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Rainfed Farming Systems of Hyper Arid North-Western Rajasthan: An Analysis

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Abstract: Three micro-farming situations (MFS's) were identified in rainfed area of district Bikaner. The identified MFS's varied considerably with respect to socio-economic conditions, composition of crops and livestock, productivity, economics and constraints associated with crop and dairy animal components of existing farming systems. Among the crops clusterbean either grown as sole or mixed crop had maximum area followed by pearl millet+moth bean mixed crop. Clusterbean+sesame, sole clusterbean and chickpea were most remunerative crops in MFS-I, II, and III, respectively. Highest milk productivity was registered in MFS-III followed by MFS-I and II. Pest incidences, lack of improved seeds, less remunerative prices, lack of improved tech-know-how were major constraints in crop production, and their relative significance were crop and micro farming situation specific. Scarcity of fodder emerged as major constraint in milk production in all MFS's.

Key words: Hyper arid, micro farming situation, crop, dairy animal, productivity, economics, constraints.

Crop production is very risky in hyper arid western Rajasthan. The crop yields are meager and consequently the income from cropping alone is hardly sufficient to sustain the farmer's family. Therefore to mitigate the risk and uncertainties of income from conventional cropping, it is essential to use farming system approach in production programme that yield regular and evenly distributed income. Farming systems are complex and dynamic and were evolved in response to particular agro-climatic, ecological and socio-economic conditions (Collinson, 1983; Hilderbrand, 1981). Small farm households operating diversified production systems are striving to meet both consumption and production goals under marginal conditions for agriculture. Furthermore, farm household formulates management strategies and make decision within the context of the whole economic system exploited by the household including off-farm enterprises (Byerlee and Collinson, 1980; Shaner *et al.*, 1982). Drawing on these new insights and concepts, farming system research evolved an approach of agricultural research and development. Understanding the existing farming system is an essential prerequisite for formulating viable innovations (Bunting and Watts Padwick, 1983). Farming system research is an interdisciplinary process and broadly three activities viz. diagnosis, planning and experimentation and assessment are involved in it. The diagnosis include target grouping, selection of priority group and survey (CIMMYT, ESA, 1986). Thus, survey of existing farming system becomes the first step of farming system research. The present study was undertaken to assess the productivity, economics and associated constraints of crop and dairy animal components of existing farming system in rainfed areas of Bikaner district.

Materials and Methods

Three Micro Farming Situations (MFS's) were identified based on physiography, landforms, soil types, rainfall, cropping pattern and livestock composition in rainfed area of Bikaner district. The brief description of characteristics of these MFS's is presented in Table 1. Two villages from each MFS and 20 farmers having average land holding (5-10 ha) from each village were selected randomly. Data were collected through personnel interview method by using pre-tested schedule during 2004. Some socio-economic information about selected villages was collected from secondary sources. Economics of crops and dairy animals was computed by using standard procedures. Simple tabular and percentage analysis was employed for drawing inferences. To identify constraints associated with crop and dairy animal, a comprehensive list of constraints were given to farmers and asked to rank them according to severity by assigning value one to most limiting constraint, 2 to next important and so on, then the rank value averaged across the respondents in particular MFS and a composite score obtained.

General description of study area

District Bikaner covers an area of 27351.9 km^2 and lies at 27°11'-29°03' N latitude and 71°54'

Table 1. General characteristics of microfarming situations

MFS	Features
MFS I: Sandy plains having hard pan	Lying largely in Kolayat tehsil extending towards Phalodi; Sandy plain having hard and compact substratum at shallow depth; 15-20 cm rainfall; Loam soils having hard substratum; low fertility; Limited Kharif cultivation of clusterbean, moth bean, bajra and sesame (sole or mixed crop) along with open grazing is major land use. Sheep and goats are major livestock followed by cattle.
MFS II: Sand dunes with undulating interdunal plain	This MFS occurs largely in Pugal and Bikaner tehsils. Characteristics of soils are very much related to associated landforms. Invariably the soils are sandy having low WHC and fertility. Wind erosion is very severe. Crop failure and low productivity is a rule rather than exception in this MFS. Cultivation of clusterbean, moth bean and pearl millet is common in this MFS. Small ruminants e.g. sheep and goat have major share in livestock.
MFS III: Sandy plains with limited rabi cultivation	Occurs in Lunkarnsar tehsil and surrounding areas of district Churu; 25-37 cm rainfall; Sandy loam having WHC 5-8 cm/m; Clusterbean, moth bean and pearl millet are important kharif crops, limited cultivation of gram during Rabi season is unique feature; sheep and goat along with cattle are important livestock.

