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Grazing Lands and Biomass Management in Western Rajasthan : Microlevel Field Evidence

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Abstract : In a given ecological context a society evolves its two-way adaptation strategy involving adaptation (rationing) of the needs to resources as permitted by the natural resource base and adapting (developing/manipulating) natural resource base to meet increasing human needs. This process of dynamic nature- society interactions is illustrated with the emerging situation of grazing/fodder resources in the arid zone of western Rajasthan. The traditional strategies of farmers, including pastoralists, are becoming infeasible or ineffective in the changed demographic, institutional and technological context. Faced with increased pressure on grazing resources and their rising scarcity, new adjustments are being tried. The paper pleads for an understanding of these trends and for designing of range management strategies accordingly. The paper draws on the farm and village level data collected at different times between 1963 and 1982.

Key words : Rangelands, grazing resources, crops, agroforestry, common property resources, biomass.

Introduction: Previewing the Argument

The meaning of range lands or range resources in the developing countries with high man:land ratio is very different from the concept as evolved and used in the developed countries. The differences primarily relate to the area or size of unit, ownership and access to resources, as well as expected type of output from these resources. These in turn influence the status, usage, and upkeep of the resources, and also the institutional arrangements governing them. From the users' perspective, the purpose of the range resources is to ensure supply of total biomass, which besides fodder and forage, includes materials for fuel, fiber, fencing and even food. Hence, the assessment of current productivity and development requirements of range resources should extend to total biomass from them. Due to heavy pressure on land, areas formally declared as permanent pastures (range areas), often owned by the communities or government and accessible to the whole community, are too small to fully meet the total biomass needs of the people. Hence the supplies from range lands are supplemented by biomass from other sources, such as the crop lands, community forest, etc. An important and related issue is the prevalence of crop and livestock based mixed farming systems in these areas. This further reinforces the need and utility of integrated use of diverse sources of biomass.

Thus, the range management issues in the context of the developing countries, are an integral part of the people's overall strategies for production and usage of biomass from different sources. The present paper, therefore, is focused on the wider issues of relating biomass production with usage, where not only fodder and forage have a primacy, but range resources also play some important roles.

Arid Region of Western Rajasthan: Constrained Production Environment

The arid region of western Rajasthan consists of eleven north-western districts. The region is characterised by highly erodable sandy and sandy loam soils with scattered rocky patches, low and highly erratic rainfall, deep and often saline ground water. On the basis of *tehsil* level information on soil, vegetation and water resources, a team consisting of soil scientists, agronomists

and conservation specialists, had broadly assessed the use capabilities of the land in different districts of the region (Anon, 1960). They divided the region into three zones on the basis of the extent of lands of different use capability classes. Accordingly, the bulk of the area of the region (zone I) consists of the lands belonging to land classes VI and VII. These are suitable only for pasture and range development, according to the FAO use capability classification of lands for conservation purposes. Less than a quarter of the area of the region (zone II) contains different proportions of lands of classes VI and VII and also tracts of land class IV. The last could be put to restricted crop cultivation if accompanied by a number of conservation measures and practice of crop-fallow rotation. The remaining part (zone III) of the area contains the lands of classes III and IV in different proportions. The former is considered suitable for cultivation. After mapping the areas according to the classification indicated above Jodha and Vyas (1969) reported that nearly 79% area of the region, unless transformed by irrigation, is not suited to high use intensity involved in crop farming. This also implies that the overall biomass production possibilities in the region are quite limited. Details presented in Table 1 can help better appreciation of the situation. Over 56% area is characterised by extremely poor soils, low rainfall, very short growing season, and high frequency of rain failures to permit enough opportunities for biomass production. Another part (zone II), accounting for nearly 23% of the region

Table 1. Indicators of constrained production environment and intra-regional heterogeneities in the arid region of western Rajasthan (11 districts)[1]

Features	Zone 1	Zone 2	Zone 3
Land use capability classes	VI, VII	VI, VII, IV	III, IV
Annual mean rainfall (mm)	< 300	300-500	500-700
Rainy days a year (no.)	13-19	20-27	25-35
Length of crop growing season (weeks)	9-11	12-16	15-20
Frequency of drought (crop failure) in ten years (no.)	5-7	3-5	2-3
Ground water : depth of wells (m)	12--150	75-100	15-50
Average size of :			
– Land holding (1971) (ha)	19.7-24.6	9.9-14.7	3.5-6.4
– Animal units per 10 persons (1977) (no.)	20-32	13-17	5-9
Farm activity favoured by land classes	Pature based livestock rearing, extensive type of land use	As under zone 1, and restricted cultivation with crop-fallow rotation	Normal cultivation and restricted cultivation on class IV land
Zone's share in region's :			
– Area (%)	56.3	22.5	21.2
– Population (1971) (%)	21.5	34.5	44.0
– Livestock (1977) (%)	29.6	39.9	30.5
– Cropped area (1980-81) (%)	28.3	37.6	34.1

1. Source : Table based on data culled out form report of the State Land Utilisation Committee (Anon, 1960), District Census Hand Books (1971), Statistical Hand Books of different districts, Report of Agricultural Census 1971, Statistical Abstracts of Rajasthan (different years).

is only slightly better than zone I. Only 21% area of the region has better potential for agricultural (or biomass) production.

Key constraints and potential

Despite its intra-regional heterogeneities a number of important features of the region's natural resource base and their implications may be noted.

First, highly erodable and nutrient-poor soils and paucity of moisture do not permit intensive use of land, particularly in the zones I and II. They favour activities like pasture based livestock rearing as against crop farming. Secondly, low and unstable rainfall and short period of moisture availability cause greater uncertainty for production of grain (i.e., maturing of crop) as against producing other biomass from the same crops.

Thirdly, the natural vegetation including desert trees, shrubs, bushes, perennial grasses (and even annual grasses at times) are relatively less sensitive to length of wet period and fluctuations in rainfall than the domesticated crops. The former imparts greater certainty to production of biomass in the arid areas.

Historically, the societal responses to the above constraints (and potentials) have emphasised the land use practices and cropping systems which enhanced quantity and certainty of biomass availability and thereby helped sustain livelihood activities without unduly increasing the use intensity of land.

