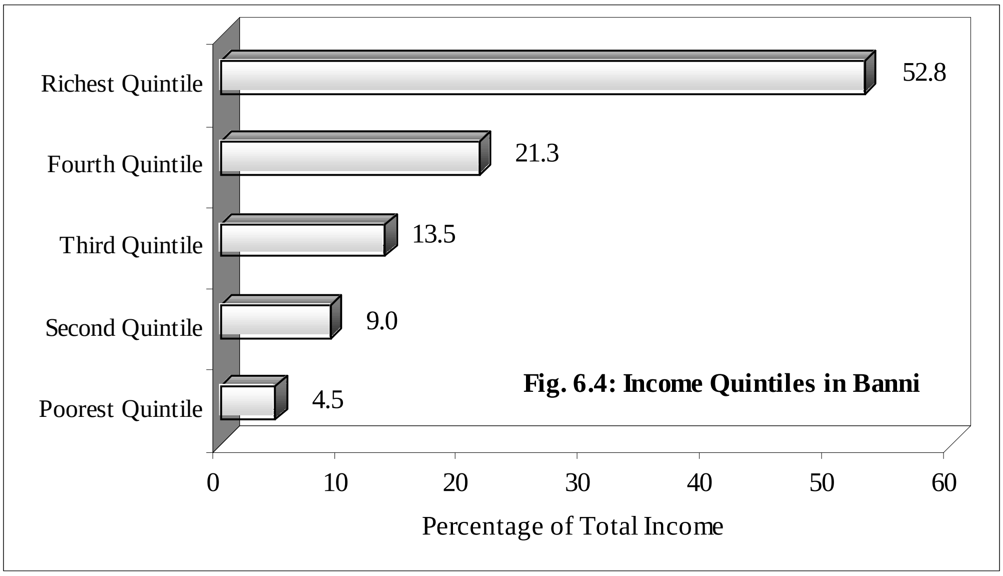


Fig. 6.4: Income Quintiles in Banni

Lorenz curve has been used to observe the income disparity among the herder and non-herder families. The income disparity was more pronounced in the livestock owning families than those without livestock (Fig. 6.5). It is important to mention here that while herders are utilising both the biomass resources in earning their income, the families without livestock (non herders) are using only *Prosopis juliflora* to generate income for them. It may be recalled here that the mean GHAI of herder families is about Rs. 76,700/- (Table 6.8), which is more than 3 times that of non-herders. Clearly, those families, which do not own livestock, are the poorer lot in Banni with more even income distribution. Both Gini and CV are higher in the herder groups (Table 6.10).

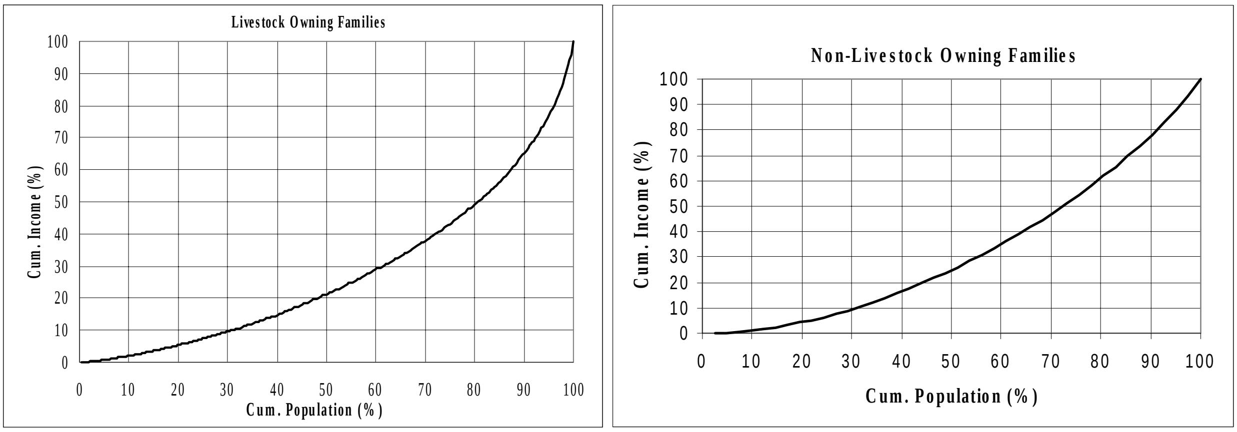


Fig. 6.5: Lorenz curve for total income of (a) livestock owning families (n=210) and (b) Non-livestock owning families (n=41)

Within the livestock owning families, however, the distribution of income is not the same for all the different herd types. The values of Gini coefficient and the CV across different herd type emphasize that the group with lower annual income has more equitable earning than the groups with high annual income (Table 6.10). Clearly, all the buffalo herders showed high level of inequality in income distribution than the cattle and small ruminant (sheep and goat) herders, which have low income.

Table 6.10: Inequality in Gross Annual Household Income (GAHI) across households with different herd types			
Herd Type	**Mean GAHI (Rs.)**	**Gini**	**CV^2**
Cattle	33,908	0.31	0.32
Buffalo	69,828	0.43	1.30
Cattle + Buffalo	111,662	0.45	0.78
Buffalo + Sheep/Goat	92,519	0.30	0.28
Sheep and Goat	46,964	0.14	0.10
Herders	**76,731**	**0.44**	**1.13**
Non-Herders	**24,261**	**0.35**	**0.39**
All Families	**68,175**	**0.46**	**1.28**

As a first step in explaining how the degree of income inequality within Banni can be so varied between herder and non-herder families, we used decomposition analysis, determining the contribution to inequality from three major income sources. The decomposition analysis provides: (a) measure of the overall inequality (b) the contribution of each income source within the total income (measured as a squared weight, w^2), (c) the inequality measures within each income source and (d) contribution of income inequality from a particular source to the overall measure. In principle, one could expect that by disaggregation of the full sample into sub-samples, each identified by, and defined homogenously with respect to occupation types, or size of livestock holdings, one could distinguish various resource dependent mechanisms contributing to inequality.

The obvious starting point in terms of resource dependence being the ownership of herds, we looked at the differences in income distribution between herders (livestock owners) and non-herders (without livestock). The decomposition of inequality was undertaken in terms of role of three major streams, LBI, PJBI and OTHI (Table 6.11).

Table 6.11: Decomposition of total income inequality in herders and non-herders									
Income	**All Family (n= 251)**			**Herder (n= 210)**			**Non-Herders (n=41)**		
	w^2	**CV^2**	**Rel. Cont.**	**w^2**	**CV^2**	**Rel. Cont.**	**w^2**	**CV^2**	**Rel. Cont.**
GAHI (All Sources)		**1.28**			**1.13**			**0.39**	
LBI	0.49	2.48	0.950	0.55	1.91	0.94	0.00	0.00	0.00
PJBI	0.03	2.04	0.042	0.02	2.47	0.04	0.50	0.84	1.08
OTHI	0.02	4.41	0.063	0.02	4.54	0.06	0.09	2.65	0.59
		COV			**COV**			**COV**	
LBI & PJBI		-0.09	-0.016		0.01	0.00		0.00	0.00
LBI & OTHI		-0.20	-0.030		-0.23	-0.04		0.00	0.00
PJBI & OTHI		-0.26	-0.009		-0.15	0.00		-0.63	-0.67

* The overall $CV^2 = \sum w_i^2 CV_1^2 + 2\sum \sum w_i w_j COV_{i,j}$. The relative contribution is obtained by dividing the absolute components (CV_i^2, i=1…3; or $COV_{i,j}$, i≠j) by the total CV^2 to facilitate intra-group comparison (See Chapter 2 for details). Sum of the relative contributions is unity.

The inequality was much lower in the non-herder households than among herders, where there are very large differences between the poor and the rich sections. Clearly, there is larger wealth accumulation in the herder category, while the low levels of wealth are more evenly distributed among the non-herders. In the case of non-herders, the income diversification is less, and most of the inequality within the category comes from woody resource-based incomes. The disparity tends to get evened out by the income from these two sources as can be seen from the negative contribution of covariance between PJBI and OTHI. The large inequality in the herder category driven by the LBI is consistent with the logic of increasing the herd size as a means for wealth accumulation. The strategy of increasing herd size finds an explanation not only as one driven by cultural tradition, but also as one based on a sound economic principle under conditions of open access to fodder resources.

In the case of herders, the absolute contribution to inequality is high from the both woody resources and other sources. However, the relative contribution of these to the total inequality is low. The woody resource based income has only a negligible role in altering the overall inequality, which is determined by the dominant share of LBI in the total income. The income from woody resource is nearly neutral in bringing about changing the total inequality. However, the income from a variety of other sources (other than either grass or woody resource based options) does play a small role in reducing the inequality. It seems likely that that the households owning lower herd size supplements the income from sources based on options other than wood or grass resources.

Additionally, due to the major shift in stock composition from cattle in favour of buffalo, we also undertook a similar exercise across households grouped into five buffalo herd-size classes (Table 6.12). The distribution of income is highly skewed and most of the inequality for all size classes taken together comes from the buffalo ownership pattern, which in itself is, *prima facie*, an indicator of wealth distribution. As is to be expected, the contribution of incomes from woody resource to the inequality falls of sharply as the herd-size increases, with near zero contribution in the largest size class.

Table 6.12: Decomposition of total income inequality across buffalo herd size

Income Stream	All Buffalo		1 to 5		6 to 10		11 to 20		21 to 40		>40	
	CV^2	Rel. Cont.*	CV^2	Rel. Cont.*	CV^2	Rel. Cont.*	CV^2	Rel. Cont.*	CV^2	Rel. Cont.*	CV^2	Rel. Cont.*
GAHI (All Sources)	**1.12**		**0.65**		**0.67**		**0.77**		**0.32**		**0.58**	
LBI	1.81	0.93	0.65	0.14	0.55	0.32	1.01	0.69	0.38	0.90	0.60	0.98
PJBI	2.60	0.04	2.51	0.27	1.84	0.09	2.42	0.08	2.87	0.03	2.96	0.00
OTHI	4.47	0.06	2.72	0.56	5.20	0.28	3.30	0.06	4.54	0.06	4.26	0.00
	COV		**COV**		**COV**		**COV**		**COV**		**COV**	
LBI & PJBI	0.09	0.02	0.22	0.06	-0.03	-0.01	0.90	0.26	0.27	0.10	-0.04	0.00
LBI & OTHI	-0.24	-0.04	-0.05	-0.02	0.84	0.29	-0.25	-0.06	-0.16	-0.06	0.83	0.02
PJBI & OTHI	-0.05	0.00	-0.03	-0.02	0.24	0.03	-0.52	-0.03	-0.69	-0.03	-0.69	0.00

* see note to Table 6.11

The small size class (1 to 5 buffalos) have a significant dependency on the woody resource and a sizable contribution to the inequality from the woody resource. However, the share of inequality from incomes other than either livestock or the woody biomass is the highest in the small size class, although when all size classes are considered, there is not much difference in the contribution from PJBI or OTHI to the overall inequality. The incomes from sources not based on grass or wood are highly important for all the small and medium herders. For the small herders (1 to 5 buffalos), OTHI is the largest contributor to income disparities rather than either the grass or woody resource. In other words, it is the opportunities unconnected with these resources that appear to be primary factor determining the economic status in this group, although they continue to be herders and attach cultural significance to their status as a pastoral community.

6.3 Naliya

The Naliya region is agro-pastoral with hardly any regular out-migration of people. Agriculture is the main livelihood system with a certain degree of dependence on livestock as a secondary income. Most households own a livestock that are maintained to a large extent for own use. Income from livestock is an important complement to that from agriculture. The area, however, experiences considerable in-migration, particularly from Banni and partly meets the resource deficit of Banni. Of late, there has been an expansion of agriculture and encroachment of grassland for agriculture. We have attempted to gather some data on this aspect. The grassland system in the region is also used by wild ungulates. The key issue here is the conflict over land use needs of biodiversity conservation *vs* agricultural expansion.

6.3.1 Income Sources

In the Naliya region, 11 different income streams can be recognised (Table 6.13). While, all these economic activities support various livelihood base of the region, the agro-pastoralism is the most predominant livelihood mode. However, there is a caveat to be kept in mind while analysing an agro-pastoral subsistence economy: it is not entirely correct to totally separate agriculture and livestock incomes, since outputs from one, such as crop residues from agriculture and draft power and manure from livestock, are used as inputs in other. As it is empirically very difficult to remove the effect of such overlapping incomes, we treated these two income sources as independent of each other. The size of landholdings is a major factor determining the socio-economic stratification and has overarching effects on the pattern of income generation including that of livestock sector.

The concepts of income used in this study region include (a) the direct sale of products from agriculture, livestock, common land resources (like MFP) and handicrafts (b) imputed cash equivalent to household consumption of crops, crop residues and livestock products and (c) earnings from wage labour, government and private sector employment and profits from self-employment. Also, to understand the economic patterns of the survey regions, most of the analyses are based on pooled household level income data. Therefore, no attempts were made to disaggregate the analysis at sub-regional or village levels.

Table 6.13: Different income sources in Naliya

Income Sources	Income Groups
Agricultural Income	**Farm Based Income (FBI)**
Milk Sale	**Livestock Based Income (LBI)**
Ghee Sale	
Livestock Sale	
Other Livestock Products (Dung and Wool)	
Farm and Non-farm Wage Labour	**Miscellaneous Source Income (MSI)**
Fishing	
MFP Collection	
Handicraft	
Remittance (Service)	
Other subsidiary sources (artisans, shops etc.)	

In the present study, income analysis has been done mainly on the Gross Annual Household Income[23] (GAHI) and the data set used for income analysis relates to 171 out of the 174 survey schedules. Subject to qualifications given in Chapter 2 on methodology, the definition of GAHI applied to the Naliya region is given below:

Agriculture	Incomes from all kinds of crop production; Imputed incomes were used in the case of own consumption or in cases where production data was not accompanied by the details of sales
Milk Sale	Cash received through sale of milk as per actual prices reported by the respondent, which depends on whether it is of cow or buffalo. Sale forms only a small fraction of total production. Imputed incomes were used when sale is not reported.

[23] The net household income was not possible to compute, as the different production costs for each production system were not available at household level.

Ghee & Mawa Sale	Cash received through sale of ghee (made from unsold milk or cream of skimmed milk sold) and of mawa (a from of milk-cake) used in making milk-based sweets. Imputed values were used when production data is not accompanied by sales information
Livestock Sale	Cash realised through the sale of animals (young & adult). The sale of cows and buffalo is as milch animal; of bulls as draught animal and of goat/sheep for slaughter; Imputed values were not used.
Other livestock Products (dung and wool)	Cash receipts from the sale of dung and wool. Imputed values were used for all the dung production reported, when sale proceeds are not given
Wage Labour	All kinds of wages earnings from casual work within and in the adjoining villages
Fishing	Earnings from costal fisheries
NTFP	Earnings from various non-timber forest produce such as honey, wax, gum, etc.
Handicrafts	Earnings reported from the home-based handicrafts, in which women's contribution is very high
Remittances	Includes all forms of money received by the household as pensions or from relatives living outside the region
Other Sources (artisans, shops etc.)	These include various forms of income generated from small enterprises, work as artisans, trade or business

The data show that the mean Gross Annual household Income (GAHI) in the Naliya region is Rs. 64,275. The GAHI ranges between the a low of Rs.1,800 to a high of Rs.947,000 (SD = Rs.97,247). The distribution of GAHI highly skewed with more families in the lower income groups (Fig. 6.6).

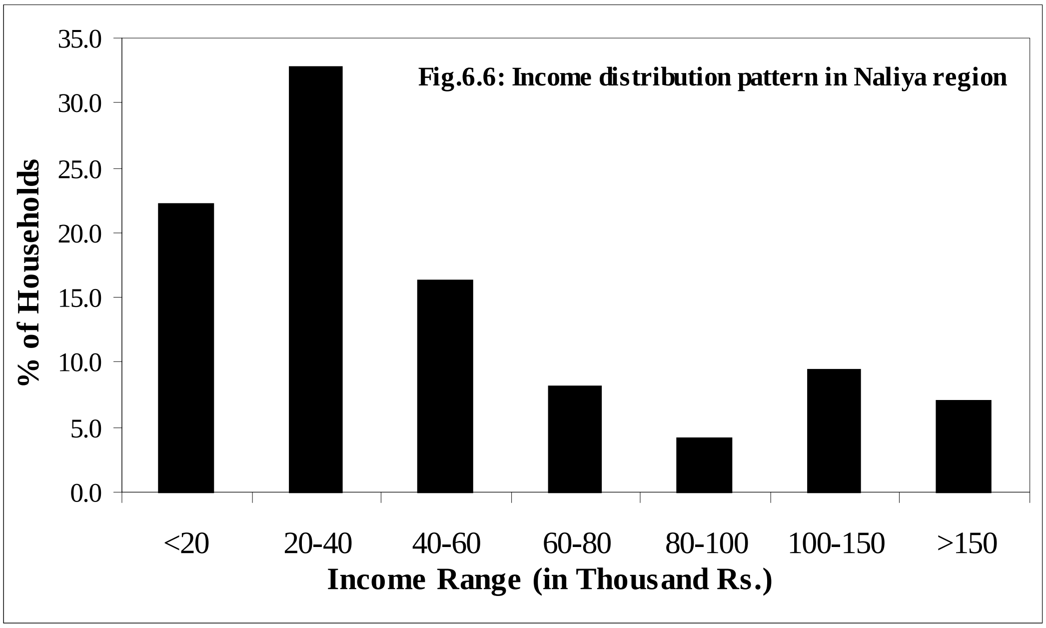


Fig.6.6: Income distribution pattern in Naliya region

It is seen that most of the households fall in the agro-pastoral (i.e. FBI plus LBI) group. Nine families each earned their income exclusively from agriculture and livestock sectors (Table 6.14). All the three sub-sectors farming, livestock and miscellaneous (non-farm & non-livestock) are fairly common in the villages surveyed. The distribution of income from each source and their relative contribution in the total economy of the Naliya region is very uneven (Table 6.15). Of the total average annual income, largest share comes from the FBI (46.5%) followed by LBI (37.2%) and MSI (16.3%). It is, however, clear that although both the agriculture and the livestock sectors play quite substantial roles in the overall economy of the region, even the miscellaneous income sources with major share from wage labour (farm as well as non-farm) also significantly contribute the household economy of the region.

Table 6.14: Income generation pattern in Naliya		
Income Source	**No. of Households**	**Mean Gross Annual Household Income (Rs.)**
Only FBI	9	23,662
Only LBI	9	17,653
Only MSI	14	21,889
FBI & LBI	64	94,832
FBI & MSI	8	25,775
LBI & MSI	19	31,608
FBI, LBI & MSI	48	71,600
ALL	**171**	**64275**

The income is very unevenly distributed as is evident from the large standard deviation (SD = Rs. 97,247/-). About 77% of the total income of the households studied belongs to the richer quintiles, while only about 4% income is rested with the poorest quintile (Fig. 6.7). While FBI recorded an increasing share in the richer income groups, the MSI showed a reverse pattern where the poorer families has greater share from this source (Table 6.16). LBI is a significant component across all quintiles.