-74°22'E longitude in north-western part of Rajasthan.

The general regional slope of district is from SSE to NNW and regional elevation above mean sea level is about 152 m in western part and 275 m in eastern part. The western, south-western, northern and north-eastern parts of the district are largely covered with dunes of different types and magnitude with flat to undulating interdunal plains. The central, eastern and southern parts of district constitute largely the flat and undulating alluvial plain. The district has no major rivers except a few short intermittent and ephemeral channels near Kolayat.

Climate: Extreme climatic conditions characterize this region. The mean daily temperature ranged from 40°C in June to minimum of 8°C in January. Temperature increases sharply during summer and the maximum temperature varies from 38.8°C in January to 45.5°C in June and occasionally temperature above 45°C is recorded when heat wave passes across the region. January is the coldest month, the period during which frost is common from 18th December to 22nd January. Average annual rainfall is 24.7 cm, which varies from 10-20 cm in western parts to >30 cm in eastern parts with CV of 50-65%. More than 85% of the rainfall is received during the south-west monsoon season (July-September), mainly under the influence of depression passing across the region. About 7-10% of the rainfall is received during winter season under the influence of western disturbances and small quantity occasionally during the hot weather period from circulation system associated with dust/ thunderstorm activity. Annual potential evapotranspiration (PET) ranges from 160-200 cm, which varies from 190-200 cm in western part to 160-170 cm in eastern part. The wind direction remains predominantly south-west from April onwards up to October and from north-east during intermittent months. The wind regime starts building up along with temperature reaching a peak during June and starts decreasing from October onwards. The average wind speed is 6.5 km h^{-1} in March to 13.5 km h^{-1} in June. *"Loo"* and dust storms are common convective climatic phenomenon during hot weather period.

Soils: This region is endowed with variety of soils developed from alluvial and aeolian parent materials of the quaternary formations. Profiles of soils are weakly developed due to aridic soil moisture and hyperthermic temperature regimes. The characteristics of soils are closely related with associated landforms. The soils of this region are predominantly light textured, loamy fine to coarse sand in texture, having high infiltration rate (7-15 cm h^{-1}), poor water holding capacity (being 40-50 mm m^{-1} in dunal and 70-80 mm m^{-1} in interdunal plain soils), weak structured and highly erodible. Fertility status of soils is very poor, the organic matter (0.05 to 0.3%) and N content of these soils are very low, which is attributed to high temperature, low rainfall, scanty vegetation cover and light textured soils. The available P content is <20 kg ha^{-1}, in which inorganic Ca bound-P constitutes major part. The soils are well supplied

with K and slightly high values were observed for dunes and interdunal soils than sandy plain soils.

Vegetation: Psammophytic scrub desert and mixed xerophytic woodlands are major vegetation types occur in district Bikaner. *Calligonum polygonoides-Panicum turgidum* community included in psammophytic scrub lands covers mostly sand dunes and undulating interdunal plains; while *Prosopis cineraria-Ziziphus nummularia-Capparis decidua* community covering the flat aggraded older alluvial plains and flat interdunal plains are included in mixed xerophytic woodlands. *Lasiurus sindicus* is most prevalent grass community covering interdunal plains, lower dune slopes; whereas dune tops are largely occupied by *Panicum turgidum*. Halophytic scrub vegetation with *Sporobolus marginatus-Eleusine compressa* dominated in saline depressions and interdunal areas.

Land utilization pattern: About 53.0% of total area of district is under cultivation. The area under culturable waste and fallow constitutes 23.0 and 10.0% of total area, respectively. The area under forest and grazing land is only 3.0 and 2.5%, respectively.