Societal Adaptations

Strategies

Societal adaptations to arid environment can be seen in the form of various practices ranging from scattered settlement pattern (called *Dhanis*) and nomadism on the one hand to folk agronomy and ethno-engineering (involving a variety of measures designed) for conservation and security of water on the other. However, our concern at the moment is to highlight the societal responses *vis-a-vis* scarcity and instability of biomass supplied. Accordingly, we may look at the desert farmer's traditional systems designed to maximise production of biomass and combat its instabilities.

Table 2 sketches the key components of the farmer's strategies. Accordingly, indigenous agroforestry, crop-fallow rotation, common property resources (CPRs), folk agronomy emphasising biomass production, collective security measures against biomass scarcity, crop-livestock based mixed farming, supply led adjustments in use of biomass, etc., constitute important provisions of the desert farmer's biomass centered strategies. These provisions, individually or jointly, help in meeting different objectives of the farmer, including sustained supply of forage and fodder

Table 2. Some details of biomass oriented strategy of the farmer in the western Rajasthan

Components of strategy	Objectives/functions							
	Biomass		Annual perennial links	Extensive landuse	Collective security	Adjustment to weather	Flexible demand/supply	Conversion of biomass into economic gains
	Augmentation	Stability						
Indigenous agroforestry	*	*	*	*				
Common property resources	*		*	*	*			
Folk agronomy:								
– Crop-fallow rotation	*			*				
– Cultivar choice[1]	*	*		*		*		
Crop-l. stock mixed farming				*			*	
Supply-led management practices[2]						*	*	*
Seasonal migration					*	*		

1. Crops with high stalk grain ratios, high salvage potential.
2. Extent of storage, processing, recycling according to relative scarcity/abundance of supplies.

(Table 2). This may be illustrated by highlighting the functions of key components of the strategies.

Microlevel evidence

Mix of extensive and intensive uses of land : The farmer in the arid areas tries to achieve twin goals of higher biomass production, especially fodder, and lower use intensity of land (to avoid erosion) through a mix of several measures. The practice of crop-fallow rotation and provision of indigenous agroforestry are two important methods in this respect.

Crop fallow rotation : The data from villages in Jodhpur and Nagaur districts (belonging to zone II) indicated that 29 to 38% area of the cropland was under fallow during 1963-65 (Table 3, section A). This not only helped in rebuilding of soil fertility, but also provided space for grazing and collection of fodder, fuel and other non-crop material. Part of the land fallowed for a prolonged period, called *Bira* (protected fallow plots), was specifically done for collection of fodder.

Provision of indigenous agroforestry : The number of trees, especially *khejri* and *ber* bush colonies called, *malla*, within the plots and *matt* (shelterbelt) on the field borders, were different components of the indigenous agroforestry system in the study villages (Table 3, section B). Trees provided fodder, fuel and other material, beside keeping part of the crop land under natural vegetation. *Khejri* trees are lopped for fodder and fuel every year after the harvest of *kharif* (rainy) season crops (Mann and Saxena, 1980). *Ber* bushes with

Table 3. Indicators of extensive pattern of land use, emphasis on biomass production, and changes therein at farm level in the study villages of Jodhpur and Nagaur districts in the arid region of western Rajasthan[1]

Details	Areas and Years			
	Jodhpur		Nagaur	
	1963-65	1982-84	1963-65	1982-84
A. Land holding level data :				
Sample farms/holding (no.)	38	38	43	43
Average land holding (ha)	9.3	7.8	8.4	7.1
Proportion of land holding :				
– Fallowed total[2]	29	15	38	14
– Fallowed as *bajra* (for fodder harvest) (%)	11	4	30	9
– Planted to crops	71	85	42	86
Proportions of cropped area devoted to % crops with				
– Long maturity (%)	78	73	66	62
– High stalk grain ratio (%)	62	65	74	73
– High salvage value (%)	75	75	69	70
B. Plot level data :				
Total plots monitored (no.)	27	27	32	32
Khejri trees (no./ha)	20	26	18	29
Ber-bush colonies (no./ha)	8	3	15	9
Plots with matt (Shelterbelt) (no.)	8	0	17	2
C. Average no. of years when above plots harvested during 10 years (1972-73 to 1982-83)				
– For grain yield		6		5
– For fodder from crops		8		7
– For *loong* (topfeed trees)		10		10
– For *pala* (topfeed bush)		10		10
– Fencing/fuel material		10		10

1. Source : Jodha (1968, 1986). Number of village was two in each of the districts.
2. Unintended fallows due to rain failure are excluded.

deep roots are cut (harvested) before planting the next crop. They resprout and grow with the crops without root competition. The fodder from *khejri*, called *loong*, and from *ber* bush, called *pala*, are available every year. They are less affected by rain conditions compared to crop-based biomass. Hence they are called desert farmers' natural insurance measures (see Table 3, section C). During the drought years *loong* and *pala* fetch as high price as the food grains. During good rain years the crop yields, both grain and fodder, around *khejri* trees and *ber* bush colonies (*malla*) in the plots, are often higher, as compared to the other parts of the same plots. Trees and bushes influence micro-climate and help the accumulation of humus. Unlike trees and *ber* bush colonies within the field, the trees, bushes and shrubs constituting *matt* (shelterbelt) are not harvested, except for fuel, thatching, etc., though camels and goats browse on them. Thus, agroforestry components perform several functions besides acting as renewable resources of fuel and fodder.

Folk agronomy : Emphasis on high biomass production and extensive pattern of land use is also reflected by choice of cultivars in crop farming (Table 3, section A). The crops like local pearl millet (*bajra*) and sorghum (*jowar*) with longer maturity period, indeterminate type (i.e., crops having recurrent flushes of flowering), and high stalk-grain ratios get higher preference. Similarly the crops which have high salvage potential (i.e., possibility of harvesting fodder, if not grain, in the event of mid-season rain failure) get higher priority.

Complementary use of perennials and annuals (agroforestry) : Provision of indigenous agroforestry clearly reflects this facet of farmer's strategy for higher and stable production of biomass. The perennials like *khejri* trees and *ber* bushes besides facilitating better performance of crop, act as more stable sources of biomass for the farmer. Table 4 presents relevant details of biomass production from perennials and annuals including planted crops in Jodhpur and Nagaur districts.