Table 6.15: Distribution of income from different sources in Naliya Region					
Source of Income	**Gross Income (Rs.)**	**Contribution (%) to total income**	**No. of H'holds**	**% of total H'holds* (n=171)**	**Avg. Annual Income (in Rs.)**
FBI	**5105608**	**46.5**	**129**	**75.4**	**39578**
LBI	**4093368**	**37.2**	**140**	**81.9**	**29238**
Milk Based	3789720	34.5	138	80.7	27462
Livestock Sale	121100	1.1	19	11.1	6374
Other Livestock Products (Dung and Wool)	182548	1.7	68	39.8	2685
MSI	**1792120**	**16.3**	**89**	**52.0**	**20136**
Labour	661380	6.0	55	32.2	12025
Service	598840	5.4	20	11.7	29942
Others sources	531900	4.8	30	17.5	17730
Total Income	**10991096**	**100.0**	**171**	**100.0**	**64275**
* There are, in general, multiple overlapping income streams for each household and therefore the percentages will not sum to 100					

Table 6.16: Income share (%) from various sources across different income groups				
Quintile	**TINC (in Rs.)**	**% of TINC**		
		FBI	**LBI**	**MSI**
Poorest	12239	19.0	42.9	38.1
Second	24029	27.9	32.8	39.3
Third	35421	30.6	35.5	33.9
Fourth	60099	34.8	48.4	16.8
Richest	186009	57.1	34.3	8.6
Total	**64275**	**46.5**	**37.2**	**16.3**

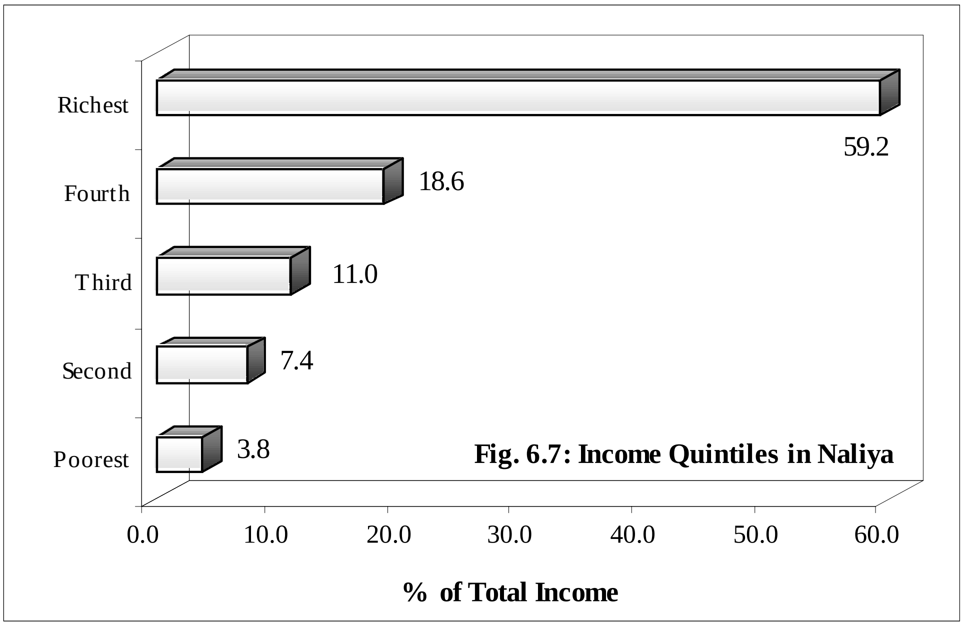


Fig. 6.7: Income Quintiles in Naliya

In order to understand different income patterns in the region, the income data were further disaggregated in terms of land-holding categories. The average annual income across different land holding families ranged from about Rs. 26,500 (landless and marginal) to about Rs.2.00 lakh (large farmers). Across land ownership group, the large farmers recorded the highest average annual income, of which about 62% was contributed from FBI and 34% from LBI Table 6.17). In case of landless families, about 7% of FBI comes from sharecropping. Contribution from LBI is almost nearly uniform (34.1 to 39.7 percent) across various land holdings. Contribution from MSI is highest in the landless and lowest in the large farmers.

Table 6.17: Mean Gross Annual Household Income (GAHI) across land holding categories

Land Holding	Households	Mean GAHI (Rs.)	%		
			FBI	LBI	MSI
Landless	37	26,398	7.0	37.5	55.5
Marginal	11	26,579	18.4	34.4	47.2
Small	27	41,248	39.8	34.9	25.3
Semi medium	36	45,492	39.2	39.2	21.5
Medium	45	86,436	51.2	39.7	9.1
Large	15	205,400	61.9	34.1	4.0
Total	**171**	**64,275**	**46.5**	**37.2**	**16.3**

The income distribution pattern across landholding size is quite similar to that of the quintile based income pattern, discussed earlier. The richer groups possess significantly large landholdings and possess better irrigation sources (Table 6.18). Interestingly, mostly the richer groups also own the livestock.

Table 6.18: Land & livestock holding pattern across different income quintiles

Income Quintile	Households with Irrigation source (%)	Total Landholding (acres)	Livestock Holding (No.)			
			Cattle	Buffalo	Sheep/ Goat	ACU
Poor	3	257	32	0	122	54
Second	9	388	124	3	808	312
Third	18	434	164	11	370	238
Fourth	41	788	184	23	806	386
Richest	74	1084	257	116	1349	680

Table 6.19 shows that farm and livestock based incomes are positively correlated with landholding indicating that agricultural and livestock based incomes are closely linked with landownership. By contrast, the simple correlation between the income from miscellaneous sources and landholding is negative suggesting that miscellaneous income consisting mostly of wage labour is of significance primarily for the poor.

Table 6.19: Relationship between landholding and income sources

Income Source	Correlation Coefficient
FBI	0.67
LBI	0.63
MSI	-0.16
TINC	0.66

6.3.2 Dependency on Grassland Resources

We saw that the livestock based income is substantial across all the income groups (see Table 6.16) and therefore an integral part of the region's economy. Livestock sector in an agro-pastoral system can depend on both agriculture and on the common grazing resources, which includes the village pastures and the large grassland tracts. In this work our prime concern is to examine the dependency on the grass resources.

The dependency on grassland resources was ascertained by eliciting responses on the degree of dependency on the different fodder resources in different seasons. The respondent was asked to assign scores on a 10-point scale to the resources in different seasons. These responses were normalised and converted into a measure of the dependency on the resource. The analysis of data revealed that the livestock remained highly dependent on the grasslands during monsoon and post-monsoon (winter) seasons. This is only to be expected, as these are the seasons when grass is plenty in these grazing lands. During winter season, even the harvested agriculture fields serve as a major fodder source. During the summer, however, higher degree of dependency was reported on supplementary green and dry fodders, with low degree of dependency on the *gauchar* lands (Table 6.20).

Table 6.20: Seasonal changes in fodder dependency (%) on different resources

Season	Village *Gauchars*	Livestock Feed	Green Fodder	Dry Fodder	Harvested Farmland
Summer	11.6	12.5	25.9	49.1	0.9
Rainy	86.5	10.6	1.0	1.0	1.0
Winter	39.1	4.5	8.3	14.1	34.0

During the rainy and winter seasons, when there is plenty of grass on the common pasturelands, livestock of all sections – poor and rich – depend almost completely on it. Summer, is a difficult period for all the livestock owners and the differences in resource dependency of the rich and poor become apparent in the dry period. The strategy to meet the fodder requirement during the lean summer period varies greatly among the different income quintiles. About 39% of the requirement of the poorest families is met from the grassland resources in summer, while the richer sections reduce their dependence (Table 6.21). The richer agro-pastoralists opt to partially meet the requirements through purchases of livestock feed, green fodder and dry fodder. The richer groups are also able to use the residues from their agricultural production system and post harvest farmland, without the need for cash outflows.

While the pattern of grazing in common *gauchar* lands by different income groups has direct economic implications, indirectly, it also has an ecological side. Due to the differentiation in the dependency pattern, with the reduced dependency of the richer groups, who own larger herds, on the grassland, the grazing pressure on the system declines to an extent, leaving the poor to get more out of the open access resource. The reduced grazing pressure during the lean period is beneficial to the recovery of grasslands during subsequent rainy season. However, the true extent of this needs more detailed investigation, which could not be undertaken as part of this effort.

Table 6.21: Changes in fodder dependency (%) on different resources across income groups during Summer season

Quintiles	Average Score				
	Village *Gauchar*	**Livestock Feed**	**Green Fodder**	**Dry Fodder**	**Harvested Agri. Fields**
Poorest	39.0	9.3	21.2	30.5	0.0
Second	14.5	14.6	15.7	55.2	0.0
Third	12.4	20.2	23.3	44.2	0.0
Fourth	11.8	12.6	21.8	53.9	0.0
Richest	4.9	8.4	35.9	47.3	3.4

6.3.3 Social Cost of Grassland Resources

We saw that there are definite patterns of dependency on the grassland across seasons and income groups. Considering the dependency on private and public (i.e., open access) resources, it would be instructive to examine the share of social cost in the livestock-based production. The social cost of livestock outputs can be inferred as a first approximation by the use of imputed values of the fodder consumed from the open access resources. The computation of imputed social cost was adapted from Nadkarni (1987).

The social cost is estimated by imputing a nominal value to the fodder consumed by livestock through free grazing on the open grasslands. Table 6.22 shows the seasonal dependency of different income class on the grassland for their fodder requirement through free grazing. Only 11.6% of the fodder demand is met from the *gauchar* lands during the summer, while the same grassland fulfils nearly 86% fodder demand during the rainy season. As discussed earlier, there is marked variation in such dependency across different income groups, which point to differentials in social costs incurred by different income groups.

Table 6.22: Seasonal dependency on *gauchar* lands across income groups

Quintiles	% Dependency		
	Summer	**Winter**	**Rainy**
Poorest	39.0	48.8	83.4
Second	14.5	32.6	90.2
Third	12.4	43.3	89.3
Fourth	11.8	41.4	87.2
Richest	4.9	35.7	85.7
All Family	**11.6**	**39.1**	**86.5**

Since the level of dependency significantly differs across the seasons, while estimating the fodder consumption by the livestock for the entire year, we separately estimated the seasonal values, which were then summed up to get annual values. The livestock units were converted to ACU. The daily fodder consumption for each ACU was considered as 7 kilogram (Singh et al, 1993), which in combination with the actual level of dependency, as reflected in Table 6.23, was used to estimate the total quantum of fodder extraction from the *gauchar* lands. Finally, to get the total economic cost of such dependency a notional cost of paise 50 per kilogram of grass was ascribed.

Table 6.23: Social cost of free grazing in different seasons across income groups								
Quintiles	**Total ACU**	**Social Cost (in Rs.)**						
		Summer	**Winter**	**Rainy**	**Annual**		**Per Household**	**Per ACU**
					Total	**%**		
Poorest	54	8836	11061	18904	38801	4.1	1141	719
Second	312	18989	42736	118256	179981	18.9	5294	577
Third	238	12405	43273	89246	144924	15.2	4262	609
Fourth	386	19050	67046	141375	227471	23.9	6690	589
Richest	680	14032	101989	244658	360,679	37.9	10305	530
Total	**1670**	**73312**	**266105**	**612439**	**951856**	100.0	**5566**	**570**

The information obtained on the paid-out expenses is not suitable enough for detailed analysis. Therefore, we have not been able to go to the next step of comparing the social cost with the private costs. The differentials in social costs across income-groups warrant closer scrutiny. At the first glance, it would seem that the rich are, as it were, less dependent on the open grassland and the share of social cost on the rich would, therefore, be comparatively less. However, Table 6.23 tells a different story. The bulk of social cost for the year is accounted for by the richest quintile (Rs.0.36 million or 37.9%), while that for poorest quintile is only Rs.38,801 (4%), although the poorest incurs higher social cost per animal per year. While the social cost incurred by the poor helps in subsistence, the high social cost incurred on the richer sections could be a major input for the profitability of the relatively larger agro-pastoral enterprise. There are important lessons to be drawn from this for the grassland management.

6.4 Convergence Despite Contrasts

Banni (Typology-I) and Naliya (Typology-II) grasslands provide an unusual study in contrasts, despite the similarities of *de facto* open access resource management regimes. Livestock based economic activity is the sustainable livelihood option in Banni due to the ecological and environmental peculiarities. Naliya on the other hand has a thriving agricultural base adjoining the extensive grasslands, which naturally makes it an agro-pastoral system. Incidentally, agro-pastoral systems have been a characteristic feature of the Kachchh region itself and to that extent Naliya is, in a sense, somewhat typical of the agro-pastoral systems of the district.

Banni was, before the large-scale invasion by woody cover, renowned as the best grassland system in this part of the world and, going by well-known accounts, was also very rich in biodiversity. The undisturbed Banni was as important for biodiversity values as is the Naliya region today. However, the woody invasion not only altered the ecological dynamics, it also wrecked havoc with the livelihood system. For reasons, not too well known, the Naliya grasslands have so far remained relatively free of the mesquite invasion. Grasslands as ‘common resources’ still play a crucial role in the economies of both typologies. In case of Banni, the economic activities in their present form may cease to be viable if the degradation of grasslands goes unchecked.

The lack of alternate economic resources such as agriculture and absence of property rights force people of Banni to be dependent on the market for their subsistence needs. The case is somewhat different in Naliya, where in view of alternate resource availability for livestock, migration is almost non-existent, while in case of Banni migration to other areas, including Naliya, is common. The grasslands of Naliya serve as refuge to the livestock of Banni during periods of resource scarcity, as was confirmed by the surveys in Naliya. Not only the grasslands, the empty agriculture fields in Naliya region also offer the grazing opportunities for the migrating populations and even a symbiotic relationship between herders from outside and the farmers: some farmers allow livestock into their fallow fields and collect the dung in return. There is no practice of collecting any grazing fee or rent from the migrant herders.

The income pattern in both the typologies is highly skewed, which is largely determined by livestock based economic activity in the case of Banni and agriculture production in the case of Naliya. Livestock is central to the economic activity in Banni. The livestock-based economy of Banni has shifted from one based on the breeding and sale of certain breeds of cattle and bulls to one based on milk production. This shift has been accompanied by increase of buffalo and decrease of cattle and small ruminants. In contrast, buffaloes make up only 6% of the Naliya livestock with the rest comprising of sheep/goat (60%) and cattle (34%). Our extrapolations show that the milk production of Banni is worth more than Rs.100 million annually, which is likely to be a conservative estimate, since the data of this study is more representative of a dry period, and not of a normal year. The milk production in Naliya, on the other hand, is more for own consumption than for the market. Nevertheless, it forms an important component of the household budgets of the agro-pastoral communities.

The decomposition analysis of incomes in Banni shows that diversification brought about by the woody invasion plays an important role in the income of non-herders and the small herders. The income diversification appears to help in the survival of the poorer herders without having to give up entirely the pastoral way of life. The empirical evidence from African pastoral system also suggests that the incomes from non-pastoral activities are frequently invested in the livestock production system (Little 1992). It is also argued, that such income diversification can act as a means of preserving the herd capital. In a sense, income diversification among pastoralists does not necessarily mean that they are shifting their production base away from livestock. In this context, the role of non-livestock based income in pulling down the probability of migration in Banni may be recalled. Although it does not, *ipso facto*, corroborate the proposition about the possible role of income diversification in complementing the livestock sector, it does appear to be consistent with it when all the other results that point to the persistence of the pastoral system are also considered.

The relationship between risk and diversification seems to be straightforward in the case of pastoralists of Banni. In absence of agriculture in Banni, the herders wish to diversify their income sources, but it is controlled by many other variables like heterogeneity of ecosystems (grasslands) or socio-economic differentiation among the communities (mainly due to different economic status). The present study suggests that the rich and poor herders (or owners of different herd types) pursue diversification differently, as different groups do not perceive risks in the same way. Obviously, in the risk management strategies of Banni pastoralists, the income opportunity from the mesquite – *Prosopis juliflora* (realised at present through charcoal and NTFP) has an important role. Despite the economic significance of woody resource, the Banni herders still prefer grassland based pastoral mode of income generation. In fact, this study suggests that the management of mesquite is needed not only to improve the grazing potential of the Banni, but also as an alternative income channel to support the herders during periods of acute scarcity.

The overwhelming perception of the local people point to the possibilities for participatory management of the grassland as well as woody resource (i.e., treat it as an economic resource) in Banni region. On the other hand in case of Naliya, the pattern of resource dependency indicates that there is considerable scope for enhancing the economic outputs from the grassland. The findings clearly point to the need for a strategy to improve the synergy between agricultural and pastoral activities in Naliya.

From the vantage point of resource dependence, the poor as well as rich families of both the typologies remain dependent on the open access grasslands, though there are differences in the degree and seasonality of it. An interesting feature of Banni is that the dependence of richer families on grasslands is so high that because of resources shortages during lean periods, the larger herders have no option but to migrate with their herds to other areas, including Naliya grasslands. In the case of Naliya, despite large agricultural land holdings, the rich families having larger herds have greater dependence on grasslands in the absolute sense. Thus there exist significant differences between the poor and rich in their dependence on common resources. While poor families depend on these resources for their subsistence, the rich families, despite having with large herds and large land holdings, use these grasslands at enormous social cost to accumulate wealth.

The dependence of the poor on the open access grassland is consistent with the observations of Jodha (2001) that such resources in fragile ecological zones are of crucial importance to the poor. Beyond that, this study shows that in Naliya, the richest group with large irrigated landholdings garners the maximum benefit of social costs on grassland. The finding is similar to that of Nadkarni (1987) on the dependence of some agro-pastoral villages in Karnataka on forest resources. In that study, it was seen that while in absolute terms the richer farmers exploit the fodder from the forest much more than the poor, in relative terms, free grazing in the forest is vital for the survival of the livestock economy of the poor.

As far as management of these common resources is concerned, it is clear that while at the macro level the entire Banni can be seen as pastoral hinterland of Kachchh, policy makers and decision-makers must acknowledge that not everybody is in the same boat with regard to the economic risks they face or degree of dependence on the renewable resources (grass and wood) in Banni. There are clearly different economic strata as governed by the size and type of livestock asset and current level of economic use of *Prosopis juliflora*. Therefore it is important to recognise that while there are some rich sections among the Banni pastoralists, the region as a whole is characterised by a rather low quality of life. The literacy rates are dismally low, infant mortality rates alarmingly high, public infrastructure is virtually non-existent; schools are in pathetic state and primary health services nearly lacking. These pastoral communities exist in a highly marginalized state and overall economic improvement is needed to alter this.

On the other hand, in case of Naliya grasslands, the time of the use of the resources and proportion of the local population that depend on these resources for fodder values, is very crucial in view of its role in sustaining the biodiversity. The results presented indicate that the local people extract the maximum resources during post monsoon season, when the area is full of green grass. Incidentally, this is also the breeding season for rare and endangered birds. Therefore, the management goal here becomes one of ensuring the availability of suitable habitats for the wildlife and of rational use of the grass resources by domesticated livestock

Both Banni and Naliya situations point to the need for innovative and pro-active management regimes for the grasslands in both regions – one that will not only regenerate the grassland system, but also rationalise the economic activity based on woody resource in Banni and another that will improve the grassland system through of Naliya for both livestock and endangered wildlife. In both cases, the management strategy needs to be informed by the recognition that the key stakeholders have crucial economic interests in the resource regeneration and that the stakeholder involvement can be realised only by altering the open access regimes into one based on legitimate entitlements and usufruct rights. Despite the contrasts, there is a convergence in the management goals in the two typologies because of the sound economic and ecological rationale for grassland regeneration.

7 Modelling Resource Dynamics

7.1 Background

The Banni grassland is being rapidly transformed due to the woody invasion and, as pointed out before, the linear extrapolations of the changes in grassland can be quite misleading. There are tightly bound non-linear feedbacks associated with the economic returns, grazing potential of the grassland, the livestock numbers and extent of woody cover. The Naliya grassland is not so complicated and the empirical evidence also shows that there were no noticeable changes in Naliya in recent years. Considering the need to address the questions that requires understanding the dynamics of the renewal resources in Banni, we adopted a system dynamic modelling framework. However, the modelling effort presented here remains very much relevant even for the Naliya system, with requisite changes in the model parameters. In particular, were a woody invasion to occur in Naliya, as in Banni, and there are some indications of it, the model for Banni can easily be used to visualise the possible scenarios.

The Banni region of Kachchh was in the ecological sense, at least 50 years back, a pristine grassland-savannah system maintained as such by grazing. The peculiar geo-environmental conditions made the region unsuitable for economically sustainable activity other than livestock rearing. The grassland resources have in the last few decades been severely degraded by the synergetic effects of grazing and woody invasion. The woody invasion has been assessed using satellite imageries as well as field surveys. The woody invasion by the exotic mesquite – Prosopis juliflora has considerably shrunk the good grass cover. As in the case of well-known instances of invasions by species introduced into alien environments, here too the exotic invader has several characteristics that enable it to rapidly dominate through competitive advantage over the native species. The interim reviews had emphasised the considerable relevance of studying the dynamics of the ecology and economics in the context of the remnant pastoral economy characterised by open access grassland and the changes brought about by mesquite invasion of the grassland.

The simple ecological model proposed here attempts to capture the key features of the dynamics of the livestock, grassland and woody invasion incorporating the basic features of the linkages into a mathematical model.