Irrigation: The net irrigated area of district Bikaner is 158084 ha, which constitutes about 10.0% of the net cultivated area. Canal, tube wells and wells are the major sources of irrigation accounting for 70.0, 23.0 and 7.0% of the total irrigated area, respectively. In Khajuwala, Chattargarh, Pugal and Lunkarnsar tehsils canal is the major source of irrigation; while in Nokha and Dungargarh tehsils the wells are main source of irrigation.

Crops and cropping pattern

This region is characterized by monocropping system with crops like pearl millet (*Pennisetum glaucum*), clusterbean (*Cyamopsis tetragonoloba*), moth bean (*Vigna aconitifola*) and sesame (*Sesamum indicum*), which are sown both as sole and mixed crops in various proportions. Keeping the land fallow in alternate year is also common. All these result into cropping intensity below 100%. Wherever groundwater and canal water is available for irrigation groundnut (*Arachis hypogea*), cotton (*Gossypium* sp.), wheat (*Triticum aestivum*), rapeseed (*Brassica juncea*), isabgol (*Plantago ovata*), cumin (*Cumminum cyminum*) are grown. Amongst the fruit crops ber (*Ziziphus maurtiana*), aonla (*Emblica officinalis*) and datepalm (*Phoenix dactylifera*) are promising for this region. The common crop rotations of this region are:

Rainfed: Moth bean-fallow-pearl millet-fallow; Clusterbean-fallow-pearl millet-fallow; pearl millet+clusterbean+moth bean+sesame-fallow-pearl millet-fallow; pearl millet+clusterbean-moth bean+pearl millet-fallow-clusterbean-fallow.

Irrigated: (a) Well irrigated: Groundnut-wheat; pearl millet-mustard; clusterbean-wheat; pearl millet-cumin; pearl millet-isabgol. (b) Canal Irrigated: Groundnut-wheat; pearl millet-wheat; clusterbean-wheat; cotton-wheat.

Livestock: Livestock plays an important role in agrarian economy of this region. Total number of livestock in Bikaner district is 24.2 lakh. Sheep and goat are major livestock followed by cow, which constitute 39.0, 28.0 and 25.0% of total livestock population, respectively. This region is endowed with some of the well-known breeds of milch cow, carpet wool producing sheep, meat and milk producing goat and draught purpose camel.

Results and Discussion

Socio-economic status

Size of household varied from 6.3 to 7.6, being maximum in MFS-III and minimum in MFS-I. Literacy rate was 52.5, 32.5 and 61.3% in MFS I, II and III, respectively. Work participation rate was about 50.0% in all MFS's, indicating surplus labor prevailing in rainfed areas of district Bikaner. Agriculture is the main source of income and had 80.1-94.0% share in total income in different MFS's (Fig. 1). Relative contribution of crop and livestock varied considerably among different MFS's. Share of crop production in total income was 50.2, 44.3 and 42.8% in MFS-III, I and II, respectively. Livestock contributed 37.3-43.8% to total income, being maximum in MFS-III, followed by MFS-I and II. Non-agriculture activities contributed 6.0 to 19.9% to total income.

Cropping pattern: Except in MFS–III, crop is grown only in kharif season. Cluster bean+sesame mixed crop constituted about 2/3 cropped area, followed by mixed cropping of pearl millet+moth bean in MFS-I. Relatively heavier soils, better compatibility with plant height, easiness in harvesting, less damage by wild animals coupled with remunerative price of crops, favored the maximum area under cluster bean+sesame mixed cropping in MFS-I. Sole clusterbean was major crop in MFS-II and III and constituted 89.0 and