Data collected from the same farmers during different rounds of field work revealed:

a) During the low rain fall years top feeds (*loong* and *pala*) play important compensatory role in overall supplies of biomass (i.e., fodder).

b) During good rainfall years crop by-products contribute the largest share of total biomass produced.

c) As seen in the field and indirectly revealed by Table 4 during good rainfall years, biomass from agroforestry components is not fully harnessed, partly due to labour shortage and partly due to sense of complacency. Not only *pala* and *loong* remain unharvested, but in many cases even *bajra* stalks are not harvested.

d) During low rainfall years there is also greater emphasis on collecting material for fuel, fencing and thatching (including from CPRs, for own use, as well as for sale).

e) The last and most important inference suggested by the above Tables is the greater stability of biomass from perennials. This is revealed by the values of coefficient of variations reported in the last rows of the Table.

Complementarity of CPRs and PPRs : The emphasis on biomass production and extensive use of land is not confined to household and plot levels. At community level also there are several provisions to ensure stable flow of biomass and encourage 'extensive' use of land. These include keeping part of the land (often the sub-marginal lands) as village CPRs. CPRs are the resources which every member of the community can use. They include village pasture, forest, wasteland, watershed drainage, pond, etc. (Jodha, 1985a). Villagers, particularly the rural poor, depend very heavily on the CPRs. CPRs are an important source of forage, cut fodder, fuels and other materials. People supplement their own supplies of biomass by seasonal or year round collection of material from CPRs.

Table 5 presents some indicators of complementarity between CPRs and PPRs (private property resources) as a part of the desert people's

Table 4. Average estimated harvest for collection of biomass items during different rainfall years in two villages each in Jodhpur and Nagaur districts in the arid region of western Rajasthan[1]

Years	Rainfall (mm)	Biomass yield from different sources					
		Fodder			Grain	Fuel/fencing/thatching material	
		Top feeds (*loong*+*pala*) (kg ha^{-1})	Grass (kg ha^{-1})	Crop by-product (kg ha^{-1})	Food grain (kg ha^{-1})	Crop by-product (cart load)	Others (cart load)
Jodhpur :							
1963-64	159	377 (78)[2]	85	62	7	0	2
1964-65	377	305	780	2250	503	3	2
1965-66	295	318	250	435	108	2	2
1972-73	270	325	345	515	115	0	3
1973-74	473	342 (53)	1850	2160	615	4	2
1977-78	389	305	500	1250	212	0	3
1982-83	211	310	380	690	180	0	4
1983-84	378	246 (38)	320	1120	372	0	4
c.v. (%)	30	11	92	71	75	–	–
Nagaur :							
1963-64	139	385 (80)	115	183	18	0	3
1964-65	472	380	1100	2500	612	4	3
1965-66	221	465	315	710	232	1	3
1972-73	198	420	400	915	214	0	4
1973-74	510	390 (48)	615	1240	558	3	2
1977-78	521	405	930	2440	642	5	3
1982-83	256	440	640	915	312	0	4
1983-84	410	335 (35)	938	1280	495	2	3
c.v. (%)	42	9	53	51	54	–	–

1. Source : Based on field studies conducted.
2. Figures in parentheses indicate share of *pala* (*ber* bush fodder)in total quantity of top feed.

strategy to ensure higher and stable supplies of fuel, fodder, and other material. Information is presented in the form of ratio between CPR:PPR lands, ratio of contributions of CPRs and PPRs to animal unit grazing days and, ratio of supplies of fodder, fuel, other material from CPRs and PPRs. The values are presented in Table 5. If interpreted in terms of percentages the same data would reveal:

a) Of the total land resources available to villagers, CPRs constituted 21 to 28% in different districts during 1982-84. This figure was much higher (33 to 51%) only thirty years ago (figures in parentheses in Table 5).

b) During 1982-84, around 66 to 79% of animal grazing was contributed by CPRs. This was for all sample farmers and not only the rural poor as reported earlier (Jodha, 1986).

c) About 55 to 65% of fuel (including dung) collected by all sample households (including rural poor) was contributed by CPRs.

d) About 29 to 41% of the collected fodder (non-crop products) was contributed by CPRs.

e) About 59 to 68% of fencing and thatching material, which is ultimately recycled as fuel, was contributed by CPRs.

The above facts clearly reveal the importance of CPRs in supplementing PPRs in meeting fodder and fuel needs at the village level in the arid region.

Collective security against periodic scarcities : Rain induced scarcity of biomass, especially fodder, is quite recurrent in the arid region. To guard against its impact several institutional arrangements have been evolved by the desert people. The provision of CPRs as discussed above

Table 5. Complementarity of CPR's and PPR's in providing biomass for different uses in the study villages of selected districts in the arid region of western Rajasthan (1982-84)[1]

Details	Jodhpur	Nagaur	Jalor	Barmer
Ratio CPR:PPR lands[3]	2.4:7.6 (3.3:6.7)	2.1:7.6 (4.8:5.2)	2.2:7.8 (4.1:5.9)	2.8:7.2[2]
Ratio of contributions of CPRs and PPRs in animal unit grazing days	6.6:3.4	6.8:3.2	7.1:2.9	7.9:2.1
Ratio of CPRs and PPRs contributions to collection/harvest of different items:[4]				
Fuel	5.5:4.5	6.1:4.9	6.5:3.5	–
Fodder	3.5:6.5	2.9:7.1	4.1:5.9	–
Fencing/thatching	6.2:3.8	5.9:4.1	6.8:3.2	–

1. Source : Data and records collected for a study of CPRs by Jodha (1986).
2. These data relate to 1963-65.
3. Figures in parentheses indicate situation during 1951-53 and are presented to show the decline in the area of CPRs
4. Data presented here relate to all sample households and not only the rural poor as reported in an earlier paper. (Jodha, 1986).

is most important among them. The concern for collective needs and mutual help is also reflected through what may be described as seasonal CPRs. Accordingly, fellow villagers are allowed free access to private lands, for animal grazing during post-harvest season, use of top feeds and collection of dung and other material. Similarly, under the system of periodic closure of parts of village territories to animals (called *chait rakhai*), individuals' right to graze even on their own lands are suspended. The closure of territory coincides with the spring season, beginning around the month of *chaitra* (late March-April), to permit regrowth and sprouting of perennials including trees (Table 6). The above practices are on the decline now. Contribution to charity feeding during scarcities is another indicator of collective risk sharing system. Seasonal maintenance entrustment on mutually agreed terms (Jodha, 1986), are other measures to help each other. Most important, there are several informal institutional arrangements, including community sanctions, to regulate operation of collective security measures. There is not enough quantitative information on these aspects except the data on their changes presented in Table 6.