What we are dealing with is essentially a remnant pastoral economy based on a pastureland degraded by peculiarities of the ecological conditions brought about by mesquite invasion and possible overgrazing. The mesquite invasion itself appears to be driven by free grazing livestock. Each animal in the herd acts as a highly efficient seed dispersal agent, spreading the seeds far and wide. However, more importantly, from an ecological-economics (EE) perspective, the determinants of behaviour of the system's ecological and economic variables are the peculiarities in the prevalent property management regime imposed on the natural resource base consisting primarily of the renewable biomass resources of the grassland and the woody biomass. The biomass production from the grassland – the input into the livestock-based primary economy – is referred hereafter as the grazing potential. The biomass resources are expressed in animal equivalent units or the biomass production per year that can sustain one Adult Cattle Unit[24] (ACU).

The woody biomass is another economically valuable renewable resource having such high fuel value that a large national market operates for the wood-charcoal or *kolsa* as it is known locally. The woody species is an exotic invasive species, which is recognised as one of the biggest threats to the native

[24] Refer Chapter 5 for definition

biodiversity. Despite its high economic value, and its adverse impacts on the local ecology, the prevailing legal framework prevents its economic exploitation or management by local communities. It exists by virtue of the legal status accorded to the region, as property 'owned' in an economic sense exclusively by the state. Despite certain ambiguities with regard to which agency of the state, has the right to exercise the exclusive ownership, the legal provisions allows the state forest department to control this resource and legally prohibit economic activities based on it. At the same time, private ownership of the land on which both these resources exist and compete is not allowed making the state the sole legal owner of the land and excluding any stakes for private individuals in the land resources. In contrast, the grass biomass exists as an open resource for free grazing livestock, with absolutely no restrictions on the access rights or any system of access fees or permits. Thus, as far as the livestock based economy is concerned, grass is a 'free good', or a resource that every grazier is free to harvest and nobody owns. It is no coincidence that the most valued asset of the grazier is the stock of living and moveable resource consisting of a variety of animal breeds, which are also producers. The 'bio-economic' problematic is characterised by the following peculiarities:

a) Animals are highly valued moveable property and producers rolled into one
b) While animals can freely graze and live off the grassland, land ownership is denied to the grazier
c) Grass, the primary input for the livestock-based production system exists in a state of open access, with each herder trying to maximise the consumption by his stock of animals
d) Woody cover which is both a threat to the biodiversity and ecology exists as exclusive property of the state
e) Invasion of the grassland by the woody species leads to continuous reduction of the grass resource
f) Animals act as the primary agent enabling the rapid invasion of the grassland by the woody species
g) Any removal of the woody invader is hampered by the legal/policy environment

The ecological, economic and property management regime poses an interesting problem into which much insights could be gained by the modelling of the ecological and economic behaviour. The essential feature of modelling effort is to capture the features introduced by the renewable nature of the resource base (grass and wood) and the population changes in livestock – the primary agency in the economic system. The controlling devices to alter the time paths of the ecological and/or economy are the management strategies on livestock, interventions to improve the grazing potential, economic activities based on woody species, and increasing grass cover by arresting woody invasion or reclaiming back woody area as grassland.

7.2 Ecological-Economic Modelling - Conceptual Overview

The modern econometric analysis of natural resource problems is considered by many to have its origins in the work of Hotelling (1931), which emphasises the role of an inter-temporal or dynamic approach (Hanley *et al*, 1997). The dynamics of the grassland resource economics is being examined using an approach proposed by Perrings (1997). The work of Perrings integrates an ecological model of rangeland resource dynamics into an economic analysis using an econometric approach, specifically one using utility function, under an optimal control theoretic perspective. Environmental stochasticity is also introduced into the approach using parameters with a non-zero standard deviation. The resource dynamics in the work of Perrings is based on two state variables: a) Livestock present in a year on the rangeland and b) the carrying capacity of the rangeland or the maximum cattle that the rangeland can support in that year. Unlike in the usual ecological models, where the carrying capacity is assumed to be a constant, it is assumed to be a state variable and a function of both time and stocking level, since stock of livestock alters the grazing potential. The utility function that incorporates the costs and benefits of livestock off-take is examined in the light of the dynamics of rangeland resources mediated by stochastic effects, particularly erratic rainfall.

The logistic growth model is the natural starting point for modelling natural resource dynamics. It is assumed that under the very best of conditions, there is an upper limit or carrying capacity to the grassland resources per unit area. The grassland resource is expressed in terms of grazing potential or the annual biomass production necessary to satisfy the yearly intake of one 'standard' adult cattle or sustain one ACU. It is assumed that the carrying capacity of the region determines the maximum allowable stock of animals grazing on the system, although in practice, depending on the rainfall and grassland resources, the actual stocking levels could exceed this limit, inflicting very high levels of grazing pressure on the grassland.

We have adapted this approach to study of the dynamics of ecological-economic system in the Banni region. For this we propose a modelling framework with three state variables:

a) Livestock present on the grassland system
b) Grazing potential of the grassland and
c) Area invaded by woody species displacing grassland.

The total area that can be covered by grass and woody species is constant while the grazing potential is both a function of livestock levels and extent of woody invasion. The variability of rainfall and stochastic effects are incorporated in the same way as is in Perrings. Growth of livestock is assumed to be function of rainfall, mean availability of graze and the effective grassland area. The property rights regime is assumed to be essentially open-access, implying that there are no well defined economic or social incentives for the pastoralists to take the external costs of resource degradation into their stocking strategies.

The utility function is based on the benefits and costs of maintaining livestock. We also propose to address the effects of woody species on the utility function. The cost of holding livestock includes recurring costs of labour and maintenance intermediate inputs. The short and long-term fate of the grassland is assumed to be irrelevant to the utility maximising decisions of livestock owners. The benefits accrue from the sale of milk and milk products, and animals, besides certain specialised role in cultural transactions.

The approach of Perrings (Perrings, 1994, 1997; Perrings and Walker, 1995; Perrings and Stern 2000) for the dynamics of pastoral economy and rangeland resources differs from many prevailing models, by treating the carrying capacity of the range itself as a dynamic variable. There are also other studies such as that of Braat and Opschoor (1990), which have tried to model the risks in the pastoral economy driven primarily by the incomes derived from animal sales and high environmental uncertainty. Some of the ecological parameters of the model are treated as random variates with the same coefficient of variation as of rainfall. The model presented here is based on the approach for the modelling the dynamics of rangeland bio-economics discussed by Perrings (1997). The key elements for the specification of the dynamics of a pastoral-economy and ecology in this manner are:

a) Current state of the variables such as herd size will affect the future rangeland carrying capacity
b) High degree of variance determines the evolution of the system and such variations randomises the trajectories of all variables over time
c) Very high degree of uncertainty that are attached to the future value of state variables

The first of these imply that the current carrying capacity of the range is not independent of the past activities on the rangeland and current herd size is dependent on the past changes in the carrying capacity. This makes the problem somewhat different from the usual problems of renewable resource studied within the framework of optimal control theory (Perrings, 1997). The second is concerned with random variations in the system. The third relates to the high degree of uncertainty associated with the resource. The main source of stochastic behaviour in the system is the natural variability of rainfall. The effect of variance in rainfall on herd size and carrying capacity is not instantaneous, but involves usually a seasonally determined time lag. The variance in the rainfall gets transferred to the parameters that determine the dynamics of the resource resulting in high fluctuations in the state variables. The variance needs to be considered in the model by treating the nominal values of parameters as means of a normally distributed random variable with variance equal to that of annual rainfall.

The ecological system discussed here is characterised by the presence of two renewable ecological resources: a) grass and b) woody biomass. While the grazing potential of the grassland and thereby the carrying capacity of the grassland is highly dependent on rainfall, the woody species does not exhibit such dependence. Accordingly, the parameters of grass are treated as normally distributed random variables, while that of woody species are devoid of random variations. However, the coupling of the rate equations does introduce stochastic behaviour into the overall dynamics of both.

A peculiar feature, which is central to the ecological system studied here, is the degradation of the grassland by the rapid spread and establishment of the woody species, which has assumed the form of an exotic invader. The natural ability of the woody species – *Propsopis juliflora* – to spread and establish are rather limited in the absence of an agency that can assist it in this process. Wild or domesticated herbivores are known to act as vectors for the rapid spread and establishment of such woody species, increasing the rates of establishment and spatial spread into invasive scale as compared to the unassisted negligible rates. In the case under study, the large stock of domesticated livestock acts as 'vectors' for the invasion by the woody species.

The carrying capacity per unit area (per ha) of the region, κ, in any year, t, is not a constant but depends on the state of the resource and the grazing pressure on it in the previous year. The livestock in any year, t, will depend on the level of grassland resource and is assumed to follow a logistic growth. At present, income from milk production is the key driving force for the livestock based economy. It is assumed that a portion of the grazing potential of the region is consumed for milk production and this constitutes an additional harvest of the grazing potential over and above that needed for mere maintenance of the herd. The extent of harvest is central to the milk-based economy with free-grazing cattle under conditions of open access. The current carrying capacity, κ, is therefore, diminished by an amount equal to that harvested. Thus, as the individual herder would try to harvest more by getting more animals to graze, the capacity of the grassland to support more livestock will tend to decrease. Under conditions of open access, each herder would try to extract the maximum grass resource resulting in higher grazing pressure and lower graze availability per animal. This would also entail lower milk production per animal.

The region of Banni is essentially an open access property regime. Outside the region, the property rights are well defined. While, the Banni land is technically owned by the government and is even covered by the protective provisions of the Indian Forest Act (1980) severely curtailing resource use, the grass is effectively an open resource without any enforcement of legal restrictions on its extraction through harvesting or free grazing. There are neither any restrictions nor access fees on grazing within the region, while the harvesting of woody biomass in any form is formally banned.

Neither free grazing by animals nor invasion by woody species occur in an unrestricted manner outside the limits of Banni, since those areas are not managed as open access. The total area for grass plus woody cover is, thus, limited to Banni[25]. Further, the highly saline tracts of the region are unsuitable for grasses. The total area considered in the model is, therefore, the area suitable for grasses but may have been or is likely to be invaded by woody species.

The ecological-economics model proposed is an attempt to capture all the key features of this renewable natural resource based economy. The striking peculiarity of the system, from the ecological-economics perspective is the dual property management regime (PMR) that exists over the

[25] It is not argued here that woody invasion does not occur outside Banni. On the other hand, invasion is, indeed, a problem on all public or quasi-open access land outside Banni as well. However, the total area of Banni is limited by its bounds and there is no reason to envisage expansion of the area beyond the current limits.

two economically important natural resource bases: a) grass resources in a state of open access management regime and b) the woody biomass maintained as a protected resource by the legal status of the area. We call this dual mode of resource management not with regard to the legal status of land, which remain unchanged, as protected forest land, but in respect to the renewable biomass resources of grass and wood. However, there is a subtle but important distinction between grass and wood in as much as they are resources, which can be used for economic activity. Customary rights of free grazing are granted over the grass, while any economic activity in the woodlot including the extraction of NTFP is strictly forbidden. The model, *inter alia*, would also throw some light into the close connection between the resource dynamics and the existence of the dual property regimes. In sharp contrast to the high stochastic behaviour associated with the grassland system, the dynamics of woody species is characterised by the near absence of such variance, reinforcing its invasive role in the ecosystem.

7.3 Mathematical Model of Resource Dynamics

Considering the characteristic features of the system, the model proposed here differs from other models of rangeland carrying capacity by the inclusion of the invasion of grassland by woody species under the dual PMR discussed earlier. The model proposed consists of a system of three coupled differential equations for the continuous case and the equivalent difference equation for the discrete case of year-to-year changes. The model is employed in this study, more as a heuristic tool than as a predictive instrument, to gain insights into the dynamics of the system. The values and outputs are, therefore, indicative rather than approximations of the real-life values. More importance is attached here to the inter-linkages among the herd size, grassland grazing potential and the extent of woody cover. There are possibilities for formulating a more complex model to better approximate real life conditions, if sufficient data is available on the different aspects of the system. Instead, we have tried to capture the essential elements, adhering to the principle of parsimony in modelling or maximising insights from the simplest of models. The major considerations that have weighed on the modelling effort are summarised below:

a) Ecological model must be simple and yet realistic enough to contain the 'core' features of ecological or resource degradation problem.
b) Economic model should help in arriving at appropriate production and utility functions by incorporating problem-specific state and control variables from the mathematical model for ecological dynamics
c) Combination of ecological and economic models must allow for the computation of net present values over various time horizons
d) The problem formulation must serve as a simple and intuitive heuristic tool to explore the linkages between the ecological and economics variables in a clear theoretical framework
e) Numerical simulation of the model should help in arriving at inferences on the modes of resource management and policy by simulations using appropriate choice of parameter values and constraints

The basic assumptions underlying the model are:

a) Grassland resource based economy is made of identical price-taking livestock owners
b) Livestock owners enjoy open access to the grassland resources
c) Livestock owners try to maximise the utility derived from the profits of livestock production without regard to the future state of the grassland system
d) The livestock depends almost exclusively on the grassland systems
e) The grassland systems exist in a state of ‘Open Accesses’ property regime without any significant restrictions on access to grazing
f) Grass availability is the major constraint to herd expansion

g) Livestock provides a range of benefits to herd owners mainly from the sale of milk, milk products and sale of animals, especially certain breeds of draught animals
h) There are no barriers to the spread and growth of woody species in the areas covered by grass
i) Variability of the rainfall is a major constraint on grassland regeneration
j) Low rainfall conditions do not have as significant adverse effect on the spread of woody species as on grasses

The key variables and parameters employed in the model are listed below:

A	=	Total area with grass potential
X	=	ACU dependent on the system at time, t
W	=	Area under woody cover at time, t
G	=	Area under grass cover
κ	=	Grazing potential per ha of the grassland (a normally distributed variable)
μ	=	Maximum grazing potential in ACU per ha of the grassland
α_i	=	Relative growth rates for x, κ and w (i=1,2,3; α_i are normally distributed random variables with cv equalling that of rainfall)
γ	=	Grazing potential per ha loss per animal due to grazing pressure
η	=	Inhibition of grassland regeneration due to woody cover proportional to the woody cover ratio
ε	=	Enhanced rate of spatial spread of woody cover per 1000 ACU

The total area,

$$A = G + W \tag{7.1}$$

Alternatively,

$$G = A - W \tag{7.2}$$

G = A-W will be non-negative (A-W) $\geq$ 0, since under the best possible conditions the entire area could be under grass cover and it can never exceed the total area A.

In these expressions, A is the total area that can support grasses; G is the area currently having grass cover and W is the area invaded by woody species. An area will be considered as 'invaded' by woody species only when the woody species is well established to the extent of dominating that part of the landscape. These may be considered as roughly equivalent to the portions identifiable as dense woody cover in satellite imageries. The area under grass cover, however, consists of a mix of patches totally covered by grass and those with a scattering of woody species at various stages of growth. The grazing potential of the region, K, is the product of grazing potential per unit area and the area under grass cover:

$$K = G*\kappa = (A-W)*\kappa \tag{7.3}$$

Since, G and κ are non-negative, K is also non-negative: K $\geq$ 0.

The ordinary differential equation (ODE) for livestock can be expressed as:

$$\frac{dX}{dt} = \alpha_1 X\left(1 - \frac{X}{K}\right) \tag{7.4}$$

Re-writing, K using (7.4):

$$\frac{dX}{dt} = \alpha_1 X \left(1 - \frac{X}{(\mathrm{A} - \mathrm{W}) * \kappa}\right) \tag{7.5}$$

The ODE (7.5) represents the resource limited, logistic growth of livestock with a net relative (exponential) growth rate of α_1. The logistic growth used in (7.5) is often used model the carrying capacity (κ) concept. Under good conditions, $\alpha_1 \geq 0$, and herd size tend to rise and under adverse conditions or severe resource scarcity, $\alpha_1 \leq 0$, there will be decline in the stock.

The dynamics of grassland resources could also be represented by a logistic growth function and the ODE for its rate of change in the grazing potential is given by:

$$\frac{d\kappa}{dt} = \eta \alpha_2 \kappa \left(1 - \frac{\kappa}{\mu}\right)\left(1 - \frac{W}{A}\right) - \gamma \frac{X}{A} \tag{7.6}$$

In equation (7.6), α_2 is the intrinsic relative growth rate (ACU per ACU per year), μ is the maximum carrying capacity under the best possible conditions, γ is the loss in grazing potential per ACU, and η ($0 \leq \eta \leq 1$) is the inhibition of the regeneration of grazing potential in proportion to the woody invasion.

The increase in woody cover is assisted by the seed dispersal by livestock and germination rates considerably enhanced by the process of passing through the animal's digestive system. In addition, the survival probability and establishment rates are multiplied by the deposition of the seeds in dung or animal droppings. In the situation being studied, the spreading outside the potential grassland limits is not feasible due to the limitations imposed by the property management regime. The effect of animals acting as agents for spread of woody species is incorporated as a factor, ε, that increases the natural rate of spread in proportion to the livestock. The rate of spatial spread depends on the perimeter of the existing woody cover, since only spreading outwards away from the periphery can qualify as spreading. The equation for increase of woody cover can be expressed as:

$$\frac{dW}{dt} = \alpha_3 \sqrt{W} \left(1 - \frac{W}{A}\right)(1 + \varepsilon X) \tag{7.7}$$

7.4 Management/ Control Variables

The state variables X, κ, and W are restricted to non-negative values for all ecologically meaningful cases. In general, these equations could be modified with the addition of additional terms, Q_1, Q_2, Q_3 and Q_4 to these equations, where the Q_i represent harvest or off-take or control variable. In general, each $Q_i \leq 0$ or $Q_i \geq 0$. In the equations that follow, Q_1 is the off-take of livestock in ACU, Q_2 is the grazing potential removed for milk production, Q_3 is the woody cover from which charcoal is produced resulting in a temporary reduction of the woody cover and Q_4 is the area from which woody cover is reduced by uprooting in a given year. These coupled ODE's may also be rewritten as difference equations with these additional terms:

$$X_{t+1} - X_t = \alpha_1 X_t \left(1 - \frac{X_t}{(\mathrm{A} - \mathrm{W}_t) * \kappa_t}\right) - Q_1 \tag{7.8}$$

$$\kappa_{t+1} - \kappa_t = \eta \alpha_2 \kappa_t \left(1 - \frac{\kappa_t}{\mu}\right)\left(1 - \frac{W_t}{A}\right) - \gamma \frac{X_t}{A} - \frac{Q_2}{A} \tag{7.9}$$

$$W_t + 1 - W_t = \alpha_3 \sqrt{W_t - Q_3} \left(1 - \frac{W_t}{A - \theta\ Q_4}\right)(1 + \varepsilon\ X_t) - Q_4 \qquad (7.10)$$

Equation 7.10 calls for some discussion. The two control variables, Q_3 and Q_4, correspond to woody cover used for charcoal making and the area from which mesquite is uprooted, respectively. The use of woody biomass for charcoal making does not change the invaded status of the area. It only reduces woody area contributing to invasion at the given time. Therefore, the woody invasion is proportional not to W_t, but to W_t-Q_3. The control variable Q4 reduces Wt itself. If re-invasion of the area cleared of mesquite (Q_4) is to be prevented, that much has to 'closed off' to woody invasion, which would mean that the area available for woody species to spread in now reduced by that amount. This is true only if re-invasion is controlled. The re-invasion control is signified by θ (equals either 0 or 1). If θ = 0, re-invasion can occur; if θ = 1, then re-invasion is kept in check. The area cleared of woody cover through uprooting, with or without controlling reinvasion, becomes an addition to grass cover.

Positive Q_1 implies net off-take of livestock and conversely, a negative Q_1 represent addition or restocking from outside. However, at no time can the positive off-take exceed the current stock and any addition to the stock should not exceed the maximum carrying capacity of the system. In many rangeland economies, the off-take of livestock is the key economic variable central to the livestock-based income as in the case of the model proposed by Perrings (1994). Even in the case of Banni, some time in the past, the sale of animals for draught power provided a substantial income stream, perhaps more lucrative than sale of milk and milk products as is the case at present. In most rangeland economies, off-take of animals is for meat and the stocking strategy in such a case is aimed at maximising the income from sale of animals for meat. However, in Banni, traditionally, the herders were expert breeders who bred and sold specialised breeds and not for slaughter.