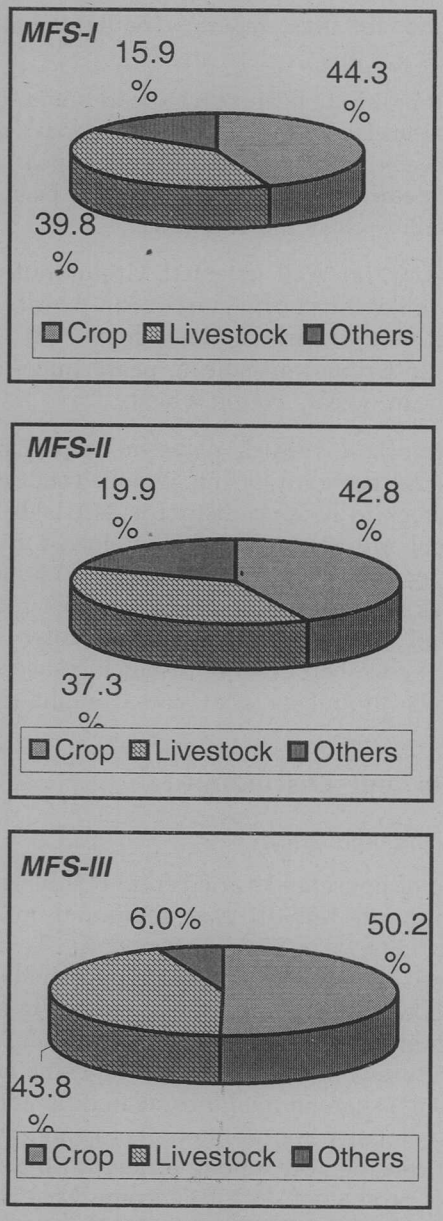

Fig. 1. Source of income (% share) in different MFS's.

56.0% of cropped area, respectively. Short duration, relatively better yield and remunerative price are the major factors that favored the area under clusterbean. Mixed crop of pearl millet+moth bean covered 5.0 and 8.2% cropped area in MFS-II and III, respectively. Chickpea occupied 28.0% of the total cropped area in MFS-III. Thus, legumes grown either as sole or mixed crop covered maximum cropped area in rainfed situation of district Bikaner.

Livestock composition: Small ruminants had major share in the livestock (Fig. 2). Their share in total livestock varied from 56.6-80.5%, being maximum in MFS-II and minimum in MFS-III. Among the small ruminants, sheep had 50.4-64.3% share. The cattle had maximum share in MFS-III (35.8%) followed by MFS-I (20.2%) and MFS-II (14.6%). The share of camel in total livestock was maximum in MFS-III followed by MFS-II and MFS-I.

Productivity, economics and constraints associated with major crops

MFS-I: Productivity of seed was higher in legume+oilseed (clusterbean+sesame) system than millet+legume (pearl millet+moth bean) mixed crop system and reverse was true with respect to biomass productivity (Table 2). Cost of cultivation was higher in CB+S than PM+M mixed crop system and variable cost had about 78.0% share in total cost. Human labor had maximum share in variable cost i.e. 73.5 and 84.3% in CB+S and PM+M mixed crop system, respectively. Operation wise, intercultural activities had maximum share in variable cost of both mixed crop systems. CB+S was more remunerative than PM+M mixed crop with higher net return (Rs. 1576.9 ha^{-1}) and return per rupee invested (1.32). Pest and disease incidence and unavailability of improved seeds was most important constrains in production of both mixed crop system (Table 3).

MFS-II: Millet+legume (pearl millet+ moth bean) mixed crop system was superior to sole clusterbean with respect to seed and biomass productivity (Table 2). Cost of cultivation was lower in sole clusterbean than PM+M mixed crop system. Variable cost constituted 77.3 and 80.3% of total cost of cultivation of sole clusterbean and PM+M mixed cropping, respectively. Item wise, human

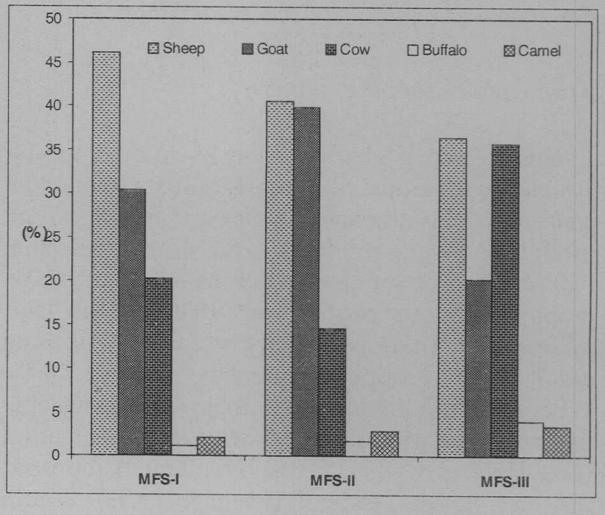

Fig. 2. Livestock composition in different MFS's.