Crop and livestock based mixed farming: Mixed farming based on crop production and animal rearing is one of the ways to ensure balance between extensive and intensive uses of land as it does require keeping of some areas under natural pasture. Through linkages between farming, forestry, pasture and livestock, the mixed farming helps in diversification of sources of fuel and fodder and cycling of biomass.

Biomass orientation of folk-agronomy : Crop farming, despite its unsuitability in several areas, is an essential part of mixed farming systems in the arid region. The folk agronomy (i.e., traditional art and science of raising crops and managing resources) is not only sensitive to crop attributes like resistance to drought, etc., but it puts heavy emphasis on fodder component of the crops. Accordingly, the desert farmer gives high priority to cultivars with high stalk grain ratio, higher salvage potential, i.e., forage availability in the event of crop failure.

Supply-led flexibilities in biomass management : In the arid areas of western Rajasthan, supply of fuel and fodder or biomass, in general, fluctuates depending on the rainfall. The farmer changes his management (both harvest and usage) of biomass resources according to the quantum of biomass available. A comparative picture of biomass production and consumption practices during the years with poor and good rainfall can illustrate the point. Table 7 presents the relevant data from sandy villages of Jodhpur and Nagaur districts. During the low fainfall years,

Table 6. Management of CPRs in western Rajasthan : Whether past practices continue following land reforms[1]

Practice	Practice continues	Practice	Practice continues
A. Indicators of private cost of use of CPRs :		C. Indicators of revenue earning :	
Grazing tax (*ghas mari*)	No	Auction of dung collection rights from CPRs	No
Fee for grazing in some CPRs on priority basis	No	Auction of top feeds from CPRs	No
Livestock-related levies (*laag baag*)	No	Auction/sale of wood from CPRs	Yes
Compulsory labor contributions for desilting ponds (*begar*)	No	Penalities for breaking grazing regulations	No
Penalities for disregarding grazing regulations[2]	No	Cash and kind taxes and levies from users of CPRs	No
B. Indicators of regulated use of CPRs :		D. Indicators of investment in CPRs :	
Evenly scattered watering points	No	Periodic desilting of ponds[4]	Yes
Deliberate rotation of grazing around different watering points	No	Payment to watchman (*kanwaria*)	No
Periodical closure of parts of CPRs (e.g. *chaitrakhai*)	No	Maintenance expenses of community bulls[5]	No
Periodical restriction on entry of animal category (e.g. sheep/cattle) to parts of CPRs	No	Support to scouts to survey water and fodder situation on migration on routes during drought	No
Posting of watchman (*kanwaria*) with power to enforce regulations[3]	No		

1. Source : Table adopted from Jodha (1985a).
2. *Panchayats* also have provisions for imposing penalties, but such cases relate to trespassing by persons on migration routes during droughts, or to complaints of damage to one's crops by others' animals, which are brought to Panchayat officials for impounding.
3. Feudal authorities collected substantial revenue from CPRs but reinvested only a small proportion of it.
4. Periodic desilting of ponds now takes place through government relief expenses during drought years.
5. Some *Panchayats* have provisions for maintenance of community.

the farmer undertakes several steps to augment production/collection of biomass (Table 7, section A). These include measures like collection of seeds as fodder or fuel to harvesting of pre-mature crops. Most of these measures, being inferior options, are completely disregarded during the good rainfall years.

Similarly, in the matter of use of biomass, i.e., both fuel and fodder, a number of measures involving processing (e.g., chaff cutting) and recycling of biomass are adopted during the years of scarcity (Table 7, section B). The extent of these measures become negligible during the years with good rainfall.

Thus, the relative abundance of biomass and scarcity of labour during good rainfall years lead to lower extent of harvesting and conservation of biomass resources. The opposite is the case during the years of scarcity. The difference in farmers' approach to biomass management during good and low rainfall years has several implications. Most important among them is that non-harvested components of biomass (including crop stalk in some cases) during the good rainfall years represent a slack resource, which could be harnessed and through storage, used for meeting deficit during the low rainfall years. The fact that non-harvest of top feeds (*loong* and *pala*) during a year adversely affects their yield in the succeeding year, further adds to the importance of the above mentioned slack resource.

Same rule applies to fodder (and even fuel) which is used without processing (i.e., chaff cutting) during the years of abundance. A few very closely monitored cases in the study villages showed that *bajra* and *jowar* stalks when fed after chaff cutting, can meet the need of 2 to 3 times more animals than what is possible through unprocessed feeding of stalks.

Table 7. Differences in the patterns of management and usage of fodder and fuel during years of scarcity and abundance in study villages of Jodhpur and Nagaur districts in the arid region of western Rajasthan[1]

Details	Areas and Years			
	Jodhpur		Nagaur	
	1963-64	1965-66	1972-73	1973-74
Rainfall (mm)	159	377	198	510
A. Proportion of plots used for augmenting biomass supplies through : (%)[2]				
– Collection of weed as fodder	33	3	48	0
– Harvesting field borders	43	4	39	3
– Harvesting premature crops	10	0	42	0
– Harvesting grain crops as fodder	31	0	62	0
– Premature harvesting of:				
– *ber* bush for fodder, etc.	58	0	70	2
– *khejri* tree (lopping) for fodder and fuel	45	2	65	0
B. Proportion of sample households[3] undertaking the following measures (%)				
– Used stalk				
– after chaff cutting	98	14	100	36
– without chaff cutting	2	86	0	64
– Reused leftover fodder of productive animals for feeding unproductive animals	54	5	78	12
– Mixed leftover fodder (waste) for making dung cakes	60	6	94	20
– Left bajra stalk, ber-bush unharvested	0	7	0	12
Collected fuel/fencing/thatching material from CPR's (including for sale)	48	16	52	20

1. Source : Field surveys for Jodha (1968, 1974, 1985a).
2. Number of plots monitored in the villages was 60 in Jodhpur and 88 in Nagaur district.
3. Number of sample households covered by above information was 62 in Jodhpur district and 75 in Nagaur district.