The cultural and economic conditions such in this study region forces different kind of economic returns for the pastoral economy. Over the last three decades or so, the main livestock based income is from the sale of milk and milk products, with supplementary incomes from sale of a small percentage of specially bred animals for draught power. In such conditions, the off-take is not very large and constitutes a very small percentage as borne out by the data from household surveys. Therefore, we have assumed that every year a small percent of the stock is sold as beasts of burden outside Banni. The bulk of income is from milk and milk products, which is realised by using a part of the current grazing potential to enhance milk production. As remarked earlier, under conditions of open access, this assumes the form of competitive grazing resulting in higher grazing pressure and likely reductions graze availability per animal for milk production. The grazing potential harvested for milk is denoted by Q_2.

From the management perspective, the 'off-takes' from woody cover are of considerable significance. It must be kept in mind that there are two kinds of 'off-take' from in this context – one of harvesting the woody biomass to be used as fuel or timber and second, that of either eradicating woody cover from parts of the area or actually planting more woodlots as plantations. These two cases of 'off-take' are denoted by Q_3 and Q_4: a) Q_3 for harvesting of woody biomass from a portion of the woody cover and b) Q_4 for reducing woody cover through uprooting. These needs to be better understood in ecological and management terms. The harvest of woody biomass is a well-developed income stream in the region, albeit illegal under the present legal regime. On an average, this can be done in a 3½-year cycle, with assured re-growth of the woody cover. Even after the most intensive lopping, woody cover is restored 3½ to 5 years. Under this system, while the area remains infested by woody species, it ceases to contribute actively to the invasion for a few years due to absence of seed production. On the other hand, complete removal of woody cover by uprooting would restore the grass cover, adding to the grazing potential. Conversely, any conversion of grass cover into wood lot by plantations ($Q_4 < 0$) would reduce the grazing potential and enhance the invasion of grassland by woody cover. In the absence of a management regime, the area from which woody cover was uprooted can be re-invaded.

The present state of woody invasion is the result of a management strategy with Q_3=0 and negative Q_4 (establishing woodlots). In order to improve the grazing potential, we need to consider the ramifications of Q_3 and Q_4. In the numerical solutions under different management scenarios, we express the off-takes as follows:

$$
\begin{aligned}
&Q_1 = q_1X, \; (Q_1 \geq 0, q_1 \geq 0, X \geq 0) \\
&Q_2 = q_2\kappa \\
&Q_3 = q_3W, \; (Q_3 \geq 0, q_3 \geq 0, W \geq 0) \\
&Q_4 > 0 \; (Q_4 \geq 0)
\end{aligned}
\tag{7.11}
$$

The parameter q_1 is an approximation of the prevailing ratio of animals sold to total stock, q_2 is an approximation of the likely fraction grazing potential used for milk production and q_3 is the fraction of woody cover from which woody biomass is harvested for fuel and timber. The values used in the simulations are indicative, nominal values and are not necessarily derived from empirical data.

7.5 Deterministic Trajectories

The trajectories of the model variables can best understood by examining the deterministic model and the model behaviour for different range of parameter values. If the off-take terms are excluded, the model behaviour of the non-linear coupled equations tends to be complex if we consider the entire parameter space. Without the woody invasion (3rd equation), systems of this kind equations can give rise to asymptotic convergence to equilibrium or stable points, through damped oscillations. For certain set of parameter values, the same non-linear system could exhibit 'deterministic chaos' or extreme sensitivity to initial conditions, yielding non-convergent solutions. A detailed mathematical analysis of the system of equations is beyond the scope of this work. Suffice it to state here that the in the absence of any factors inhibiting the spread of woody species the obvious asymptotic behaviour of the three variable system is the certain death of grassland and the complete dominance by woody species. In that state, livestock cannot exist due to the absence of grazing potential.

The presence of woody-invasion dramatically alters the trajectories by a secular decline in the grass cover and consequent changes in X and κ. The rate equations have maxima/minima at points determined by the equations:

$$
\frac{\partial}{\partial X}\left(\frac{dX}{dt}\right)=0\,;\; \frac{\partial}{\partial X}\left(\frac{d\kappa}{dt}\right)=0\,;\; \frac{\partial}{\partial X}\left(\frac{dW}{dt}\right)=0 \tag{7.12}
$$

The rate of growth of grazing potential is maximum at $\kappa = \mu/2$. The maximum sustainable yield is possible at the ACU value corresponding to this point on the trajectory.

The system of coupled ODE or the equivalent system of difference equations could be solved numerically to obtain the time trajectories and understand the system behaviour. Since management or control options are discrete events such as off-takes in a given year, the difference equations (7.8, 7.9 and 7.10) are solved numerically to generate the time trajectories.To better understand the dynamics of the non-linear system, the solutions are first studied with constant values of each parameter. The system is also solved numerically later after introducing random variations to the parameters that are normally distributed random variates. As remarked earlier, the nominal values of these parameters are the mean values for in a normal distribution with the coefficient of variance (cv) equal to that of rain. The nominal values used for the standard run or the base line simulations, which approximate the current conditions in the Banni region, are given in Table 7.1. The time behaviour of the system is discussed using the computed time series of state variables.

The parameters used in the baseline are estimated from known secondary data. The total potential grassland area is derived from various reports on Banni. It is the total area of Banni excluding highly saline tracts, where grass cannot grow well. The relative growth rate of herd (α_1) is an approximation from the estimated from the livestock census data, from the years in which livestock recorded increase. The relative growth rate of grazing potential (α_2) is estimated from the various ecological and physiological studies on grasses. The natural rate of woody invasion (α_3) is estimated from the few studies on woody invasions in similar environments. There is no study on Banni, which gives an estimate of the natural spread of *Prosopis juliflora* in the absence of herbivores. We have also considered the actual woody cover that a full-grown bush can have and the area over which seeds can be dispersed without the aid of animal vectors. The factor enhancing the rate of spread of woody cover above the above the natural rate (ε) was inferred from satellite imagery data, which gives the actual spread in the presence of livestock. Two parameters, inhibition of the grazing potential per ha by woody species (η) and the loss of grazing potential per animal (γ) are not based on any direct empirical data. The value given to γ is in the same range as employed in the work of Perrings, while value assigned for η is an informed guess.

Table 7.1 Parameters used in the baseline simulations

Parameter	Value	Remarks
A	160,000	Approximately the total extent of potential grassland in Banni, excluding parts of the region not very suited for grass (ha)
α_1	0.2	Relative growth rate of herd (exponential rate of increase in herd size relative to previous year's herd size); The value used is the mean of normally distributed random variable with CV that of rain
α_2	0.4	Relative growth rate of grazing potential per ha (exponential rate of increase GP per ha relative to previous year's GP per ha expressed in ACU) The value used is the mean of normally distributed random variable with CV that of rain
α_3	0.001	The natural relative rate of spread of the woody species without animals acting as dispersal agents. It is not a random variable
ε	0.0004	The enhanced dispersal rate of woody species by herbivores; increase in dispersal coefficient per ACU
η	0.75	Inhibition of the regeneration of grazing potential per ha due to woody species
γ	0.1	Loss of grazing potential per animal
M	0.8	Maximum grazing potential per ha
X(0)	20,000	Initial value for livestock (ACU)
K(0)	0.6	Initial value of grazing potential per ha (ACU/ha)
W(0)	128,000	Initial value of woody cover (ha) or 80% cover of potential grassland

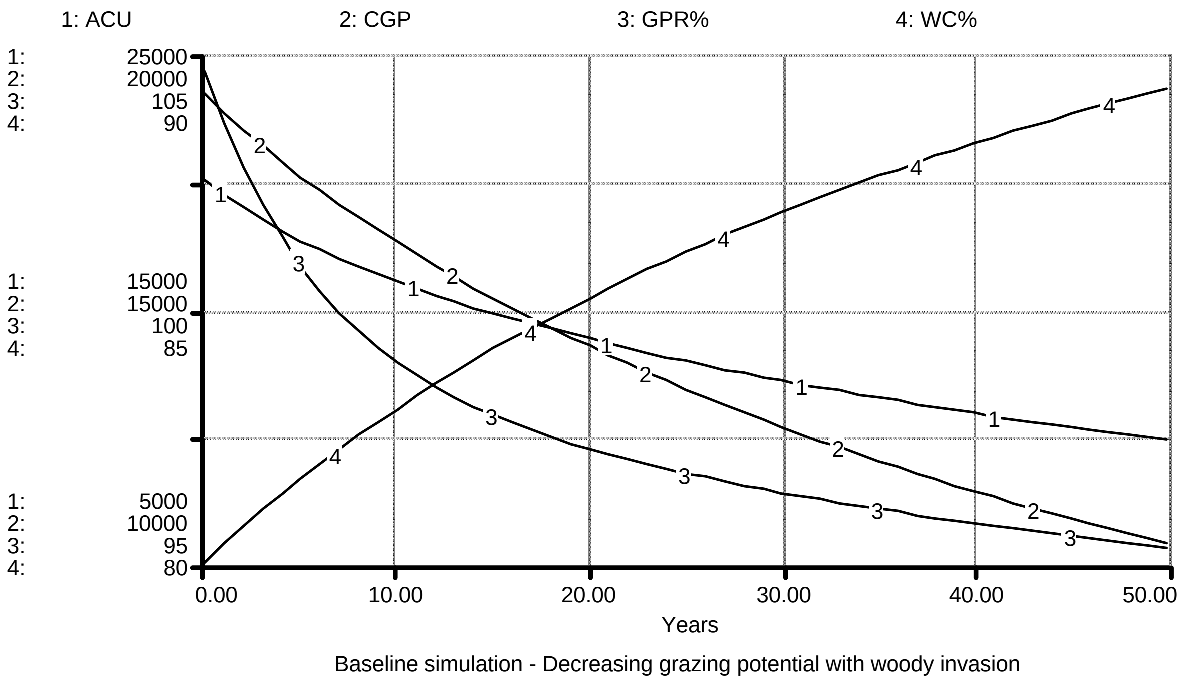


Fig. 7.1: Baseline simulation: Trajectories showing secular increase in woody cover and decline in grazing potential (1: the livestock numbers in ACU; 2: CGP, the current grazing potential; 3: GPR%, the grazing pressure or ACU to CGP ratio in percentage); 4: Percentage woody cover

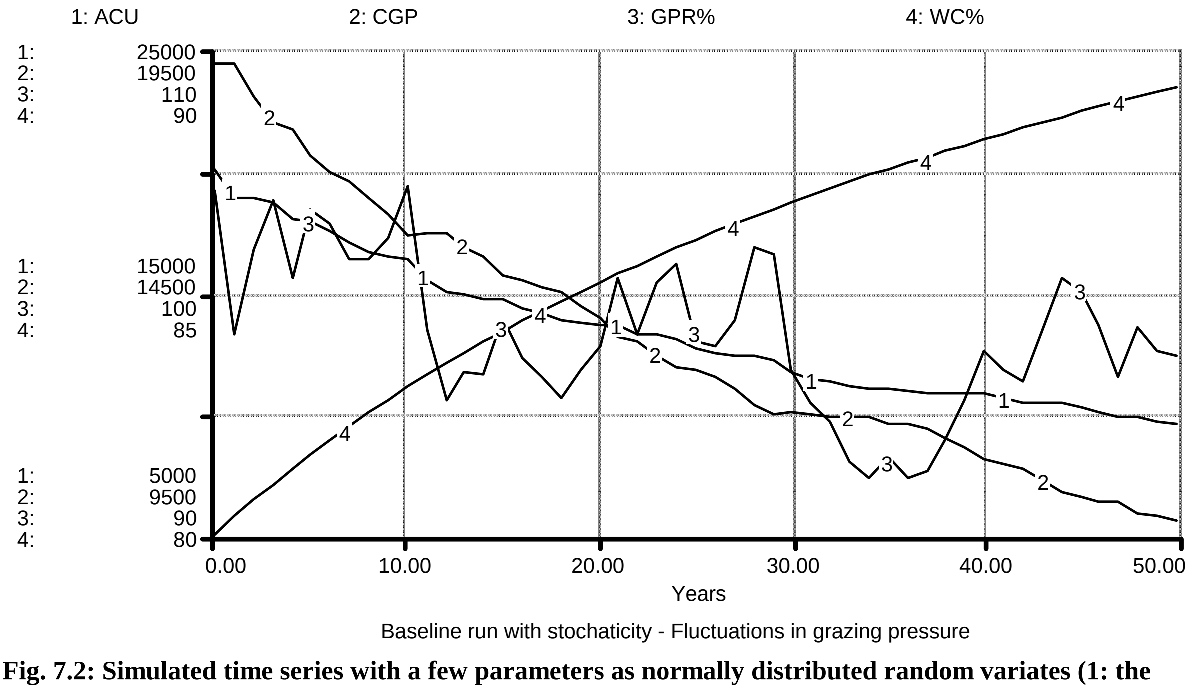


Fig. 7.2: Simulated time series with a few parameters as normally distributed random variates (1: the livestock numbers in ACU; 2: CGP, the current grazing potential; 3: GPR%, the grazing pressure or ACU to CGP ratio in percentage); 4: Percentage woody cover

The plots (Fig. 7.1 and 7.2) show that with uncontrolled spread of woody cover, the grass cover is lost continuously resulting in declining grazing potential. The grazing pressure tends to be high under the assumed set of parameter and initial conditions.

7.6 Parametric Sensitivity

The response of various state-variables to variations of parameter values gives insights into the relative importance of different parameters in the system of coupled equations. Figure 7.3 shows sensitivity of the number of livestock (ACU) to variation in the regeneration rates of the grazing potential. The parameter ε represents the role of herbivores in spreading the woody cover and it constitutes a strong positive feedback increasing the woody cover with increase in animal population, which in turn accelerates the depletion of grazing potential. The parameter γ denotes the grazing potential required per ACU, which has a high negative feedback on the grazing potential, depleting it with increments in the ACU, ultimately reducing the number of livestock that can be sustained on the grassland. The increments in animal stock reduce grazing potential synergistically by the role of these parameters.

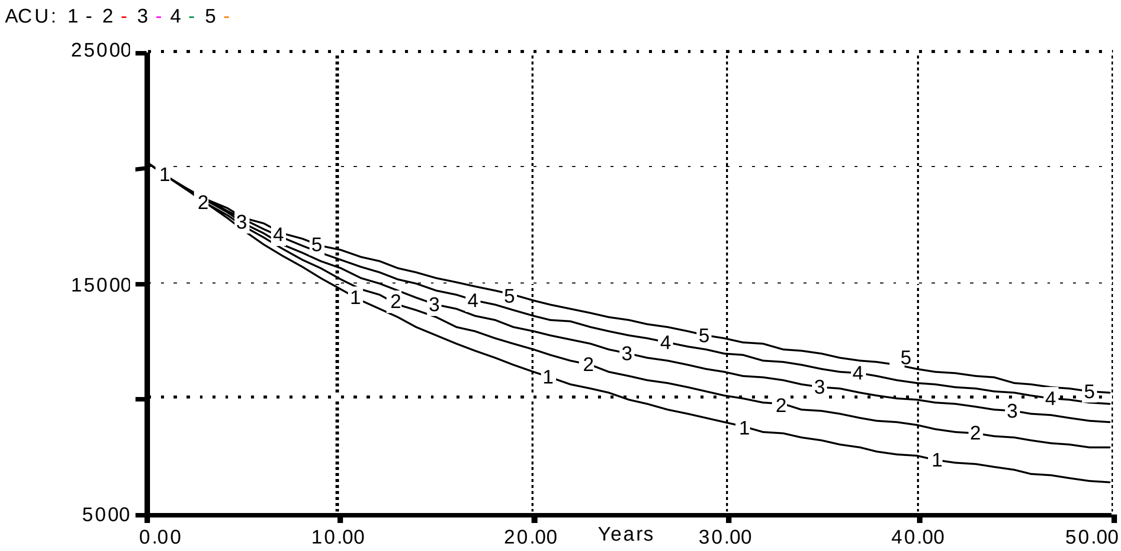


Fig. 7.3: Sensitivity of stocking level to grazing potential regeneration rate. Curves 1 to 5 represent sensitivities to α_2 = 0.05 to 0.45, in steps of 0.1

The rate of regeneration of grazing potential is denoted by the parameter α_2 in the ecological model. The regeneration rate is highly stochastic, being highly dependent on the rainfall and aridity. In addition, high grazing pressure, i.e., large ACU/CGP ratios, leads to fast depletion of the grass cover, and severely hampering the natural recruitment and seed production by grass. In fact, prolonged overgrazing tends to bring about changes in the species mix of the rangeland and is known to favour the dominance of so called 'unpalatable' grass species. The sensitivity plot (Fig. 7.3) shows that while increments in regeneration rates do help in sustaining larger herds, the marginal increase in the herd size sustained per unit increase in regeneration rate tend to fall at higher values of α_2 as evident from the reducing gaps between upper curves.

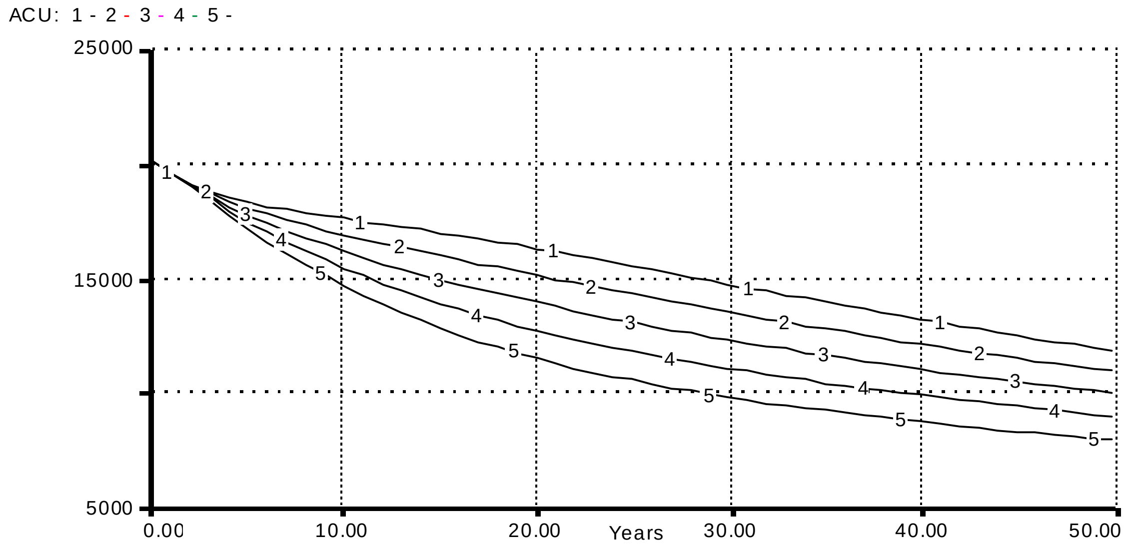


Fig. 7.4: Sensitivity of ACU to grazing potential loss per ACU. Curves 1 to 5 represent sensitivity to γ (0 to 0.2; steps of 0.05)

The grazing potential lost per animal is denoted by the parameter γ in the model. The sensitivity plots (Fig. 7.4) show that increments in graze requirements per herbivore, leads to progressive decline in the number of livestock that can be supported when all other condition remain unchanged in the system.