Table 2. Productivity and economics of major crops in various MFS's

	MFS-I		MFS-II		MFS-III	
	CB+S*	P+M	CB	P+M	CB	CP
Productivity (q ha^{-1})						
Main product	2.8+0.9	2.5+1.3	2.7	3.0+1.5	3.3	3.5
By-product	4.5+2.5	6.5+2.5	4.6	6.5+2.8	4.9	4.5
Economics (Rs. ha^{-1})						
Total variable cost	3774.9	3600.7	3132.1	3616.5	3518.9	3470.5
Total fixed cost	1068.2	1036.4	918.7	890.0	1015.6	1015.6
Total cost	4843.1	4637.1	4050.8	4506.5	4534.5	4486.1
Gross return	*6420.0*	5007.5	5045.0	5125.0	5822.5	6150.0
Net return	1576.9	370.4	994.2	618.5	1288.0	1663.9
Return per rupee invested	1.32	1.08	1.25	1.13	1.28	1.37

*where CB-Clusterbean, S-Sesame, P-Pearl millet, M-Moth bean and CP-Chickpea, MFS-Micro-farming situation.

Table 3. Constraints of major crops

MFS	Crop	Constraints	CS	Rank
MFS-I	Clusterbean+sesame	Pest and disease incidence	1.5	I
		Unavailability of improved seeds	3.0	II
		Less remunerative price	3.3	III
		Lack of technical know-how	3.8	IV
		Lack of credit facilities	3.9	V
	Pearl millet+moth bean	Pest and disease incidence	1.7	I
		High price & unavailability of improved seeds	2.5	II
		Lack of technical know-how	2.6	III
		Stray animals	3.3	IV
		Lack of credit facilities	4.1	V
MFS-II	Clusterbean	Pest and disease incidence	1.4	I
		Lack of technical know-how	2.0	II
		Less remunerative price	3.3	III
		Unavailability of improved seeds	4.1	IV
		Lack of credit facilities	4.6	V
	Pearl millet+moth bean	Lack of technical know-how	1.6	I
		Pest and disease incidence	1.7	II
		Unavailability of improved seeds	3.3	III
		Less remunerative price	3.6	IV
		Lack of credit facilities	4.9	V
MFS-III	Clusterbean	Pest and disease incidence	1.4	I
		Less remunerative price	1.9	II
		Unavailability of improved seeds	2.5	III
		Lack of technical know-how	2.7	IV
		Lack of credit facilities	3.2	V
	Chickpea	Unavailability of improved seeds	1.8	I
		Pest and disease incidence	1.9	II
		Lack of technical know-how	3.1	III
		Less remunerative price	3.9	IV
		Lack of credit facilities	4.2	V

Table 4. Productivity, economics of dairy animals in different MFS's

	MFS-I	MFS-II	MFS-III
Productivity (kg SAU^{-1} $annum^{-1}$)			
Milk	1030.1	855.9	1122.4
Economics (Rs. SAU^{-1} yr^{-1})			
Total variable cost	8569.1	8703.6	8601.6
Total fixed cost	470.9	391.8	280.0
Total cost	9040.0	9095.4	8881.6
Gross return	9659.4	9475.0	9792.7
Net return	619.4	379.6	911.1

labor had maximum share in variable cost. In sole clusterbean, harvesting had maximum share in variable cost followed by sowing, intercultural operation, land preparation and threshing. The share of various operations in variable cost of PM+M was: harvesting (33.8%), land preparation (23.8%), sowing (20.5%), threshing (15.7%) and intercultural operation (4.1%). Sole clusterbean was more remunerative crop than PM+M mixed crop system with higher net return and return per rupee invested. Pest and disease incidences was most important constraint in cultivation of sole clusterbean followed by lack of technical know-how, less remunerative price, lack of improved seeds and lack of credit facilities (Table 3). In PM+M mixed crop system the important constraint in order of severity was lack of technical know-how pest and disease incidence unavailability of improved seed.