Public Interventions and Traditional Strategies Under Strain

Public policies and programmes

In the changed circumstances, public policies and programmes, which represent formal institutional dimensions of resource management/development, are being commented upon. Furthermore, only those public measures are discussed, which directly influence the status and productivity of resources contributing to the supply of biomass. These measures relate to (i) land distribution policies; (ii) usage regulation of land, especially the common grazing lands; and (iii) land development and productivity promotion programmes (Jodha, 1988).

Ever since the introduction of land reforms programme in the 1950s, distribution of land by privatisation of common property lands (used mostly for grazing) has been the major component of land policies in the state of Rajasthan and elsewhere in India. The policies were strongly welfare oriented (as indicated by 'land to the poor' approach), and completely insensitive to use capabilities of land. This resulted in massive transfer of sub-marginal lands from natural vegetative cover to crop farming with low and uncertain productivity (Jodha, 1985a).

Distribution of land was not accompanied by any obligation on the part of land recipients, to use the land according to its use capabilities. Furthermore, there were no measures and provision to regulate the use intensity of land, both crop lands and grazing lands. The traditional informal arrangement regulating use of the land by rotational grazing, periodical resting

of land, etc., got disrupted with the introduction of formal, legalistic system of village administration, represented by village *Panchayats*.

For raising land productivity considerable efforts were made on technological front. However, in the case of crop technology the focus was on raising grain yield by high yielding varieties, etc., with little attention to biomass used as fodder. The measures to raise productivity of range lands, through a variety of methods like reseeding, use of chemical inputs, soil working, etc., were too much "technique" dominated. They were quite insensitive to institutional factors, which condition the people's participation and adoption of technologies. Other policies focussed on non-crop options on the land. The new initiatives in terms of agroforestry systems and silvipastoral programmes rarely crossed the boundary of research-cum-demonstration farms and pilot project areas, again due to the dominance of "technique" and their crucial dependence on "subsidy" to sustain them.

To sum up, the range resource-related public policies and programmes in the arid zone, in the context of which farmers' evolve their own responses and strategies, were neither guided by biomass requirements, nor made sensitive to the use capabilities of arid land. Yet, as public interventions, they were strong enough to disturb the existing biomass oriented farmers' strategies.

Apart from public policies and programmes, the rapid population growth and increased role of market forces have also played significant role in the reduced feasibility and efficacy of traditional strategies. However, as Jodha (1985b) reported, public interventions have accentuated the role of other two factors.

Reduced effectiveness

The balance between extensive and intensive uses of land : This balance is disturbed by extending crops to sub-marginal areas and reduced extent of periodical fallowing of land. The proportion of land fallowed has declined from 29 to 15% in Jodhpur villages and from 38 to 14% in Nagaur villages during the last 20 years or so. Due to increased pressure of population, not many farmers can afford to leave land fallow (Table 3, section A).

Decline of indigenous agroforestry : As shown in Table 3, section B, several components of indigenous agroforestry, especially *ber* bush colonies (*Malla*) and shelterbelts (*matt*) have declined ignificantly. *Ber* bush has disappeared due to recurrent use of tractors unlike bullock (mostly by hire) for cultivation (Jodha, 1974). Tractor, unlike bullock-operated plough, cuts the deep roots of the *ber* bush. The roots, by regular regeneration, not only offered fodder and fuel but acted as soil binder. Disappearance of shelterbelts is largely due to encroachment by farmers, who gradually extend their plot areas beyond the legal field borders.

The only redeeming feature of the situation is that with the disappearance of *ber* bush, the farmers have increased their attention to protection of *khejri* trees in their crop fields (Table 3, section B). Thus, one source of biomass insurance (e.g., *khejri* for top feed) has partially substituted the other (i.e., *ber* bush for fodder). Decline of *pala* (*ber* bush fodder) production is also revealed by Table 4.

Decline of CPRs : Though CPRs perform several useful functions such as a source of collective sustenance during scarcity periods, a major source of fuel and fodder and a contributor to balance between intensive and extensive land uses, they have suffered the most both in terms of decline in their area (Table 8) and productivity (Table 9). Between the early 1950s and the early 1980s, the area of CPRs has declined by 37 to 63% in the study villages of different districts.

In general, over-exploitation and under-investment have become the key attributes of community's approach to CPRs. This has further exposed CPRs to degradation. Decline in their physical productivity is the final consequence. In the absence of any benchmark information, it is difficult to measure the decline in the productivity of CPRs. Yet, using records and oral history etails, the situation is illustrated by Table 9.

Table 8 : Changes over time in the area of CPRs in the arid region of western Rajasthan (11 districts) during 1951-52 to 1980-81[1]

Details	1951-52	1961-62	1971-72	1977-78	1980-81
CPR area (million ha)	11.3	9.8	9.2	87	8.4
CPR area as a per cent of total geographical area	60.5	51.1	47.9	45.1	43.5
Per cent decline in CPR area over previous period	–	12.4	6.7	4.5	3.4

1. Table adopted from Jodha (1985a). Common property resources include forests, permanent pastures, cultivable and uncultivable wastelands, and fallow lands other than current fallows. This Table includes several items such as state forest (besides community forest), fallow lands and remote and inaccessible waste land, etc. This is because of non-availability of break up of data to give a precise extent of CPRs (as used in other Tables). Hence, data presented here should be treated as broad indicators of status of CPRs.

Yields of practically all products of CPRs have declined.

To sum up, crop fallow rotation, indigenous agroforestry and CPRs are the key components of the traditional strategies to increase and stabilise availability of biomass, but have been adversely affected in the recent years. The other provisions like collective security of biomass, supply-led flexibility in biomass management and crop-livestock based mixed farming have been affected by changes in the above three components.

Indicators of increasing scarcity of biomass

Following the decline and degradation of resource base, the overall supplies of biomass has declined in the arid region. The village or farm level data at three points of time indicate the change (Table 10). According to it the decline during the last three decades or so in the practice of fodder stocking (*Pachasa*) at village level and villagers' contribution to common/charity feeding, has been very drastic. Similarly, there is increase in the duration of seasonal out-migration of sheep herders and in the time taken in collection of a cartload of fuel (*mundana*), which indicate increasing biomass scarcities in the study villages. A shift towards increased use of cow dung in place of wood as a fuel was also observed in some study villages.