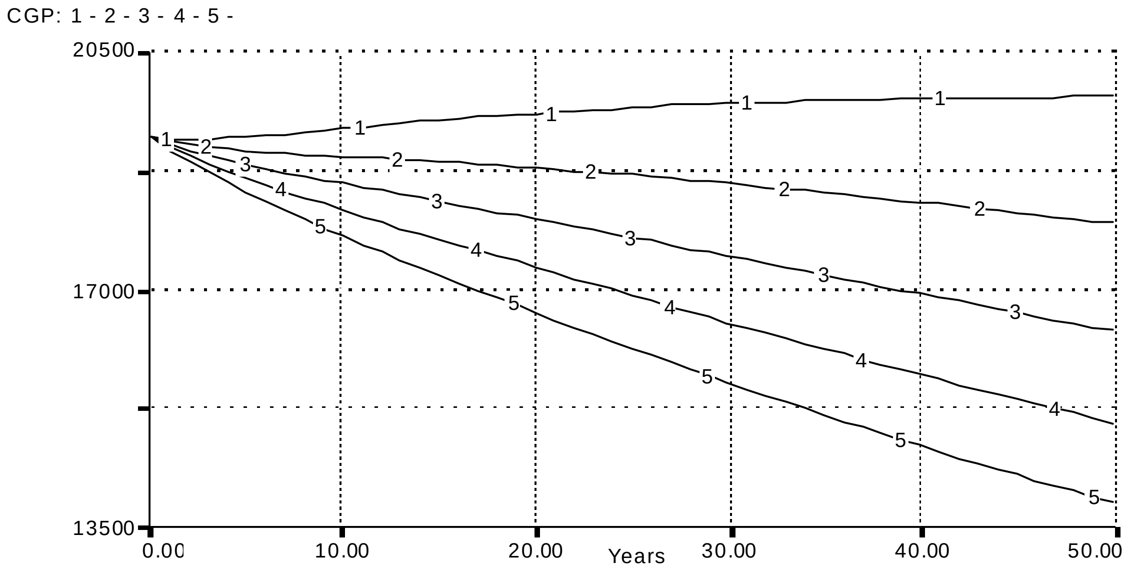


Fig. 7.5: Sensitivity of CGP to woody cover expansion rate per ACU; ε = 0.0 to 0.2 in steps of 0.05 (curves 1 to 5)

Spatial expansion of woody cover is negligible and the rapid spread takes place by the herbivores acting as vectors. The sensitivity plots (Fig. 7.5) depicts how small increments in the animal assisted rate of spread of woody cover leads to very large decline in the current grazing potential [CGP = κ(t)G(t)]. The parameterisation incorporated in the model is, thus, able mimic the role of herbivores as vectors for woody cover increase.

Understanding the sensitivity of the state variables and derived variables such as the current grazing potential to the control or management variables can provide valuable insights into how the system would behave under different policy scenarios. With this objective, sensitivity of the key system variable – CGP, the current grazing potential of the region [= $\kappa(t)G(t)$] – has been examined. The response of CGP to variations in Q_1, Q_2, Q_3 and Q_4 were simulated for the baseline parameter set. The resulting parametric sensitivity curves are depicted in Fig. 7.6 to 7.9.

The survey data analysed in this study and the secondary sources confirm that sale of animals, though important, involves only small numbers and unlike in some of the rangeland economy models proposed for the arid regions in Africa, the off-take is a economic activity on a much smaller scale in the study region. Unlike off-takes involving large numbers sold for meat, the turnover of animals in Banni region is the trade of either bulls for animal power or animals that are good milk producers. This was an important traditional economic activity of the old Banni. However, at present this plays a small role in the livestock based economy, since the demand for animal power has fallen drastically. At present, the positive off-take (sale) does not appear to exceed 2 to 5% of the stock. Increase or decrease in this has implications for both incomes and level of grazing pressure. The sensitivity plot 7.6 shows that even the low out flow rates (0 to 8%) tend to significantly improve the grazing potential in the long-term.

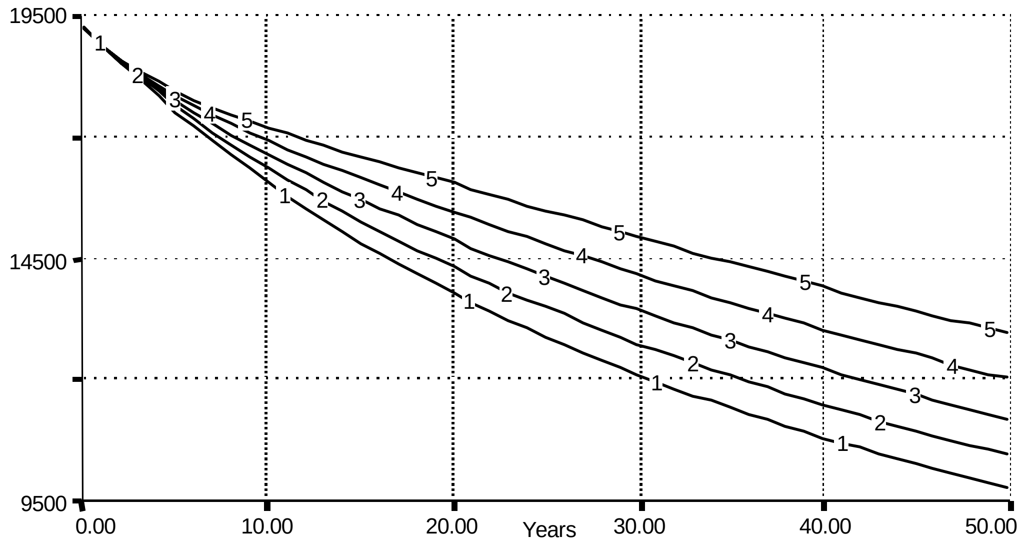


Fig. 7.6: Sensitivity of CGP to Q_1 (% ACU off-take/year; 0 to 8%, in steps of 2%)

The dominant economic activity in the region is based on milk production, which is possible only by additional uptake or consumption of grazing potential. The additional need for grazing potential for milk production is represented by Q_2 – the fraction of the grazing potential utilized for milk production. The sensitivity plots show that the model does exhibit this behaviour in a satisfactorily.

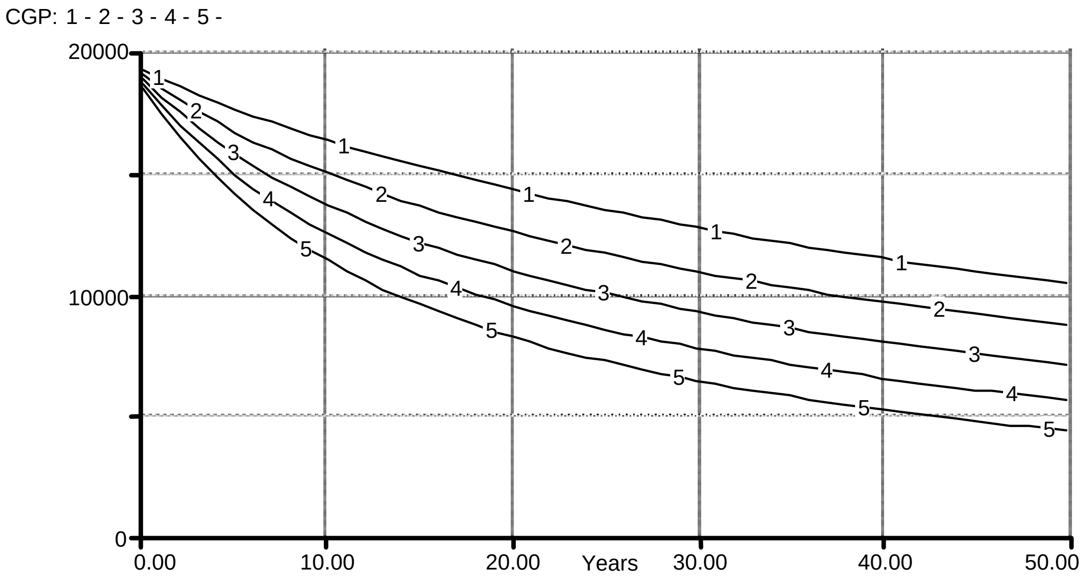


Fig. 7.7: Sensitivity of CGP to Q2 (% GP harvest per ha per year; 0 to 4%, in steps of 1%)

Another important control variable of high economic significance is Q_3 or the extent of woody cover, which may be used for wood-charcoal or kolsa making. The process involves near total lopping of the woody cover and conversion of the wood into charcoal by incomplete combustion of the wood. The bushes lopped in this manner grow back with considerable vigour, making it possible to sustain the activity in 3½ to 5 year cycle. However, this would reduce the woody area that is expanding every year, since a portion is devoid of above ground woody biomass that can produce seeds. Since the lopped area recovers, large a reduction in woody cover is not expected to occur in the long-term effects due to this activity. However, it could have high economic significance due to the economic returns from the wood-charcoal sector and marginal decrease in the rate of spread of woody cover leading to slight improvement in the grazing potential (CGP) and the economic returns thereof.

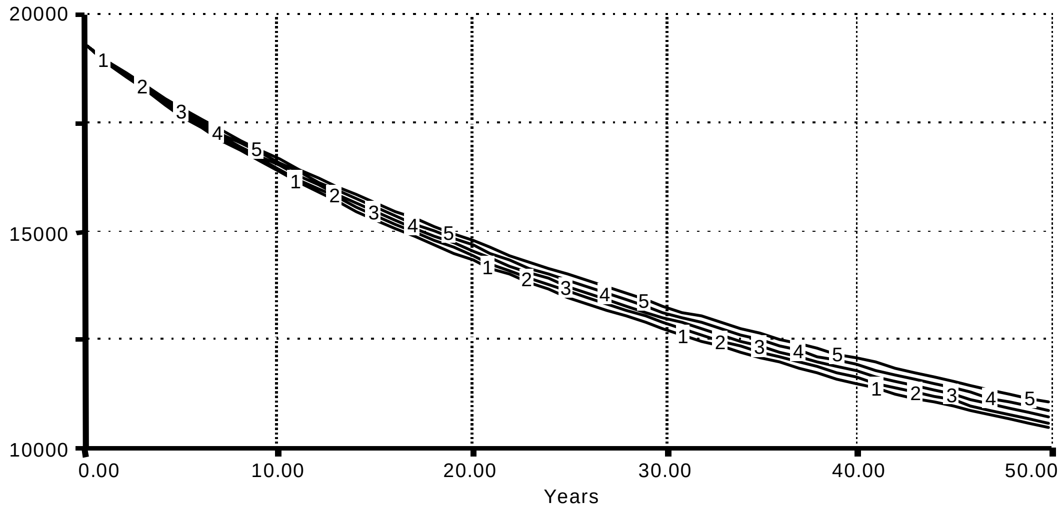


Fig. 7.8: Sensitivity of CGP to Q_3 (% woody cover allowed for charcoal making per year; 0 to 20%; Step 5%

Central to the grassland management under the present conditions is the reclaiming of grass cover lost to woody invasion and restoring it to the livestock-based economic sector. The control variable Q_4 –

the annual rate of uprooting of woody species from invaded grasslands – provides the handle to this policy option. However, there is an important caveat to be kept in mind when we consider Q_4 as a control variable. Due to the dual resource ownership/ management regime (i.e., exclusive control by the state on woody resource and the open access to grassland for livestock), changes to Q_4 can be effected under two policy options:

a) Without changing the property management regime, which means that the area cleared is liable to be re-invaded as livestock return to graze and deposit the seeds of woody species
b) Altering the property management regime of the reclaimed area so as to stop any re-invasion. This would necessarily involve changes in the land tenurial arrangements, well defined entitlements or usufruct rights

These two policy options are provided for in the numerical simulation as a switch for re-invasion control. When appropriate management regime checks woody re-invasion, the reclaimed area is closed off allowing only grass to grow in the reclaimed areas. On the other hand, without re-invasion control, the reclaimed area, however small or large it may be, remain open to re-invasion, and continue to exist as an open access land. In a rigorous sense, exercising the re-invasion control goes beyond parameter variation and involves a minor, but significant structural change in the system of equations. All model simulations, unless stated otherwise, are carried out without re-invasion control as it represents the present conditions. In the computer simulations, variations in Q_4 are, therefore, effected under the two scenarios: without re-invasion control (Fig. 7.9) and with re-invasion control (Fig. 7.10). Both cases lead to significant improvements in the grazing potential, with huge increases in the second case.

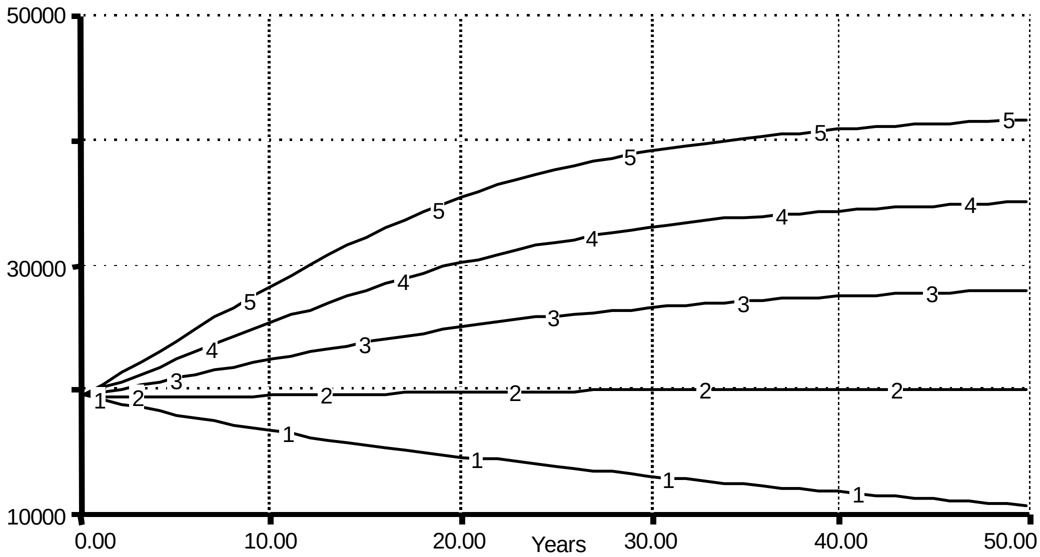


Fig. 7.9 Sensitivity of CGP to Q4 (Woody cover removal with re-invasion; 0 to 2000 ha/yr; step 500 ha

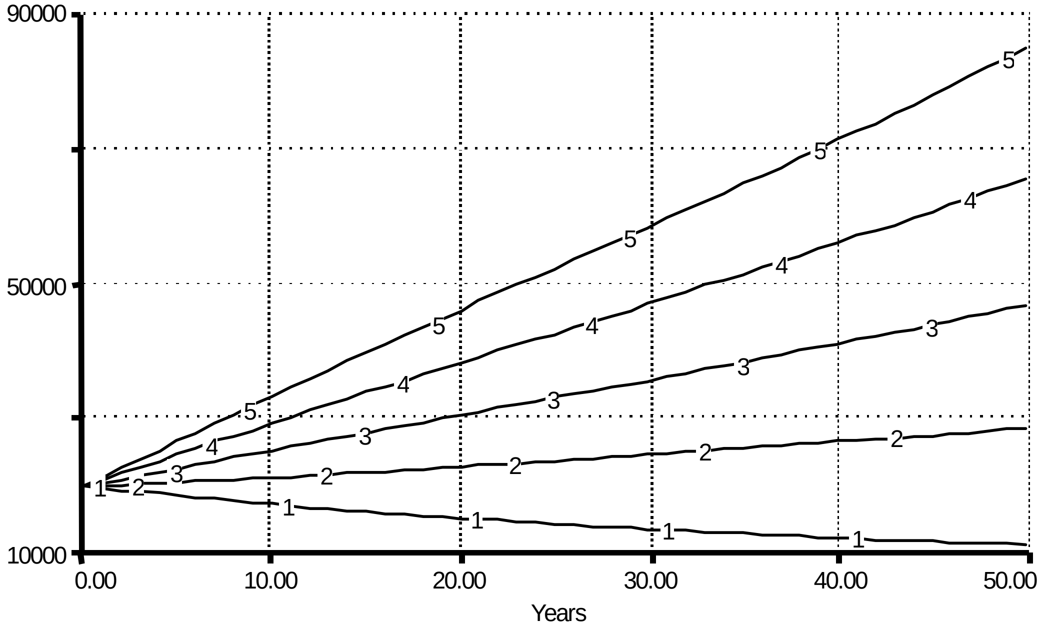


Fig. 7.10 Sensitivity of CGP to Q4 (Woody cover removal & stopping reinvasion; 0 to 2000 ha/yr; step 50(

8 Economic Model

8.1 Background

Decisions concerning natural resources management require proper valuation of the resources in terms of their economic contribution. In the context of a predominantly pastoral economy, the problem is essentially one of achieving a proper balance between livestock and the grazing potential that could be harvested. The critical question is of how determine the quantum of resource that can be harvested today (Conrad, 1999). Finding the best allocation of natural resources over time can be regarded as a dynamic optimisation problem. In such problems, the main task is to try and maximise some measure of economic value, such as the net returns or utility derived from the use of the resources, over the future time horizon, finite or infinite, subject to certain constraints imposed by the natural resources. These constraints could be the dynamics that determine the status of natural resources and any other relevant constraints. The solution to the dynamic optimisation problem is of finding a "schedule" or "time path" indicating the optimal amount to be harvested in each period.

The dynamics of the ecological resource are given by the equations for the ecological dynamics, while the relevant economic function needs to be constructed based on the economic goals. In the case of a pastoral economy such as that in Sub-Saharan Africa, it could be one of maximising the net returns from the sale of livestock for meat or it could be the maximisation of milk-based incomes in the pastoral economy in Kachchh. Central to defining the economic function is to the construction of an appropriate production function, $Y_t = H(X_t,E_t)$ relating yield (Y_t) to stock of resources (X_t) and effort expended to obtain the yield (E_t). The production functions are expected to be concave, with positive first partial derivatives; a non-negative mixed second partial derivatives; and non-positive, pure second partials (Conard, 1999).

8.2 Production Function for Milk

Consider the milk production per animal. Let m be the milk yield per animal. When fodder supply is unlimited or when the fodder supply is above a certain threshold, $m = m_{max}$, the maximum milk yield per animal. However, when fodder supply is 'sub-optimal' or under scarcity conditions, yield will decline and will tend to zero when there is no fodder supply. When the supply is abundant, i.e., it is above a certain threshold, further increase in fodder will not make any difference to the yield (m_{max}). Let s_0 be the quantity of fodder supply when the yield is reduced to half the m_{max}. We use the well-known Michelson-Menten-Monod function to mimic the constant output when resources are abundant. The following production function will represent milk yield m(t) given the fodder supply per animal, s(t), at any time, t.

$$m(t)=m_{\max}\left(\frac{s(t)}{s_0+s(t)}\right) \qquad (8.1)$$

It can be seen that when s=0, m = 0; when $s = s_0$, $m = m_{max}/2$ and when $s >> s_0$, $m \approx m_{max}$.

The number of animals producing milk will be proportional to the total number of animals, X or bX, where b is the proportionality factor. Total milk production,

$$M(t) = b*X(t)*m(t) \qquad (8.2)$$

$$M(t) = b * m_{\max}\left(\frac{s(t)}{s_0 + s(t)}\right)X(t) \quad (8.3)$$

The total grass resource harvested or consumed for milk production at time, t, is Q(t). Therefore, the resource per ACU:

$$s(t) = Q(t)/X(t) \quad (8.4)$$

This can also be expressed as:

$$M(t) = b * m_{\max}\left(\frac{Q(t)}{s_0 X(t) + Q(t)}\right)X(t) \quad (8.5)$$

Where,

Q (t) = Total grass resource harvested for milk production
X (t) = Total number of animals
b = Proportion of milch animals in the total animal stock
m_{max}, the maximum milk yield per animal

It may also be noted here that the total grass harvest for milk production is:

$$Q(t) = q(t)*G \quad (8.6)$$

where, q(t) is grazing potential consumed per ha for this purpose. Therefore, we have the production function,

$$M(t) = b\, m_{\max}\left(\frac{q(t)G(t)}{s_0\, X(t) + q(t)G(t)}\right)X(t) \quad (8.7)$$

Equation (8.7) depends on several bio-economic variables that vary in time: livestock (X), harvest rate (q), grass cover (G), and livestock (X) and the relevant parameters. The harvest Q(t) will in general be a function of the resource (K) and the harvest effort (E). The functional form will depend on the conditions under which the harvesting is carried out. It can be expressed in the Cobb-Douglas form[26]:

$$Q = Q(K, E) = d_1*K*E \quad (8.8)$$

which is a special case of the general form: $Q = d_1*K^a*E^b$, when a = b = 1. The proportionality coefficient, $d_1 > 0$. The amount of harvestable resource is evidently directly proportional to the resource level.

The effort function, E, will depend on the property regime under which the resource exists. In open-access pastures with free-grazing livestock, shepherds try to ensure that as much grass resources are extracted per animal to increase total milk production. This implies that grazing effort is proportional to the total livestock or $E = d_2*X$, d_2 being a proportionality coefficient. Thus,

$$Q = Q(K,E) = d_3*K*X \quad (8.9)$$

[26] A production function - Cobb-Douglas or its alternatives - allows increasing, constant or decreasing the returns to scale (Perman et al, 1996)

The harvest per unit area, is:

$$q = Q/G = d_3*\kappa*X \qquad (8.10)$$

where, $\kappa = K/G$ is the grazing potential per ha.