MFS-III: The seed productivity of sole chickpea was higher than sole clusterbean, but total biomass productivity was higher in clusterbean. Total cost of cultivation of chickpea was higher than clusterbean (Table 2). Variable cost constituted about 77.0% of total cost in both the crops. Human labor had maximum share in variable cost of both the crops. Operation wise, intercultural operation contributed 28.6% in total variable cost of clusterbean followed by harvesting (24.8%), sowing (21.2%) and land preparation (16.6%). In chickpea, land preparation had maximum share (35.6%) in variable cost followed by sowing (26.6%), threshing (14.4%), intercultural operation (11.6%) and harvesting (10.2%). Chickpea was more remunerative than clusterbean. Pest and disease incidence and unavailability of improved seeds were most important constraint in production of clusterbean and chickpea, respectively (Table 3).

Productivity, economics and constraints associated with diary animals

MFS-I: Average productivity of milk was 1030.1 kg SAU^{-1} $year^{-1}$ (Table 4). Total cost of maintenance was Rs. 9040.9 SAU^{-1} $year^{-1}$. Feed and human labor was most important items of cost and had 75.1 and 21.3% share in variable cost. Net return realized with per SAU per year was Rs. 618.5. Scarcity of fodder was most important constraint in milk production followed by health problems, low productivity of milk, lack of marketing facilities and less remunerative price of milk (Table 5).

MFS-II: Milk productivity was lowest and total cost of maintenance per SAU was highest in MFS-II (Table 4). Variable cost had 95.0% share in total cost and the share of feed, labor and veterinary and miscellaneous expenses in variable cost were 81.9%, 16.0% and 2.1%, respectively. Low milk productivity and higher cost of maintenance resulted in lowest net return (Re.379.6 SAU^{-1} $year^{-1}$) among three MFS's. Important constraints of milk production in order of severity was fodder scarcity,

Table 5. Constraints of milk production in different MFS's

Constraints	MFS-I		MFS-II		MFS-III	
	CS	Rank	CS	Rank	CS	Rank
Scarcity of fodder	1.7	I	1.5	I	1.7	I
Health problems	2.3	II	2.8	II	2.4	II
Low milk productivity	2.4	III	2.5	III	4.2	V
Lack of marketing facilities	4.2	IV	4.2	V	3.6	IV
Less remunerative prices	4.5	V	4.0	IV	3.1	III

health problems, low milk productivity, less remunerative price and lack of marketing facilities.

MFS-III: Average milk productivity was 1122.4 kg SAU^{-1} $year^{-1}$, which was highest among all the MFS's. Cost of maintenance was lowest in this MFS. Variable cost accounted for 96.8% of total cost. Feeding and labor cost constituted 82.8 and 15.1% of variable cost, respectively. Maximum net return per SAU per year was realized in this MFS due to higher milk productivity and less cost of maintenance. Scarcity of fodder, health problems, less remunerative price, lack of marketing facilities and low milk productivity were major constraints of milk production in decreasing order of severity.

Conclusion

Considerable variations exist among different MFSs with respect to socio-economic status, cropping pattern, livestock composition, productivity, economics and associated constraints of crop and dairy animals. Except moisture deficit, which is unquestionably most limiting factor for crop production in rainfed area; other most important constraints were pest and disease problems, non-availability of improved seeds, lack of technical know-how, less remunerative price and lack of marketing facilities which were crop and MFS specific. In milk production, scarcity of fodder was most important constraint in all MFSs. Considerable variations in different MFS's call for different strategy for improving and / or developing new farming system, which can cater diverse needs of farmers in sustainable manner.

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