Adjustment to increasing scarcities

Table 11 also presents some details which could be considered as indicators of both decline in the supply of biomass as well as adjustments to the declines. One of such indicators is people's acceptance of inferior options. Accordingly, a number of biomass items like *bajra* husks (as fodder) and seasamum stalks (as fuel), which were traditionally discarded and allowed to rot, are now stocked by the people for use. Even rich farmers do not discard these products now. Similarly, the tendency towards privatisation of products of seasonal CPRs (i.e., crop fields during the off season) is another frequency of replacing old farm fencing by material from *khejri* trees or *ber* bushes also reflects adjustment to reduced supplied of the biomass.

Shift towards private use of 'Seasonal CPRs' is partly an adjustment to decline in other CPRs and decline of collective arrangements against biomass scarcities. One of the most important forms of adjustment to scarcity of biomass could be seen in the case of livestock sector of study villages. According to Table 11 (reproduced from Jodha, 1985a) the livestock composition has undergone significant changes following the decline in CPRs as well as other changes like improved marketing facility for milk.

In the study villages not only average size of animal holding has declined, but the proportion of unproductive animals has declined. The proportions of sheep and goat, has increased. They unlike cattle can not only manage on degraded pastures but have better facility to seasonally migrate to canal areas of neighbouring states of Punjab and Haryana. Increased proportion of buffalo can be attributed to milk marketing facilities under programmes like operation flood and better provision of drinking water in the

Table 9. Decline in productivity of CPRs as illustrated by histories of four forest and grazing plots in a village of Nagaur district, 1964-65[1]

Product[2]	Production of biomass from							
	Plot 1 (6 ha)		Plot 2 (10 ha)		Plot 3 (12 ha)		Plot 4 (12 ha)	
	1945-47	1963-65	1945-47	1963-65	1945-47	1963-65	1945-47	1963-65
Timber (*babul* and *indol* trees)	12	3(0)	11	1	3	0	17	0
Top feed (*loong* from *khejri*)	8	4(2)	10	3	21	8	12(5)	3
Top feed (*pala* from *ber* bushes)	–	–	–	3	12	4(0)	15	2
Fuel wood (*khejri*, *ker*, etc.)	8	2(1)	5	2	18	6(3)	21	4
Cut grass (*kared* and *dhaman* perennials)	13	3(2)	18	4	27	9(2)	21	0
Cut grass (*bharoot*, etc., annuals)	3	5(5)	5	–	10	8(5)	13	9
Dung collection	–	–(1)	–	–	15	0	17	0
Gum (*babul* and *indol* trees)	40	0	10		–	–	–	–

1. Source : Table adopted from Jodha (1985a). Figures in parentheses added later relate to 1982-84.
2. Gum is measured in kilograms. All other products are measured in cartloads. The weight of a cartload ranged from 500 to 100 kg depending upon the product (e.g., fuel wood versus top feeds) under question. By 1985 due to introduction of rubber-tyred bullock carts (*Chhakada*) the standard of cartload changed. Compared to earlier wooden-tyred bullock carts, Chhakada could accommodate 50 per cent more product by volume and weight. However, the figures reported in the Table are in terms of load carried by wooden-tyred bullock carts. Original sources of data are auction records of ex-Jagirdar and the village panchayat. In the post-land reforms period, the practice of auctioning has declined mainly because there is not enough material to auction. This is turn is a result of elimination of most of the trees and complete destruction of even roots of perennial grasses.

villages since early 1970s (Jodha 1985a). Such milch animals seldom graze on CPRs, and in a way they represent withdrawal of rich farmers from CPRs. These sort of changes in the composition of livestock have been observed in many other parts of dry tropical areas of India (Jodha, 1986).

The Future Possibilities

Better management of arid lands with a focus on higher vegetative cover, has been a key recommendation of several studies (Ravi, 1942; Anon., 1960; NCAER, 1965; Jodha and Vyas, 1969; ICAR, 1977; Spooner and Mann, 1982). The fragility of the region's natural resource base and its susceptibility to rapid erosion due to intensive use, its comparative advantage in pasture-based livestock farming, and the accentuation of desertification due to unscientific land use practices were the key issues behind those recommendations. The specific suggestions ranged from formation of state level Board of Land Management to restriction of crop cultivation on submarginal lands and controlling the growth of animals. Some variants of the recommendations became part of public programmes like drought-prone area programmes (DPAP) and production oriented relief strategies during droughts.

Researches at the Central Arid Zone Research Institute (CAZRI), Jodhpur, also provided technical basis for public interventions like sand dune stabilisation and improvement of rangelands. However, despite these efforts, situation of vegetative cover or biomass production and its proper usage, has only worsened with the passage of time. Ineffectiveness of the above initiatives can be attributed to their overemphasis on 'techniques' (i.e., mechanical or biological dimensions) and insensitivity to institutional factors (Jodha, 1988). These programmes betray complete lack of understanding of the factors and processes at village and farm levels which are responsible for rapid loss of vegetation or biomass in the arid region. The present paper, though covering only a small number of villages, has tried to put together micro-level evidence on the dynamics of resource use in the arid areas. The insights presented by the study, hopefully, would help in reorienting the thinking on the problems and prospects of biomass producing resource problems in the arid region.

Table 10. Indicators of rising scarcity of fodder and fuel in the study villages of Jodhpur and Nagaur districts in the arid region of western Rajasthan[1]

Details	Average annual situation in the villages					
	Jodhpur			Nagaur		
	1951-53	1963-66	1982-84	1951-53	1963-66	1982-84
Pachasa[2] (unit of fodder staking) in the villages (no.)	21	13	0	35	18	3
Cart loads of fodder (stalks) contributed by the village to common/charity feeding (no.)	15	11	3	20	14	6
Proportion of households[2] sold fodder:						
– On exchange basis (%)	28	22	8	44	28	14
– For cash to trader (%)	6	30	43	16	36	62
Duration of seasonal outmigration of sheep herders (days/year)	28	42	98	20	60	112
Time it took for fuel gatherers to collect *mundana* (a cart full of fuel) for sale from village commons (days)	10	15	40	7	12	30
Proportion of households[3] stocked (traditionally discarded) inferior crop by-products for fodder and fuel (%)[4]	3	27	95	6	12	98
Proportion of farm households[3] allowed free access to others for post-harvest grazing, lopping trees and bushs, collection of dung, etc. (%)	100	56	8	100	60	15
Households[3] replacing bush fencing :						
– Every year	85	52	14	88	44	16
– With a gap of 2-3 years	15	47	66	12	36	59
– Replaced by stone fencing	-	1	20	-	10	25

1. Source : Data collected during field studies (Jodha, 1968, 1986).
2. *Pachasa* a form of staking fodder, secure for 5-8 years. *Pachasa* literally means method of fodder storage to keep it unspoiled for 50 years.
3. Number of sample households covered by above information was 62 and 75, respectively, from two villages each in the districts of Jodhpur and Nagaur.
4. Include *bajra* husks, sesamum pods/stalks, mustard and *raya* stalks, and bengal gram stalk.