Using the expression $K = \kappa*G$, the harvest of grazing potential per animal is:

$$s = Q/X = d_3*K = d_3*\kappa*G \qquad (8.11)$$

where, $d_3 = d_1* d_2 > 0$, could be considered as the 'harvest' coefficient and is the proportion of total grazing potential harvested per animal for milk production.

The grassland resources in Banni constitute a typical example of open-access property regime characterised by the total absence of any form of resource ownership, lack of communal management, non-existence of customary rights over any specified resources assigned to any particular group and dearth of communal grazing restrictions. The yield-effort function presented here has interesting implications on the stocking strategy for increasing returns from milk production by free-grazing livestock under conditions of open access property regime. Different ramifications of the consequent dynamics will be discussed in detail later.

8.3 Total Net Returns from Milk Production

Main parameters for the milk-based economy are:

- Producer price per litre of milk sold (at constant prices)
- Maintenance cost per resource (controlling woody invasion, improving grazing potential by controlled grazing, social fencing or community controls, etc.)
- Total harvesting cost per unit of grazing potential including upkeep of livestock

Net returns at time, t:

$$\pi_t = P_t\,(M_t) - C_t\,(X_t, K_t, Q_t) \qquad (8.12)$$

P(M) is the returns from the sale of total milk produced, which is given by the production function for milk and C is the cost function for the milk production. All the variables refer to the value at time, t, unless explicitly stated. The index for time (t) will be dropped temporarily for the sake of brevity in the rest of this section and will be reintroduced later.

Under constant prices, P(M) takes the simple form,

$$P(M) = p*M(X, Q) = p*M(X, \kappa, W, q) \qquad (8.13)$$

where, p is the producer price of milk.

The cost function,

$$C\,(K, X, Q) = c_k*K + c_q*Q \qquad (8.14)$$

Or, explicitly in terms of X, κ, W and q:

$$C(X, \kappa, W, q) = (c_k*\kappa + c_q*q)*G \qquad (8.15)$$

where, the grass cover $G = A\text{-}W$.

The coefficients c_k and c_q are respectively the unit costs of resource maintenance and extracting the grass resources for milk production.

The expression for the net returns can now be stated as:

$$\pi = p*M(X, \kappa, W, q) - C(X, \kappa, W, q) \quad (8.16)$$

Nominal values of selling price of milk and maintenance costs used in the simulations correspond to the mean values obtained from the data analysis (see Chapter 6).

8.4 Net Returns from Animal Sales and Woody Resource

The net returns from sale of animals can be expressed as:

$$\pi = p*Q_1 - cX - rK \quad (8.17)$$

where, p is the (constant) net producer price, c is the cost ($c > 0$) or benefit ($c < 0$) of maintaining livestock and r is the cost of access to the grassland resources.

The net producer price, p, is nothing but the price per livestock accrued to the herder at the point of sale net all transport and other costs. The net benefit and costs denoted by c is not always so simple: the very possession of livestock could imply higher social status, draught power, animal products, and insurance it confers in times of drought and scarcity. However, the maintenance of livestock, even in open access grasslands, does involve costs, which could be an increasing function of grazing pressure. The cost of access to the resource may be understood as some form of productivity related charge for grazing rights or could be interpreted as the costs involved in improving the grazing potential of the grassland. The access charge, r, could increase with higher carrying capacity and where pastoralism is based on communally managed grazing areas, it could be the sum of all costs associated with preserving the traditional rights and in enforcing communal regulation of the pastureland.

Similarly, the net return from woody resource is:

$$\pi = p_c*(Q_3 + Q4) + p_n*N \quad (8.18)$$

where, p_c and p_n are the net returns from wood charcoal making and NTFP collection.

8.5 Present Value Maximisation

It is possible to first examine the general form of the optimisation problem for the pastoral economy without the specific form of the function for net benefits, $\pi(X, \kappa, W, q)$, and find the conditions for maximisation over an infinite time horizon. The pastoral economic activity is expected to make this happen through the levels of resource utilization and stocking of livestock subject to the constraints imposed by the physical and environmental properties of the system.

If the discount rate is δ, the discount factor is defined as:

$$\rho = 1/(1+\delta) \quad (8.19)$$

The present value of net benefits over a finite time horizon, from $t = 0$ to T, is given by:

$$\Pi = \sum_{t=0}^{T} \rho^t \pi_t = \sum_{t=0}^{T} \left[\text{p M(X}, \kappa, \text{W, q) - C(X}, \kappa, \text{W, q)} \right] \qquad (8.20)$$

Maximisation of Π is subject to the following dynamic constraints:

$$\begin{aligned} \Delta X_t &= X_{t+1} - X_t = f_1(X, \kappa, W, t) - Q_1 \\ \Delta \kappa_t &= \kappa_{t+1} - \kappa_t = f_2(X, \kappa, W, t) - Q_2 \\ \Delta W_t &= W_{t+1} - W_t = f_3(X, \kappa, W, t) - Q_3 - Q_4 \end{aligned} \qquad (8.21)$$

In addition, the following static conditions also apply:

a) The initial values are given and are all positive:

$$X0 = X(0) > 0;\ \kappa 0 = \kappa(0) > 0;\ W0 = W(0) > 0 \qquad (8.22)$$

b) The variables are non-negative and there is no replenishment of the resource implying that the harvest is always non-negative:

$$x_t,\ \kappa_t,\ w_t \geq 0;\ q_t \leq \kappa_t \leq \mu \qquad (8.23)$$

The solution to this problem will provide the decision rules for optimal harvest policy under the stated conditions of resource management and property regime. The infinite horizon problem is essentially that of determining the equilibrium strategy when the state variables have attained their steady state values. For generality, let us replace the three state variables, X, κ and W by X_i (i=1, 2, 3) and let U_i (i=1,2,3) be the harvest of each X_i. The Lagrangian for the problem is:

$$L = \rho^t \sum_{t=0}^{T} \left\{ \pi_t + \sum_{i=1}^{3} \rho \left[\lambda_{i,,t+1} \left(f_i - \Delta X_{i,t} - U_{i,t} \right) \right] \right\} \qquad (8.24)$$

$$\frac{\partial L}{\partial Y_{i,t}} = \rho^t \left(\frac{\partial \pi(.)}{\partial Y_{i,t}} - \rho \lambda_{i,t+1} \right) \qquad (8.25)$$

$$\frac{\partial L}{\partial X_{i,t}} = \rho^t \left\{ \frac{\partial \pi(.)}{\partial X_{i,t}} + \rho \lambda_{i,t+1} \left[1 + \frac{\partial F_{i,t}}{\partial X_{i,t}} \right] \right\} - \rho^t \lambda_{i,t} \qquad (8.26)$$

$$\frac{\partial L}{\partial (\rho \lambda_{i,t+1})} = \rho^t \left(X_{i,t} + F_{i,t}(X_t) - Y_{i,t} - X_{i,t+1} \right) \qquad (8.27)$$

The optimal solution $[Q^*(t), X^*(t), \lambda^*(t)]$ is obtained when:

$$\partial(L)/\partial(Q_{i,t}) = 0;\ \partial(L)/\partial(X_{i,t}) = 0;\ \partial(L)/\partial(\rho\lambda_{i,t}) = 0 \qquad (8.28)$$

The solutions can be obtained, given the initial conditions: X(0) = A (A>0) and assuming:

$$\lambda_{i,t+1} = B,\ (B \geq 0). \qquad (8.29)$$

It is possible to attempt a closed solution to the problem over an infinite time horizon. We have not, however, attempted such a closed solution. Instead, have used numerical simulations to compute the net present values under different scenarios examined in the study. Of particular relevance is the Net Present Values (NPV) under different management scenarios or under different modes of resource use. The inferences from the numerical simulations are discussed in the next chapter.

9 Banni Grassland: Management Scenarios

9.1 Background

Various policy and management options could be examined by computing the economic outcomes in terms of the Net Present Values (NPV) that result from the appropriate choice of parameter set and control variables. The implications of a particular resource management regime can be seen from the NPV that result from the numerical solutions of the equations over long time horizons. It is assumed that the pastoralists would prefer to maximise the present value of net returns in the long-term by the kind of livestock management strategies they follow, subject to the constraints imposed by the dynamics of the ecological system and the natural uncertainties. The NPV of the stream of income flows over a long period is determined by the relevant discount rate, δ. What is the appropriate discount rate applicable in a given situation is matter of much debate among economists. There is also a re-think of both the relevance and theoretical basis of discount rate as an effective instrument for computing NPV in ecological-economics (Pearce, et al, 1997). However, it is beyond the scope of this work to discuss these issues. Higher discount rates are expected to lead to more intense exploitation of the currently available resources. Put it differently, higher the δ, lower the importance attached to the stocks of resources left for future use. The choice of δ or the perception of it, in a sense, determines the harvest rate of a renewable resource like fisheries or grass biomass. The exploitation of natural resources is also affected by the differences between private and social discount rates. If the private or in general even a communal perception of δ is more than that of the social one, resources in private or communal control will tend get overexploited.

Before proceeding further, it would be useful to have an overview of the current policy and resource management environment in order to better appreciate the simulation results. As emphasized earlier, management regimes for the two renewable resources – grass and woody biomass – are a study in contrasts: grass exists as an open resource while woody resource are under the exclusive control of the state. Any kind of economic use of woody resource from Banni entails legal consequences. Changes in the management regime involve major policy change and ecological restoration of the grassland system will be possible only with policy change.

In the context of the study area, the key issues around which management and policy could be shaped are:

(a) Alterations in the property management regime
(b) Defining usufruct rights so as to allow control to the herders over designated grazing areas
(c) Formulation of management plans for the Banni by the State Forest Department incorporating grassland restoration goals

9.2 Simulated Management Scenarios

In order to explore the different management options, various scenarios have been envisaged for numerical simulation and net present values (NPV) of the returns have been carried out to compare the economic gains. The parameter set corresponds to the baseline simulation, except for the parameter sensitivity runs. Different scenarios and relevant parameters are listed in Table 9.1. The economic consequences of these resource management scenarios are almost self-evident. The numerical simulations help in getting a sense of the relative size of the expected change. In addition, the effect of different discount rates can also seen from the simulations. The simulations are carried out over a 50-year time horizon.

Table 9.1 Different simulation scenarios, policy & management implications and control variables			
	Scenario	**Control Variables**	**Remarks**
A	Business As Usual (BAU)	$Q_1 \approx$ 2% of X(t) $Q_2 \approx$ 2% of CGP $Q_3 \approx$ 1% of W Q_4 = 0 IC = 0	Corresponds to the baseline simulation and represents the current situation. $Q_3 \approx$ 2% of W implies that a small part of woody cover is being harvested for wood-charcoal illegally, despite the legal barriers.
B	Relaxation of rules to allow woody charcoal making at regulated rates. Charcoal making is permitted in approximately 10% of the wooded area	$Q_1 \approx$ 2% of X(t) $Q_2 \approx$ 2% of CGP $Q_3 \approx$ 10% of W(t) Q_4 = 0 WRIC = 0	This could result in substantial increase in the total income and could damp the inter-annual income variations due to the higher share from woody biomass based income
C	State sponsored uprooting of the woody invaders by contracting the job to pastoralists and allowing them to sell wood-charcoal from the cleared area. However this not accompanied by any change in the management regime to stop re-invasion	$Q_1 \approx$ 2% of X(t) $Q_2 \approx$ 2% of CGP $Q_3 \approx$ 2% of W(t) Q_4 = 2% of W(t) IC = 0	Everything as in the BAU simulation, except for the change in Q_4, which could lead to increases in the grazing potential and consequently the livestock based incomes.
D	Systematic uprooting of the woody cover as in Scenario C, accompanied by changes in the management regime to stop the re-invasion of reclaimed grassland.	$Q_1 \approx$ 2% of X(t) $Q_2 \approx$ 2% of CGP $Q_3 \approx$ 2% of W(t) $Q_4 \approx$ 2% of W(t) IC = 1	This could result in a slow, but steady recovery of the grassland system, accompanied by significant rise in grazing potential
E	Scenario D plus Scenario B Woody cover eradication + Re-invasion Control by altering management regime + Allowing economic exploitation of woody cover under a quota system	$Q_1 \approx$ 2% of X(t) $Q_2 \approx$ 2% of CGP $Q_3 \approx$ 10% of W(t) Q_4 = 2% of W(t) IC = 1	In this case the total incomes would naturally leap upwards due to the cumulative effects and the recovery of grassland. However, given the current policy environment, the chance of implementation appears to be rather slim
F	Similar to D, with Q_4 being a small scale operation similar to the current efforts	$Q_1 \approx$ 2% of X(t) $Q_2 \approx$ 2% of CGP $Q_3 \approx$ 2% of W(t) Q_4 = 1000 ha/year IC = 1	Even the small-scale efforts for woody cower eradication with re-invasion control can be expected to bring about increases in the CGP and consequently the livestock based incomes.
X: Livestock in ACU; CGP: Current Grazing Potential; W: Area covered by woody invasion; Q_1: Livestock sales; Q_2: Consumption of grazing potential for milk production; Q3: Use of woody cover for wood-charcoal; Q4: Area completely removed of woody plants per year; IC = 0 (no efforts to control woody invasion); IC =1 (Invasion control by altering the management regime).			

If no measures are initiated to improve the status of grassland and the current situation (Scenario-A) is allowed to continue, it will lead to complete loss of the grassland system and destruction of the pastoral economy. There have been some efforts of late to demonstrate the possibilities of grassland revival through the involvement of herders and NGO's. Despite being small-scale efforts these have demonstrated considerable success. Simulation of the status-quo case or the business-as-usual case (Scenario-A) results in a NPV of nearly Rs.374 Million for the income from the livestock and wood based production (TOT) and Rs.320 Million from livestock-based production (TLBI).

The option of legalising all kinds of economic use of the woody cover, including wood charcoal making, is on the face of it undoubtedly an attractive economic proposition. Scenario-B represents this option, which is modelled assuming that 10% of the woody cover could be harvested for wood-charcoal every year. The simulations show that the NPV of TOT jumps to Rs.516 Million, while that of TLBI remains almost unchanged at Rs.320 Million from Scenario-A.

Another option, which would lead to some significant improvement in the grass cover, is that of eradicating woody cover from a fraction (say 2%) of the invaded area each year without taking any additional measures to stop re-invasion of the reclaimed area. Though it may not be the best possible step, this kind of steps are possible if the management of the area remain in the exclusively with the State Forest Department. The Scenario-C simulation shows that a huge increase in the NPV of TLBI can be expected from this measure. On account of additional income flows from the wood-charcoal making, the TOT will also increase, with the NPV going up to Rs.520 Million.

If grassland recovery has to done in more efficiently, then it does not make much sense to leave the reclaimed area open for re-invasion. This is possible only by appropriate policy measures and institutional changes. Without delving into the details of these, the Scenario-D simulates the case by assuming that re-invasion has been stopped. Clearly this can happen only if these areas are no longer in a state of open access. In this case, the NPV of TOT increases to about Rs.580 Million accompanied by a rise in the NPV of TLBI to Rs.505 Million.

The Scenario-E is a combination of B and D, in which the options of Scenario-D is used along with the option to make wood-charcoal from a part of the area invaded by woody cover. In this case, the NPV of TOT would increase to nearly Rs.700 Million and while that of TLBI would remain at the same level as in Scenario-D.

Scenario-F is the case when clearing of woody cover and re-invasion control is being undertaken on an experimental basis with the involvement of herders and NGO's. Reclaiming 1000 ha of grassland under such efforts every year, can lead to an increase in the NPV of TOT to Rs.466 Million and that of TLBI to Rs.403 Million, as compared to Rs.374 Million and Rs.320 Million in the BAU Scenario-A.

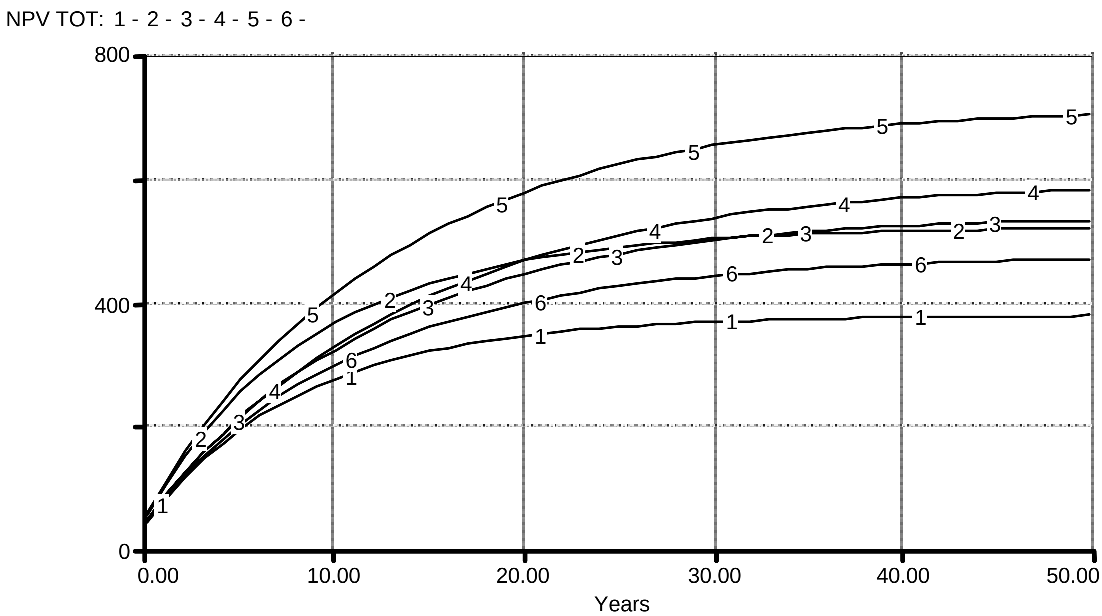


Fig. 9.1: Net Present Values of total income over a 50-year period

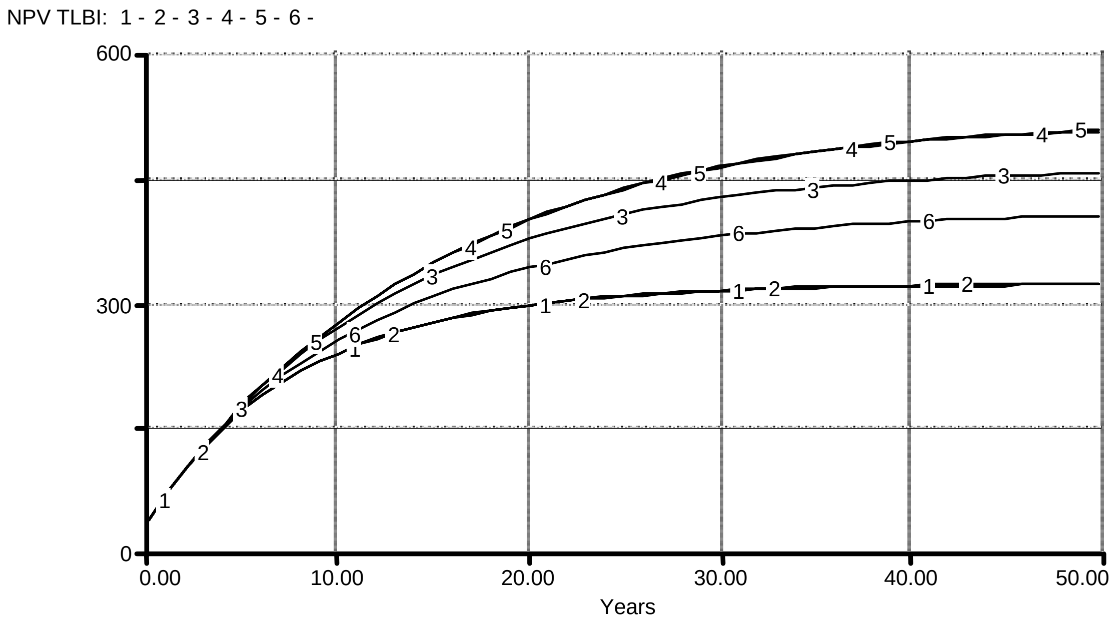


Fig. 9.2 Net Present Values of total livestock based incomes over a 50-year period

9.3 Conclusion

The scenarios and simulations do not incorporate some of the major ecological issues associated with the woody invasion of grasslands. At one level, woody invasion has caused significant erosion of the biodiversity values of the grassland, which is well recognised but not sufficiently quantified. At another level, there are many undocumented issues, particularly the effect of woody cover on the water balance. There is also a school of thought, which considers the woody invasion as a blessing in disguise. It is necessary to better understand the various beneficial and deleterious consequences of woody invasion to carry out simulations in terms of total economic values, rather than the immediate use values. The simulations carried out here are, in that sense, an inadequate representation of the system. Nevertheless, these simulations provide good insights into the policy options.