One of the realistic ways to promote sustained availability of biomass in the arid areas of western Rajasthan, is to sensitise the planning and development strategies in the region to the traditional or ongoing approaches of the farmer to biomass issues. The purpose of this suggestion is not to idealize the tradition, but use it as a source of potential options, which could be improved with the help of modern advances in the field technology and management. Guided by this understanding, I propose to summarise the key inferences from the above discussion.

Inferences are summarised separately for (i) measures dealing with augmentation of biomass availability, and (ii) measures related to demand side of biomass. The discussion on each issue is presented in terms of current trends, possibilities of encouraging or discouraging the trends, and constraints on possible interventions to help the positive trends.

Measures Augmenting Biomass Availability

Revival of indigenous agroforestry

Trends : It is quite encouraging to see an increase in the number of *khejri* trees in crop fields. For other components, e.g., *ber* bush colonies (malla) and shelterbelts (matt), the situation is discouraging, as these are rapidly disappearing.

Table 11. Changes over time in livestock farming in one village each in Jodhpur and Nagaur districts in the arid region of western Rajasthan, 1963-78

Item	Villages of districts							
	Nagaur				Jodhpur			
	1963-65		1977-78		1963-65		1977-78	
	Small farmers[2]	Large farmers[3]	Small farmers	Large farmers	Small farmers	Large farmers	Small farmers	Large farmers
Average size of livestock holding (animal units)	15	13	13	9	16	14	15	9
Share of sheep/goats in animal units (%)	38	6	42	22	40	9	46	31
Proportion of buffalo in milch stock (%)	5	23	13	46	6	27	15	51
Unproductive animals per productive animal (no.)	7	4	6	2	5	3	5	1
Cattle regularly stall-fed (except in monsoon) (%)	6	25	11	49	5	23	18	57
Proportion of animal grazing days depending on CPRs (%)	81	59	76	31	85	62	76	29

1. Source : Table adopted from Jodha (1985a). Data relate to one village in each of the district. Details of the first-four items relate to the whole village, while the last two items relate to sample households. The details of only two farming groups are presented to indicate the contrast or comparison.
2. Those owning up to 5 hectares of dryland.
3. Those owning 10 or more hectares of dryland.

Potential : Reasonably high chances exist for promoting trees in the fields, as the current initiative of the farmer is a response to a felt need for drought period insurance, especially after *ber* bush in the fields declined following tractorisation. Decline of CPRs (i.e., their area and productivity), also encouraged protection and growth of trees (in crop lands) as a component of agroforestry to serve as an alternative source of biomass.

Constraints : Owing to the factors like tractor ploughing, which discourages presence of trees or bushes in crop field, and the high cost of keeping a watch, as well as the absence of institutional sanctions for protecting 'exclusive private gains' from agroforestry, this option may face some problems in the initial stage. The modern scientific agroforestry is still unknown to the farmer.

Public interventions : At present there is little scope for effective public intervention, legal or otherwise. Some incentives to farmers might help. Discouragement of tractor cultivation may be necessary. The formal agroforestry programmes need to be sensitised to farmers' approaches to biomass production.

Retiring crop lands back to natural vegetation

Trends : This largely implies crop (grass/bush) fallow rotation. Owing to rising population pressure decline in keeping the land fallow is unavoidable. Only large farmers are able to follow this practice.

Potential : There is very limited scope for this practice except on large farms, unless 'non-crop biomass production' through new technologies becomes highly profitable.

Constraints : High pressure on land and tractor ploughing leave little chances for fallowing. Besides, there are difficulties in protecting the private gains like fuel, fodder, etc., from the fallow lands, since such fallows are also used as common resources.

Public interventions : There is little scope for any legal measures because of the inability to enforce any land use regulation within the existing institutional framework. Moreover, no viable technologies for silvipastoral systems are available as yet. Hence there is a need for public effort in this direction.

Rehabilitation of common property resources

Trends : CPRs continue to sustain people, particularly the rural poor, but the products available are increasingly inferior and less in quantity. Both area and productivity of CPRs are on the decline. Very limited evidence is available on protection and rehabilitation of CPRs, where NGOs or enlightened *Panchayats* took initiative. In most cases the decision makers, i.e., influential villagers, bother little about CPRs, as they do not depend on CPRs, except for grabbing them as private property.

Potential : There is little scope for improvement in the situation unless state policies and informal institutional arrangement at village level are changed or the NGOs take it up as a high priority activity.

Constraints : The key constraints are the state land policies which encourage privatisation of CPRs, *Panchayat's* indifference to management and usage of CPRs which tend to make CPRs as open access resources, and very low productivity of CPRs which also discourages any public initiative to manage and develop them.

Public interventions : Public measures like afforestation, reseeding of rangelands, etc., are purely technical measures and are insensitive to "CPR" dimension of these resources. This needs to be changed. The same applies to legal measures also. The steps may include prevention of further privatisation of CPRs, rehabilitation of CPRs with the help of NGOs (for usage regulation), and forest and soil conservation departments (for vegetative regrowth), incentives to *Panchayats* to improve management of CPRs, provision of 'user cost' to serve both as a disincentive for over-exploitation and a source of revenue for upkeep of the resources. Finally the CPR dimension of all resource development programmes like social forestry, range land rehabilitation, etc., should be emphasised.

Harnessing of slack resources

Trends : Farm level evidence shows (i) non-harvesting of considerable biomass, and (ii) insufficient conservation, processing and recycling of the biomass before use during the years of plenty. This represents a slack resource, which through processing and storage can help meet the needs during scarcity years.

Potential : At times the above practices can add as much as 20 to 50% to the overall availability of biomass, especially when one compares the quantity of sorghum/pearl millet stalk fed to animals with and without chaff cutting. Similarly, during any year, harvest of top feed *loong* from *khejri* tree and *pala* from *ber* bush declines considerably if they are not harvested in the previous year.