The data from the household surveys presented in this show that despite the enormous economic opportunity provided by woody growth, the preference of most people are for regeneration of grassland resources. What the revenue projections do not account for is the importance of livestock as asset. Options such as that in Scenarios C, D lead to considerable increase in the total livestock, which amount to a huge increase in the assets of the herders, in addition to the increase in livestock based incomes. Moreover, the milk sector has considerable possibilities with modernisation. There is increasing demand for milk and products – both traditional and value added ones.

Another point, which needs to be kept in mind, is that we have assumed a constant net returns from the wood-charcoal even when its production increases several fold (from a mere 2% carried on illegally to about 10% legally). This could be a very unrealistic assumption, since price is likely to fall with increasing supply. Additionally, the demand for wood-charcoal need not remain at the present level. Fall in demand for wood-charcoal, will lead to a fall in its price.

The social and cultural aspects of the pastoral community also need to be kept in mind while examining the management options. Large-sale wood-charcoal making will lead to competitive production of the commodity and the local community is more likely to get marginalised with little control over the resource. The simulations compute the income from wood charcoal assuming that the pastoral community are also the producers of wood-charcoal, which may not be valid when the production is scaled up to the levels used in the simulation. It is more likely that while a small section of pastoral community may benefit from the scaled-up production, most herders are likely to end up as seasonal labour than actual producers. However, the seasonal income from wage labour, as we have seen from the analysis of household survey data, is a significant share of the income of the herders owning small number of animals.

Since the Banni region is at present under the protected forest category, total opening up of the area for charcoal making may not be implemented as easily as the option to gradually reclaim woody areas back as grassland with involvement of both community and government agencies. It is evident that this is the option that provides a win-win solution that addresses ecological concerns and provides sound economic returns to a marginalised community. As evident from the household survey data, the human development status in the region is dismal with extremely low literacy rates, and large numbers of households at living at subsistence levels. Considering all this, the best option appear to be the middle path of reclaiming grassland by allowing wood-charcoal making only while the woody cover is being removed and disallowing the use of the reclaimed area as open access. Phrased differently, the opportunity foregone by choosing an option that yields lower returns from the woody resource could be considered as the price for regenerating the grassland and for providing a new deal to the pastoral community. More over, at present, the option to make maximum economic gains from the woody resource is non-existent due to the legal and policy environment and the price to be paid for biodiversity revival is more hypothetical than real!

10 Policy and Management Directions

10.1 Win-Win Possibilities

The ecological-economic studies on the two distinct grassland typologies – the Banni and the Naliya – point to the need for informed policy making, particularly in the context of the vulnerability of the ecological resources and livelihoods of the people dependent on them. Certain policy initiatives and institutional strengthening will help to realise some of the possibilities for developing models of stakeholder driven regime of resource management. The suggestions presented here emerge not only from the data analysed but also from the extensive consultations carried out as part of the study. It is also enriched by the study of people's perceptions.

The ecological perspective almost universally suggests the conservation of these grasslands – the remnant of once extensive systems – as ecosystems and as refuge for a host of rare and endangered biodiversity. There is, however, considerable uncertainty as to the attendant costs and requisite institutional arrangements. This study contemplates the surprising possibilities of a win-win situation: higher economic output from a conservation effort! That seems plausible without much investment or without foregoing huge economic benefits from alternate uses of these grasslands. While there is very little possibility for agriculture in Banni, in Naliya some form of marginal agriculture is the best form of alternate land use possible on the grassland. However, the economic analysis shows that the livestock-based activity contributes significantly to the gross economic output of both the regions. This study estimates that the gross output per year from grassland and woody resources of Banni is about Rs. 120 million and Rs. 29 million, respectively. The social cost of grassland use per year by all the agro-pastoral households in Naliya is about Rs.4.75 million, excluding the benefits enjoyed by in-migrant pastoralists. All indications point to the increasing demand for the milk and milk products, and consequently the potential for greater vibrancy for the livestock-based economy. The conservation problem, thus, appears to stand on its head only to resurface as a challenge of raising the efficiency of the grassland-based economic activity.

The goal becomes one of reorganising the livestock-based production dependent on open access grassland into an efficient system based on sustainable management of the grassland resource, which would also help in biodiversity conservation. The wood charcoal is a product with almost no potential for value addition and compares very poorly with the potential that a modernised milk-based system holds. There are some possibilities for value addition from wood-based products, such as furniture, which could create new income opportunities. However, the timber quality is such that the market value of such products is rather low and the market very limited. This would, however, require both skill development and proper management of the woodlots by allowing the bushes to grow into tree form though systematic lopping. Moreover, from the cultural stand point, any possibilities for modernising are likely to be wholeheartedly welcomed by the pastoralists. Such an approach could be accompanied by investments in the social sectors such as education and primary health, bringing about a sea change in present dismal situation.

The present property management and institutional arrangements are based on managing grasslands under the legal framework of Protected Forest in Banni. The biodiversity conservation plans for managing Naliya grassland as a wildlife Protected Area do not envisage an active role for people. These approaches clearly are inadequate when there are well developed economic stakes in these systems, which in itself can form the basis for an institutional framework for resource regeneration to increase the economic returns without conflicting with the conservation goals. At the same time, the experience in both the grassland systems and elsewhere do not appear to provide an open and shut case for privatisation of the commons, particularly, given the nature of resources and its economic potential. There is no evidence that privatisation – legal and illegal – has helped to arrest or reverse degradation either in Banni or Naliya. The feasible approach in both cases converges to the need for a very proactive and dynamic joint management framework, in which various stakeholders can be partners who can negotiate their competing claims. Given the current property rights regime, the State Forest Department will have to play a key role in making this possible. This cannot be accomplished by a mere replication of the lacklustre JFM currently implemented in degraded forests; but will have to be based on the recognition that these grasslands are of enormous direct economic values and the joint management has to facilitate efficiency in the economic activity based on the grasslands.

10.2 Banni – Stakeholder Partnerships

The key to the problem of improving the livestock economy, however, appears to be in the resource and property management problem, rather than in ecological management. The findings presented in this work bring out the idiosyncrasies of the present resource management and property regimes. At present, Banni – the remnant grassland degraded woody invasion – gets to be managed as a ‘Protected Forest’ (PF). Even as the land is under the PF category, grass remains an open access resource. However, the woody cover inflicted on the grassland by the invading mesquite gets to be guarded under the provisions of the Forest Conservation Act! Even though the system remains as an open resource for grazing, the people who depend on it are not given even the right to regenerate grassland by removing the woody cover. It is, indeed, a very strange situation, where more than the open access regime, it is the exclusive control of the property by managers without any definite stakes (Departments of Forest and Revenue) that appear to catalyse the degradation.

The economic activities are shaped by the duality in the resource management regimes imposed on these resources. There a duality in the sense that areas that continue to remain as grassland can exist as an open access resource, and when it is invaded, it transforms into a protected ‘forest’. The woody invasion appears to its legal mangers as an increase in forest cover at ‘zero-cost’, and a huge loss of economic opportunity for the herders who depend on it. The prevailing legal and institutional framework, therefore, deflects the grass-based economy into an unsustainable path by the inadvertent hastening of the process of grassland degradation. However, despite the all too evident degradation of grassland system, the economy is still dominated by the pastoral mode of economic activity with a significant role played by the economic activity based on the woody resources. The computer simulations make it very clear that at reasonable rates of recovering grasslands areas invaded by woody cover, considerable economic returns will accrue over the long-term (20 to 50 years), given the fact that nearly 80% of the grassland areas of Banni is invaded by woody cover.

The interesting, or more appropriately the disconcerting, dynamics of the dual mode of resource management and the transformation from one type (open access) to another (exclusive control by forest department) comes out very clearly in the system dynamics modelling. Over time, within the same geographical area, an open access resource is transformed into an exclusively controlled one through woody invasion. By this process the herders who had customary rights of resource use, lose it, since they cannot legally exploit or control the woody resource under the prevailing management regime. The study reveals the close linkages between economic returns, resource management and policy regimes. It shows the importance of properly understanding the long-term implications of the changes brought about by the resource management regimes. Even well intentioned approaches for biodiversity conservation may actually have negative effects on both economy and ecology. All these emphasise the need for an adaptive management regime that can play a proactive role in the resource management by bringing together different stakeholders into an institutional framework. The institutional framework need to provide a platform for the different stakeholders to work together as partners by negotiating their varied claims to the resource and even put in place necessary control regime over the resource by mutual consent.

10.3 Naliya – Livelihoods & Biodiversity

Several government or quasi-government agencies own most of the extensive grassland area. However, very little is under the jurisdiction of the forest department, despite the importance of the area for wildlife conservation. This study shows that although the agro-pastoral system depends heavily on the grasslands for sustaining the livestock, the local livestock numbers are not so high as to cause overgrazing. The grasslands also serve as resource for the migrant livestock from Banni and other parts. The ecological conditions here are healthier, and woody presence is very low. Here too, most of the grasslands are effectively open access for free grazing livestock. This study shows that while the grass resources are of crucial importance for the poorer sections, the richer sections draw a disproportionately higher degree of benefits from the grassland. The central problem here is of harmonising the needs of biodiversity conservation with the objective of sustainable use of grassland. Present approaches appear to be unaware of the economic significance of the grassland and of the interest stakeholders like the local agro-pastoralists or the migrant herders have.

Given the importance of biodiversity conservation, the tendency is to look up to the legal framework of Protected Area as the instrument to achieve that objective. However, it is by no means clear that this is the only means available. Such an approach will not only deny the people dependent on the grasslands a role in resource management, but worse, pits them against biodiversity conservation. Once again, the property management regime appears to hold the key to both the revival of grassland and the conservation of the endangered wildlife. The evidence seem to point to the simple conclusion that neither the privatisation of these common grazing lands nor its conversion into a wildlife reserve that is out of bounds for people can provide the solution. What we have seen is that there is very significant stake, albeit, seasonal for both local and migrant communities, which needs to be placed at the heart of any conservation planning. It is very important for the conservation planner to realise that the best and sustainable conservation need to be based on a clear recognition of the economic stakes. Enhancing the goods and services provided by the grassland is the best guarantee for its conservation. This will be possible only if an institutional mechanism is put in place to integrate the needs of resource management and biodiversity conservation.

10.4 Shaping Policy Change

The major policy issues that emerge from the study are:

1) Need for a three-pronged approach to grassland management – a) protecting the livelihoods of pastoral communities b) controlling the woody invasion of grasslands (applied largely to Banni) and c) addressing biodiversity conservation goals
2) Restructuring the property and/or resource management regimes and administrative approaches so as to bring about greater economic efficiency in the grassland resource use through higher stakeholder involvement in the control and economic use of woody biomass
3) Need for a critical reassessment of the management of grasslands under the provisions of Forest Protection Act (1980) and the approach adopted by the State Forest Department for this
4) Review of biodiversity conservation strategy for grassland systems, so as to bring about sharing of conservation responsibilities between the Forest Department and local communities in place of excessive reliance on the Protected Area approach in regions like Naliya with extensive dispersal of biodiversity values

It can be seen from the study that the current policies are almost completely devoid of a clear understanding of almost every aspect of the three crucial issues – pastoral livelihoods, economic diversification and biodiversity conservation. For example, the manner in which Forest Act – a biodiversity conservation act, is applied to Banni region has actually worked as a potent agent for the destruction of the grassland biodiversity. Also, equally significantly, the present legal and policy environment impedes involvement of direct stakeholders – the pastoral communities in resource

management. It has, in effect, throttled the development of any stakeholder based institutional framework for resource management by denying usufruct rights and perpetuating open access regimes, paradoxically under the umbrella of the exclusive rights and powers provided in the current legal and policy regime.
The findings that have a bearing on the policy regimes are:

- Need to recognise the different grassland types and the distinctions among grasslands in resource use patterns, property regimes, biodiversity values and modes of grassland degradation
- Even small but concerted efforts at controlling grassland degradation can bring about substantial economic returns to the pastoral sector, opening up possibilities for reshaping the livestock and grassland resource management
- Current policy and legal regime forces upon the Banni region a dual mode of resource management – one of exclusive state control over the woody mesquite that is invading grassland[27] and another which aggravates the problems associated with open access exploitation of grass resources[28]. In addition, there is a serious need to recognise and define the usufruct rights of maldharis once a piece of grassland is converted into the woodland.
- Open access nature of grasslands in Banni in combination with scarcity relief packages of the government tends encourage overstocking
- Inadequacy of the instrument of Protected Area as the main vehicle for biodiversity conservation strategy in the Naliya region
- Official policy towards the grasslands in Naliya ignores the biodiversity values and is encourages the conversion of grassland into farmland by re-settling people, particularly ex-defence personnel from outside the region
- Forestry efforts often lead to the conversion of grassland ecosystem to woodlands, without accounting for the long-term ecological consequences to grasslands and grassland resource based economy
- Decision makers appear to be inadequately informed of the role of property management regimes on the grassland economy and ecology

Two of the major policy and legal changes relate to (a) alterations in the resource management regime in Banni and (b) biodiversity conservation strategy in Naliya. The policy initiative needed in former case is one of adapting the Joint Forest Management approach for grassland regeneration with due recognition of the usufruct rights of the stakeholders. The later case requires the shaping of a participatory biodiversity conservation program in which the roles, duties and responsibilities of the community and forest department are properly defined. Such policy changes are a pre-requisite for any meaningful and sustainable resource management in the prevailing conditions.

10.4.1 Banni

The management of Banni grassland as a Protected Forest needs to be amended transferring it into a joint management framework involving pastoral communities and Forest Department. In principle, this does not involve any change in the legal status as any degraded forest can be brought under the JFM. However, in this case, the policy change need to move one step ahead and recognize these so-called ‘forests’ as grasslands and designate it for joint management for grassland regeneration instead of forest regeneration.

[27] Within a forest area, trees can be felled only under some management scheme (like working plan/working scheme or management plan). Thus, the removal of *Prosopis juliflora* from a forest area can be done, provide, it is prescribed in working (or management) plan. Banni is heavily infested by *Prosopis juliflora* but as a protected forest area its removal is restricted. At present no working plan exists for Banni.
[28] The maldharis have customary grazing rights in Banni.

This needs to be accompanied by eradication of woody invaders from at least a small portion every year and controlling re-invasion of the reclaimed area by bringing the reclaimed area under joint management of communities and forest department. The pastoral community's willingness and interest in grassland regeneration has been demonstrated by the success of small-scale pilot projects in Banni. The household survey data and the group discussions also reveal the preference of large sections of the pastoral community for grassland regeneration over incomes from wood-charcoal.

These policies can be backed with proper guarantees on usufruct rights for grass resource use from areas reclaimed from woody invasion and the economic exploitation of woodlot resources either as timber or non-timber produce. These are fairly feasible and reasonable propositions without altering the existing land ownership rights and hinges primarily on usufruct rights and institutional mechanisms for managing resources jointly by the government agencies (primarily the Forest Department) and local community. These policy changes for Banni could lead to more efficient use of grasslands, allowing legal economic exploitation of wood lots, and incentives for sustaining sound resource management. In fact, the situation presents a unique opportunity to reclaim grassland ecosystem while reaping enormous economic benefits. If attempted, this will be an unprecedented experiment with high potential for success. The policy changes could, in effect, assist in diversification of income as one of the risk aversion strategies for pastoralists. Policies should recognise the opportunities to rejuvenate the local economy in the region through management of woody invader.

The management interventions in Banni have been taken without any proper background studies on the economics and ecological implications. There is a policy need to recognize the role of scientific studies and 'system' approach in managing the grazing lands. Considering the highly dynamic nature of 'grassland-woodland' transitional phases and existence of many non-linear relationships between ecological and economical parameters, the entire Banni management need serious scientific review.

10.4.2 Naliya

In the Naliya region, the issue is primarily that of the conserving the existence value of grassland that supports globally important biodiversity values. Most of the grassland tracts of importance for biodiversity conservation (approx. 65 km^2) are owned by three government agencies: nearly 16 km^2 under Gujarat State Rural Development Corporation (GSRDC), 1.2 km^2 under Gujarat State Sheep & Wool Development Agency and the Forest Department, which controls the Lala Bustard Bird Sanctuary (2 km^2) and the rest under the Revenue Dept. In addition, another government agency - Gujarat Energy Development Agency (GEDA) – has already converted a large part of the grassland to woodlots for energy plantation. Among these agencies only the Forest Department is concerned with biodiversity conservation. Even the forest department had initially begun to convert the Lala Bustard Sanctuary into wood lots. One suggestion that has emerged is to transfer 25 km^2 of this government land to the forest department for biodiversity conservation. The dominant view within the forest department is of using the Protected Area framework, while an opinion also exists within the department in favour of a middle path that provides for some degree of community involvement.

Designating large areas under wildlife the Protected Area network, would, in strict legal terms, deny any access to these areas by the people and exclude any role for them in either conservation or resource management. Notifying an area under PA network is very different from designating as Protected Forest. Once designated as a PA, communities are likely to be perceived more as threat to the PA than as partners for its better management, leading to complete alienation of the local communities and pitting them against conservation efforts.

A way out of the situation is to designate the area considered for PA to be notified as an inferior *rakhal*[29] – a grassland category under PF and put in place benefit sharing arrangements with graziers and local communities based on clearly defined usufruct rights that are enforceable. The feasible approach is of designating the area for biodiversity conservation after settling the claims on grassland by local cultivators. It is possible to have a sound biodiversity conservation effort along with an overall improvement in the economic returns from the grassland systems through this approach. The current policy of re-settling ex-defence personnel on the grassland areas runs counter to biodiversity conservation goals and for all appearances militates against the interests of local people as well.

In the economic sense, the policy needs to recognise two important aspects of the grassland: a) the economic stakes of dependent pastoral and agro-pastoral communities and b) high non-consumptive value due to biodiversity significance. This study shows that these grasslands are of considerable economic significance to the agro-pastoral system. The regeneration of these grasslands could substantially increase the economic significance of these grasslands to both local agro-pastorals and the migrant pastoralists from different regions, such as Banni. Policy should recognise the economic significance of these grasslands, and work towards stakeholder driven management of the grassland. The region is of critical importance for biodiversity when resources are in plenty after a good monsoon and the problem of biodiversity conservation becomes one of ensuring that the grazing activity does not disturb the wildlife. The issue is not one of competition for limited resources, but one of scientific management with a monitoring programme. The scientific management must determine the parts of grasslands that must be kept free of grazing on a day-to-day basis in the breeding season. This is especially true for the two globally important bustard species (Great Indian Bustard and the Lesser Florican). Under a joint management framework based on a true partnership with stakeholders, this is not a difficult task to achieve, more so when the stakeholders get rewarded with higher economic returns.

10.5 Conclusion

The policy initiatives suggested are expected to substantially improve the economic status of the communities depending on the resource. The suggestions do not involve any major change in the legal framework. Most significantly, these suggestions correspond to ‘win-win’ situations where both economics and ecology stand to gain. The options considered here are also of wider relevance.

[29] Grass cover dominated forest land is called *Vidis* in Saurashtra. There are also few private *vidis* in Saurashtra. While the term *Rakhals* is used in Kachchh to denote forest lands with or without domination of grass cover and are under administrative control of Forest Department. Inferior Rakhals implied degraded forests where the grazing or cutting of grass is allowed to a certain extent.

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12 ANNEXURES

Annexure-I

Ecological-Economics Study on Grassland Ecology in Banni Region in Kachchh

Schedule No.: Date:

Name of village: Name of Panchayat:

Demographic details

Name of family head		
Name of respondent		
Age		
Caste		
How long the family has been living in this village?		
Main occupation		
Subsidiary Occupation		
No. of family members	Male:	Female:
Below 6 years	Male:	Female:
No. of literate	Male:	Female:

Literacy level	Male	Female
1-4 Class		
5-9 Class		
10-12 Class		
12 Plus	:	

Migration details

Do you migrate with your livestock: Yes/No

If yes, when did you migrate last?

Sl. No.	Place	How long did you stay?

Details of livestock

Details	Cows	Buffalo	Goat	Sheep
No. of animals at the time of migration				
How many animals did you leave at home?				
How many own animals did you have at the time of migration				

Did you take all your animals while migrating? Yes/No

If no, what arrangement do you make for the livestock left behind?

Arrangements	Tick the options
Graze within village boundary	
Purchase fodder	
Purchase subsidized fodder	
Send to cattle camp	
Send to *Panjrapol*	
Other	

Does any member of your family cultivate the agriculture land outside Banni? Yes/No

If yes give the following details?

How much is agriculture land? (in acre):

Does it belong to you?

If not yours, do you do sharecropping?

Animal Husbandry

Livestock	No. of own livestock		No. of others livestock		Where do the other's livestock come from?
Cow	At present	Lat year	At present	Lat year	
Cow Calf					
Bullocks					
Buffalo					
Buffalo Calf					
Sheep					
Goat					
Camel					
Others					

Stock Assessment

Livestock	Milking animals	New born (in last 2 years)	Dead animals (in last 2 years)	Purchased animals (in last 2 years)	Sold animals (in last 2 years)
Cow					
Cow Calf					
Bullocks					
Buffalo					
Buffalo Calf					
Sheep					
Goat					
Camel					
Others					

If there is any change in the livestock rearing (other than the present year), what are the reasons for the same? (give ranking of 0-4)

Reasons	Ranking (0-4)
It is difficult to rear more number of animals	
Grazing lands are reduced in area	
Quality of fodder is not good	
Increase in the area under Prosopis	
Drinking water for livestock does not remain available	

Fodder requirement and availability. (Per day requirement of milking animal – in Kg/bundle)

Season	Cows				Buffaloes			
	Green fodder	Dry fodder	Cattle feed	Collect from nearby forest	Green fodder	Dry fodder	Cattle feed	Collect from nearby forest
Winter								
Summer								
Monsoon								

Details of expenditure on livestock rearing (last year)

Items	Quantity	Rate	Remarks
Bhusa			
Khad (Oil Cake)			
Guvar/Govatri			
Juwar			
Green fodder			
Paral			
Thalia			
Grazing fee			
Medicines			
Others (*give the details*)			

Other than grazing in the forests, how much (in percentage) additional feed you need to give to your livestock?

Season	% of additional feed
Winter	
Summer	
Monsoon	

Income from livestock products (1998-99)

Products	Total production (Litre or Kg)						Average cost per litre/kg
	Rainy		Winter		Summer		
	Prodn.	Sale	Prodn.	Sale	Prodn.	Sale	
Per day household consumption:							
Per day Cow Milk							
Per day Buffalo milk							
Per day Goat milk							
Mawa							
Ghee							
Wool							
Dung							

Expenditure on the sale on the livestock products

Parameters	Cow milk	Buffalo milk	Ghee	Mawa	Wool
What selling rate do you expect than what you get at present?					
Transportation cost					
Because of involvement of middleman, how much do you loss?					
Interest on loan, if any					
Other losses					

What arrangement do you have for selling milk?
What other arrangement do you expect other than those available at present?
Details of animal sale

Sl. No.	Type of animals	In last two years		
		Within Banni	During migration	Total cost
	Cow			
	Cow Calf			
	Bullocks			
	Buffalo			
	Buffalo Calf			
	Sheep			
	Goat			
	Camel			
	Others			

Last year how much did you earn from animal sale?
How much do you earn from rearing other's animals?

Type of animals	Grazing fee/animal/month
Cow	
Cow Calf	
Bullocks	
Buffalo	
Buffalo Calf	
Sheep	
Goat	
Camel	
Others	

Income from different sources (Last Year)

Source of Income	Net Annual Income	Remark
Labour in kolsa making		
NTFP collection		
Gum Labour Sale		
Honey Labour Sale		
Labour in scarcity relief work		
Other labour		

Handicraft		
Earning from rearing of other's livestock		
Agriculture		
Money from outside		
Others (if any)		

What arrangements do you make during drought year?

Sl. No.	Details	Last year
	Sale of animals	
	Sent to *Panjrapols*	
	Sent to cattle camps	
	Sold ornaments	
	Taken loans	
	Migrated for a longer time	
	Stopped taking other cattle from outside	
	Labour in scarcity relief	
	Others	

Impact of *Prosopis* invasion
Does *Prosopis* grow in your surrounding? Yes/No

If yes, for how long?

How dense is *Prosopis* in the surrounding of your village, please furnish details?

Sl. No.	Direction	Ranking of density of *Prosopis* (0 -4 ranking: 0- no *Prosopis* 4 - highly dense *Prosopis*)
	East	
	West	
	South	
	North	

Is there any increase in the area and density of *Prosopis* in last five years? Yes/No

If yes give the reasons

Sl. No.	Reasons	Weightage to the cause (0 -4 values)
	Plantation by forest department	
	No steps by government to stop the spread	
	No steps by the villagers to stop the spread	
	Spread of seeds by grazing animals	
	Earning labour from kolsa making	
	Land is suitable for *Prosopis*	
	Any other reason	

If there is no increase, why is it so?

What are the grass species which used to grow quite extensively but recently they are either less or disappeared?

Sl. No.	Grass species	Sl. No.	Grass species

Management of *Prosopis* and Pasture land
If the present situation continues, in coming 2-5 years the spread of *Prosopis* will increase or decrease?

What can be done to stop the spread of *Prosopis*?

Sl. No.	Necessary steps	What measures have been taken?	What measures are required?
	At individual level		
	Measures taken by the villagers		
	Measures taken by the government		
	Others		

If no steps have been taken, what are the reasons?

Sl. No.	Reasons	Rank (0-4)
	Do not know about it	
	Lack of control mechanism	
	Lack of money/measures	
	Lack of institutional arrangements for joint efforts	
	Lack of co-operation from government	
	Other	

In future what management would you like to have for pastureland management?

Sl. No.	Management options	Rank (0-4)
	Total uprooting of *Prosopis*	
	Phase wise cutting of *Prosopis* by government	
	Handover land to village Panchayat for management	
	Control the immigration of livestock from outside	
	Allow the Kolsa making from *Prosopis*	
	Develop grass plot	
	Others	

If you are allowed to make the Kolsa from *Prosopis*, what management regime would you like to have for your income generation (please tick mark).

Mainly Kolsa based income (no livestock rearing)
Livestock rearing will be main and kolsa making a secondary occupation
Only livestock rearing
Other
If you are given land rights, what would you like to do?

Cultivate the land (dry land agriculture)
Grow fodder for livestock
Grow *Prosopis* for Kolsa making
Continue with present system
Other

Suppose govt. plans to uproot the *Prosopis*, what expenditure do you expect for the same (for your information, per ha expenditure comes to around Rs. 7500). Would you like to contribute some of this expenditure? Yes/No?

If yes, how much will you contribute?

If no why?

Name of Researcher: Date:

Response:

1. Very Good 2. Medium 3. Poor

Annexure-II

Ecological-Economic Study on Naliya grassland

Schedule No.: Date:

Name of village: Name of Panchayat:

Demographic details

Name of family head		
Name of the respondent		
Age		
Caste		
How long the family has been living in this village?		
Main occupation		
Subsidiary Occupation		
No. of family members	Male:	Female:
No. of literate	Male:	Female:
Literacy level 1-4 standard 5-9 standard 10-12 standard >12 standard	Male:	Female

a. Agriculture details

Parameters	Current	5 years back	Remarks
Total agriculture land owned (acres)			
Revenue Land (*Arjiwali*)			
Area under cultivation			
Area under Irrigation			
Source of Irrigation			
No. of crops per year			

b. Area under crops and their yield (last year):

Crops	Area under cultivation (acre)	Yield (Kg)	Quantity Sold	Rate (Rs./40Kg)	Remarks
Fodder crops					
Crop residues					

c. Expenditure on agriculture (last year)

Items	Expenditure (Rs.)	Remarks
Ploughing /Tractor hiring		
Seeds		
Fertilizers		
Labour		
Irrigation/ water cost		
Chemicals/pesticides		
Transportation		
Maintenance /Diesel		

d. Is there any change in agriculture production over the years? (last five years) - increase/Decrease

Reason (s) for change:

Agricultural Assets

Category	Quantity	Description if any
Cart		
Tractor		
Diesel pump		
Tube well		

Livestock ownership

Livestock	Total	Milking animals	New born (in last 2 years)	Dead animals (in last 2 years)	Purchased animals (in last 2 years)	Sold animals (in last 2 years)
Cow						
Cow Calf						
Bullocks						
Buffalo						
Buffalo Calf						
Sheep						
Goat						
Camel						

b. What measures do you take for your livestock during drought? (e.g. last year)
Migrate outside the village
Practice stall-feeding
Any other

c. In last five years, is there any change in your livestock number? Yes/No

If Yes, kind of change and reason for the same:

Shift towards buffalo population
Shift from livestock rearing to agriculture
Shift due to resource shortage
Any other change or reason

d. Expenditure on livestock rearing (last year)

Items	Quantity	Rate	Remarks
Bhusa			
Khad (Oil Cake)			
Guvar/Govatri			
Juwar			
Green fodder			
Paral (Paddy straw)			
Thalia (Cotton straw)			
Grazing fee			
Medicines			
Others			

e. Income from livestock products

Products	Daily production (Kg/Lt.)	Household consumption	Selling price (Rs./kg)	No. of months you don't get milk	Remarks
Milk					
Mawa					
Ghee					
Wool					
Dung					

Income from other sources (Last Year)

Source of Income	Net Annual Income	Remark
Handicraft		
Labour Work		
Salary		
NTFP		
Charcoal		
Others (if any)		

Fodder dependency: In a normal condition, source of fodder (%) at your village

Season	Village gauchar	Adjoining grasslands	Purchased/collected grass	Green fodder	Crop residue	Harvested agri. field
Winter						
Summer						
Rainy						
Duration (Months in a year)						

Fuel use pattern

Fuel type	% demand met from each source	Quantity consumed (kg or lit/ month)		
		Summer	Rainy	Winter
Wood				
Chhana (dung cake)				
LPG				
Kerosene				
Biogas				

Over the years have you noticed any change in the grasslands? Yes/No

Reduction in the grassland area
Decline in the palatable species
Expansion of agriculture
Prosopis invasion
Plantation of woody species
Any other (please specify)

Suppose, around your village there were 100 trees/shrub, how many of them are/were of the following species?

Species	Current	1985	Remarks
Desi Baval			
Kharijaar			
Kandho			
Kerad			
Bordi			
Desi baval			
Peelu			
Gando Baval			

Suppose, around your village you have collected 100 kg of grass, how much of it would be of following species?

Species	Season	Current	1985	Remarks
Kuiyar				
Dennai/Jinjvo				
Lap				
Dhamur				
Dhrab				
Khevai /Vidhad				
Dhramad				
Siyad Poochh				
Gandeer				

Wild animal abundance in terms of frequency of sightings (rank 0 to 5)

Animal	Current	1985	Reasons for change	Remarks
Haran				
Roj				
Meru/Suar				
Lackal				
Saslo				
Bhagad				
Jarak				
Hanatro				
Gorad				
Tillor				
Kunj				

In last 5 years, did wild animals kill any of your livestock? Yes/No.

No. of animals killed: Killed by (wild animal):

Do wild animals damage your agriculture? (last years' record)

Crops	Animal	% damage

Have you taken any measure to control the crop damage? Y/N (If yes please specify):

Banni-Naliya Linkage

Do the people from Banni visit grasslands around your village Yes/No

Do you allow migratory livestock to graze in your empty agriculture fields? Yes/No

If yes, at a time how many livestock herds do you allow to graze in your fields and for how long?

Do you pay money to them in turn of enriching the soil through livestock dung?

If yes, at what rate do you pay to them and how much?

Does the same livestock herd visit every year to your empty agriculture fields?

Do you see any change in the frequency of visit/number of migratory herds coming to this area in last few years? Increase/Decrease

If increase, what effect do you observe on the grassland?

Name of Researcher: Date:

Response: [1] Very Good [2] Medium [3] Poor

Annexure-III
Migration Pattern by Maldharis from Banni Region

Name of respondent:
Date:
Place of interview:
Where is your original village?
Where else did you visit before coming to this place?
How long are you staying at this place?
No. of persons in migrating group:
When did you leave your village?
Labour works at the place of migration:

No. of persons engaged	
No. of days/month labour available	
Labour Rate: Rs./day	

Livestock ownership:

Livestock categories	**Total number at the start of migration**	**Total number at present**	**No. of milking animals**	**Amount of milk produced**	**Quantity of milk sold**	**Quantity of mawa sold**
Cows						
Cow calf						
Buffalo						
Buffalo calf						
Sheep						
Goat						
Camel						

Selling price

Produce	**Current**	**At village**
Milk- Cow		
Milk – Buffalo		
Mawa		

Consumption of cattle feed

Cattle feed	Current		**At village**	
	No. of days one bag lasts	**No. of animals to feed**	**No. of days one bag lasts**	**No. of animals to feed**
Husk (bhusa)				
Khad				
Thaliya				
Kadab				

No. of dead livestock

Livestock categories	**Current year**		**Last year**
	Total since migration	**At this place**	
Cows			
Cow calf			
Buffalo			
Buffalo calf			
Sheep			
Goat			

Sale of livestock during migration

	No.	**Type**	**Cost (Rs.)**
No. of animals sold last year?			
No. of animals sold this year?			

Other expenses

Expenditure heads	**Expenditure (Rs.)**
Transportation of livestock	
Veterinary care (medicine etc.)	
Visit to original village: Frequency and approximate expenditure	
Any other	

Annexure-IV
Documentation of Ecological Changes in Banni

Date: Name of the village: Name of respondents:

Age Group	Upto 30 years	30-50 years	>50 years

(Questions on documenting the ecological changes need to be asked with reference to benchmark dates of the area *i.e. 1965* (year of *ganda baval* plantation), *1985* (*Tran bhego dushkal*) and current).

Can you identify the village boundary? If Yes

Direction	Name of the Village	Distance (km)	% of saline land
North			
South			
East			
West			

In non-saline lands, how much area around your village is under following? (in *taka*)

Years	Ganada baval with grass	Grass	Blank	Remarks
Current				
1985				
1965				

Suppose there are/were 100 trees around your villages, how many of them are of the following species (in percentage)?

#	Vegetation	Current	1985	1965	Remarks
a	Desi baval				
b	Peelu				
c	Kerad/Caparis				
d	Kandho/Khijado				
e	Layee (Tamarix)				
f	Gugad				
g	Lana/Sueada				

Rank the grasses found around your village according to their quality & presence:

#	Grass species	Percentage of grass cover			Quality ranking
		Current	1985	1965	
a	Dennai/Jinjvo				
b	Lanp				
c	Moth/Dhamur				
d	Dhrab				
e	Khariyo				
f	Dhraman				
g	Siyar punch				
h	Jevai				
i	Gandir				
j	Oen/Cressa				
k	Makhani				
l	Lana				

What in your opinion are the causes of grassland degradation? (Rank in order of decreasing importance)

#	Causes	Ranking
a	Decline in rainfall	
b	Damming of north flowing rivers	
c	Spread of prosopis	
d	Increase in soil salinity	
e	Over grazing by resident livestock	
f	Additional grazing by migrating livestock	

Grassland Resource Use

Other than fulfilling fodder requirement, what other benefits do you derive from the grasslands? Ranking of use in order of magnitude **(0- No use; 4 is very high use)**

#	Benefits	Current	Earlier (1985)
a	Thatch		
b	Herbal medicine		
c	Rope making		
d	Wild animals/birds		
e	Traditional food preparation (*athana*)		

Use of ganda baval (*Prosopis juliflora*)

Other than charcoal, what other benefits do you derive from the ganda baval? Ranking of use in order of magnitude **(0- No use; 4 is very high use)**

#	Use	Rank (0 to 4)
a	Firewood	
b	Honey	
c	Wax	
d	Gum	
e	Pods as cattle feed	
f	Fencing	
g	Small-timber	

What are the disadvantages of ganda baval spread? (Rank in order of importance; 0 is not important; 4 is most important)

#	Disadvantages	Rank (0 to 4)
a	Grassland decline	
b	Physical harm to livestock	
c	Water loss	
d	Decline in wild animals/birds	
e	Any other	

The number of following woody species has decreased over the years. In your opinion what are the reasons?

#	Species	Cutting	Coal making	Displaced by ganda baval	Soil salinity	Others	Do not know
a	Desi baval						
b	Peelu						
c	Kerad						
d							
e							

In your opinion what is the reason of spread of ganda baval?

#	Causes	Ranking
a	Plantation by government	
b	Spread of seeds by livestock	
c	Ban on coal making	
d	Other	

Wild animal abundance in terms of frequency of sightings (rank 0 is low number and 4 is high number)

#	Animal	Current	1985	1965	Remarks
a	Haran				
b	Bhagad				
c	Saslo				
d	Roj				
e	Jarak				
f	Bhundada				
g	Teetar				
h	Kunj				

Incidences of cattle lifting/killing by wild animals (rank 0 to 4)

#	Animal	Current	1985	1965	Remarks
a	Bhagad				
b	Jarak				
c	Bhundada				
d	Siyar				
e					

Other than resident livestock, how many come from outside to graze in and around your village?

Response:

[1] Very good [2]Good [3] Poor

Annexure-V:

List of *juth* (group) *panchayats* and villages of Banni region			
#	Name of *Juth Panchayat*	Name of villages	No. of villages
1.	Luna	Luna-nana and mota, Hajipir, Burkal	3
2.	Bhitara	Bhitara Nana, Bhitara mota	3
3.	Udhmo	Udhmo	1
4.	Bhagadio	Bhagadio, Chhachhal	2
5.	Mithdi	Mithdi Nani & Moti, Sarada Nana & Mota	2
6.	Servo	Servo	1
7.	Gorewali	Gorewali, Panawari, Adhyang, Patgar, Udo-moto & nano, Dhordo, Siniyaro	7
8.	Daddhar Moti	Daddhar Moti	1
9.	Daddhar Nani	Daddhar Nani, Vagura	2
10.	Hodka	Hodka, Thikriyado, Udai halki, Jararwadi, Ghadiyaro, Karanwadi, Arandawadi, Dumado, Sadai, Vad, Vadli, Ghidudi	12
11.	Dedhiya	Dedhiya Nana, Dedhiya Mota	2
12.	Bhrindiyara	Bhrindiyara, Reldi, Layvara, Sargu	4
13.	Misriyado	Misriyado, Neri, Madan	3
14.	Bhojardo	Bhojardo, Lakhabo, Jarmari wandh, Sumarawadi	3
15.	Kharod	Kharod (un-inhabited)	1
16.	Berdo	Berdo	1
17.	Raiyado	Raiyado, Lakhara wandh, Nothiniyaro	3
		TOTAL	**51**

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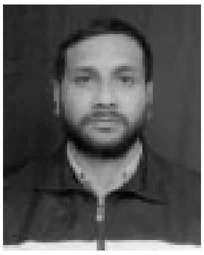

Arun M. Dixit did his doctoral work on wetland ecology. Earlier, while working at the Wildlife Institute of India, Dehradun, he was associated with a range of research projects like ecological assessment of forest vegetation in Narmada Valley and landscape level studies on wildlife corridors. He has considerable expertise in the applications of Geographical Information System and Satellite Remote Sensing to environmental management. He was member of the Technical Working Group that prepared the Gujarat State Environmental Action Program for the land sector. He has coordinated the preparation of Kachchh sub-state level action plan under National Biodiversity Strategy and Action Plan. His current research focus is on the landscape ecology of arid and semi-arid regions.

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C. S. Silori obtained his Ph.D. studying issues of people and wildlife in South Indian forests while working at the Wildlife Institute of India, Dehradun. He has also worked extensively on the human dependency on forest resources in Nanda Devi Biosphere Reserve in Himalaya and people-park relationships. He was member of the Technical Working Group that prepared the Gujarat State Environmental Action Program for the land sector. His current research focus is on ethno-botany and traditional knowledge systems in Kachchh. He is also associated with the efforts for community-based mangrove regeneration program.

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