Constraints : Relative scarcity of labour during the good rainfall years and sense of complacency generated by plenty, lead to disregard of the above biomass potential; slackening of the traditional on-farm reserves and recycling of biomass are the other problems.

Public interventions : Incentives through fodder prices, fodder bank, popularisation of fodder/fuel processing and recycling methods using modern technologies may help, though as yet there is no formal initiative on this front.

Inter-regional complementarities

Trends : The system of seasonal migration of animals, both as a form of collective security and method of adjustment to instability of biomass availabilities is rapidly changing, mainly because of the reduced area of grazing CPRs. Migration of cattle is on the decline, while migration of sheep and goat has become an annual feature. The latter migrates on a regular basis, to 'green revolution areas' of the neighbouring states, after the harvest of *rabi* crop. They make good use of grazing material, a waste for high biomass producing areas, and also help in sustaining the

organic base of 'green revolution', which otherwise is largely dependent on chemical fertilisers.

Potential : Having emerged in response to felt needs, the above pattern is of self-sustaining type. This is an indirect way of making up the deficit of biomass in the arid areas and it is likely to increase in the future.

Constraints : Usual problems which animal migrants often face during transhumance, e.g., harassment en-route, etc., are key constraints.

Public interventions : Facilities for migrants, e.g., fodder and water facilities en-route and protection against harassment especially on state borders, can help the sheep herders.

Discarding zero-input production systems

Trends : Biomass production (other than crop by-products) in the arid areas involves little cost except on labour for harvesting or grazing the biomass. The people simply harness what nature offers to them. A few large farmers who tried sheep penning and a little scratching/trenching of fallow lands (pearl millet), got almost double the yield of biomass, as compared to the fallow lands without any development input.

Potential : In view of the tradition of harnessing nature at zero cost and inability to protect the gains of investment in resource improvement for oneself (due to convention of common access to private fallow lands), the system of producing fodder and fuel with deliberate investment and effort is almost non-existent. The situation may change with the availability of highly productive silvipastoral systems.

Constraints : Absence of tradition and practice to treat fodder/fuel as a crop on the part of the people and low priority to them in agricultural R and D are the key problems.

Public interventions : Introduction of modern silvipastoral systems is one potential option. Past efforts on this front, however, have been negligible when compared to extension and support systems for arable farming. Moreover, R and D efforts on silvi-pastoral systems are completely insensitive to farm level realities.

Measures on the Demand Sides

On the demand side of biomass, the issues could be listed under two categories: (a) those relating to regulated use and prevention of over-exploitation of resources producing fuel and fodder, (b) those relating to reduction in pressure of demand on biomass resources, both by raising the use-efficiency of biomass (e.g., processing preceding their use) and by reducing the overall demand on biomass, (e.g., by gradual reduction in number of animals).

Regulated use and prevention of over-exploitation

Trends : Despite low biomass production potential, the vegetative growth of plants in several parts of the arid region is reasonably fast, if the plants are given sufficient protection and are utilised within the limits (e.g., through rotational grazing or through cut and carry system rather than open grazing). As already mentioned some investment in terms of manuring (e.g., by sheep) and moisture conservation measures can raise biomass productivity of land quite substantially. The resources to which the above description applies are common property resources and private fallow lands which are expected to be under natural vegetation.

In the case of private fallow lands, especially in the case of large farms, the trend is towards greater protection of resources.

Potential : As mentioned earlier, with the rapid decline of CPRs, the private sources of fuel and fodder are gaining importance. Private forestry (in *Bira*, i.e., old protected fallow lands) as against social forestry on CPRs, shows greater potential for spread. However, this would make rural poor worse-off, as they have little land resources to participate in this process.

Constraints : Constraints to regulated use of CPR were already mentioned. On private fallow lands, absence of community sanctions, enabling

the protection of private gains of investment, etc., obstruct the process. Decreasing access to biomass resources for rural poor may also indirectly obstruct the rapid rise of private forestry.

Public intervention : Present usage status of CPRs offers a vast potential for public interventions. Introduction of usage regulations, incentives to *Panchayats* and NGOs to implement them, introduction of grazing policies to help rotational grazing and periodical closure of CPRs are a few of the possible areas for public intervention. However, this will need initiative from the below, involving the NGOs and the village communities. Some physical measures such as spread of watering points (as in the past) in grazing lands can also help. Introduction of usage charges for CPR users is another (fiscal) measure to induce regulated use of CPRs and generate revenue for the upkeep of CPRs. Farm or village level storage, conservation and recycling of biomass can also be promoted by certain fiscal measures.

Reducing pressure of demand

Trends : There are two major ways of reducing pressure of demand on biomass, especially the fodder resources: (i) conservation and processing of biomass before use, and (ii) reduction in the number of animals. Regarding the former, despite high potential of slack resources, the trends indicate increasing de-emphasis on storage, conservation and recycling measures. Regarding the latter, at least in some areas there is a clear trend towards reduction in the number and changes in the composition of livestock. Livestock farming is becoming more management-intensive, involving high private cost. This, in the long run, may encourage decline in the herd size. However, this trend forms a part of the emerging pattern, where large farmers are increasingly depending on private resources for their livestock and the rural poor have to sustain their animals on rapidly shrinking and degrading CPRs.

Potential : The need for utilisation of slack resources and discard of surplus livestock can not be overstated. However, potential for adoption of these practices seems quite low. An integrated approach directed to demonstrate economies of small herds can help. Increase in the extent of stall feeding and consequent reduction in herd size in the areas with improved milk marketing facilities (e.g., "operation flood areas") in the western Rajasthan are the possible new directions.

Constraints : The old tradition of raising animals at social cost and the dependence on free supplies of fuel and fodder from CPR are the major obstacles to reduction in demand for biomass. Security through large number of low productivity animals is another constraint to reduction in animal number. These factors apply more to the rural poor, who do not have enough private resources to complement their use of CPRs.

Public interventions : Infrastructure, marketing, formal insurance, etc., are a few measures which can help promote stall feeding based on high management intensive livestock rearing, especially in the case of cattle. "User group" based development and management strategies for CPRs can be one way to help the rural poor in regulating their number of animals.

Livestock policies and programmes at present are not sensitive to the above issues.

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