55

PART V

CASE STUDIES IN AGROFORESTRY

9311254
PN-ABW-977
ISN = 49901

11

Indigenous Technology and Farming Systems Research: Agroforestry in the Indian Desert[1]

Barry H. Michie

The appreciation of indigenous technology is an underlying tenet of Farming Systems Research. Traditional agricultural production systems in many cases are adaptations to local social and ecological conditions which have proven to be productive and sustainable over long periods of time. Agricultural science has investigated relatively few farming systems, and as a result the observation and study of undocumented systems may be a necessary prerequisite to the improvement of local systems. The application of anthropological techniques can be a valuable component of this initial observation, particularly for eliciting the rationale of existing systems. The application of a holistic perspective can be an important tool for bringing together technical and human elements for the generation of new technology or the improvement of existing systems.

This case study describes a Farming Systems project directed by the author in India with the faculty of Mohan Lal Sukhadia Agricultural University[2], the agricultural school for the State of Rajasthan. The project dealt with an arid zone where grain is produced in association nitrogen fixing trees. The multiple benefits of this association make it unlikely that farmers will change this production system unless major climatic or infrastructural changes occur. The probable persistence of this pattern has major implications for agricultural research strategies.

Location Specificity in Farming Systems Research: The Case of India

Farming Systems Research is fundamentally a location

DSAN/XII-G-0149

specific methodology. Soils, climate, topography, cropping patterns, floral and faunal components form the bio-physical elements of an agricultural system, but even within so-called homogeneous cropping zones (GOI 1976; Morrison 1979) the diversity is great due to the variety of associations which can be formed with that set of elements. Furthermore the diversity in the bio-physical dimension is mirrored in the socioeconomic arrangements through which the bio-physical ones are organized and acted upon (Chambers and Harriss 1977; Mencher 1965; Nair 1979). The obvious implication is that what might work in one environment or system will not work necessarily in another.

In India there is explicit recognition of this diversity and attention is turning to location specific research. The fifteen volume **1976 National Commission on Agriculture Report** published by the Ministry of Agriculture and Irrigation (GOI 1976) identifies some 11 rainfall, 52 cropping and 29 livestock zones for Rajasthan, the location of the case study (GOI 1977).

Rajasthan is in the northwest part of India (see Figure 11.1), covers some 132,000 square miles, and is India's second largest state. To the west is Pakistan with the international border running through the Thar or Great Indian Desert. The major topographic feature affecting rainfall and cropping patterns is the Aravalli Mountains that enter the south central part of the state and continue in a northeasterly direction through the neighboring state of Haryana and end near Delhi. The bulk of the state lies west of these mountains and is marked by semi-arid to arid conditions. The climate is dominated by the monsoon with rainfall concentrated in the hot summer months of June through September. This is the main cropping season, called **kharif**. A second cropping season, called **rabi**, occurs during the dry cool winter months and is dependent on irrigation, light winter showers, and/or moisture retention of soils. The southeastern part of the the state receives the highest rainfall (up to 40 inches), with decreasing amounts as one moves to the west-northwest. Lowest rainfall occurs in the westernmost tracts where in places it averages less than 4 inches per year. Moving from the south and southeast to the northwest, rainfed **kharif** cropping shades from maize into sorghum and then into pearl millet. The decreasing moisture requirements of these crops reflect the diminishing average rainfall. Add to this the **rabi** crops of wheat and barley and local variations due to irrigation (particularly in the canal areas of the northwest) and soils, and the agro-climatic map or Rajasthan is quite diverse (GOR 1983; ICAR 1980).

Environmental specificity appears to be a major concern in Indian agricultural research and development planning. Not only is this reflected in the various national and state reports of the

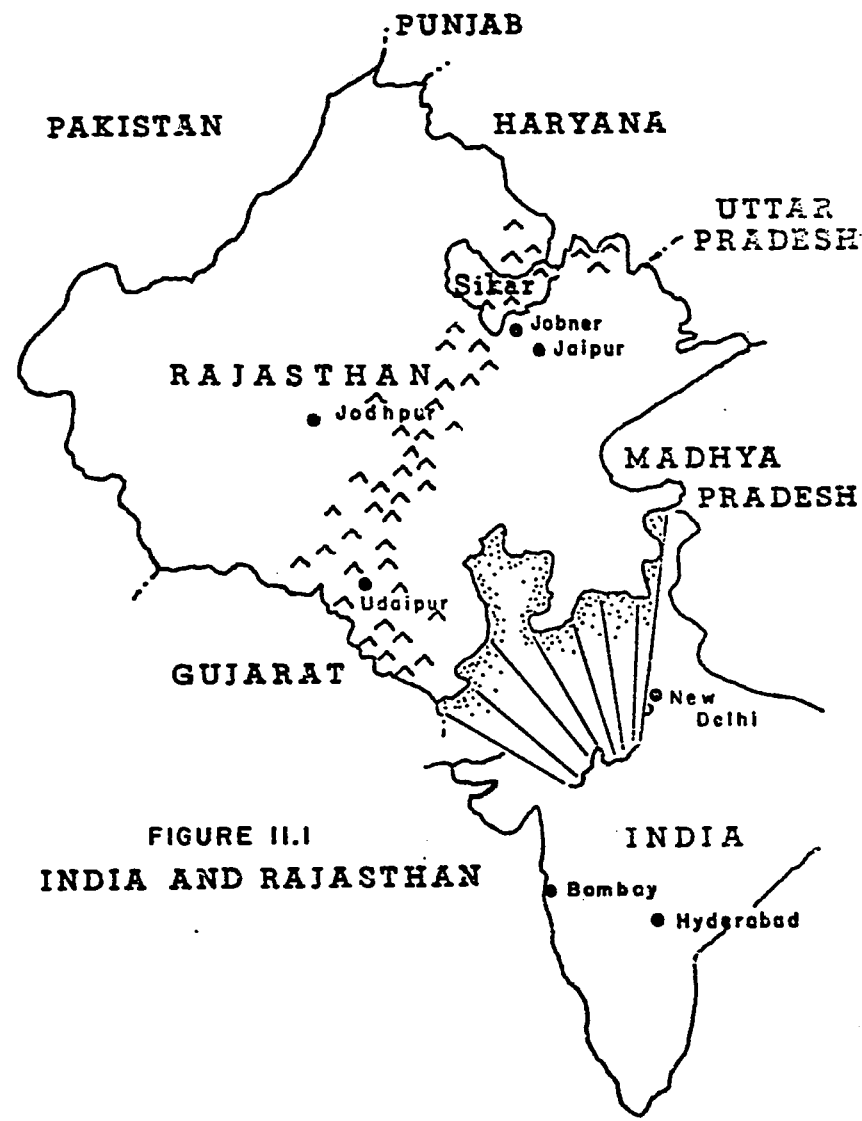


FIGURE 11.1
INDIA AND RAJASTHAN

National Commission on Agriculture but also in a major research program initiated by the Indian Council of Agricultural Research[3] with generous funding from the World Bank. The aim of this program, the national Agricultural Research Program, is the strengthening of regional research capabilities of various state agricultural universities, with the objective of identifying solutions to environmentally specific problems in their states. On guidelines similar to the National Commission reports, this program has divided Rajasthan into 5 principal agro-climatic zones, four of which are further subdivided into sub-zones. Each principal zone is to have some of its own major research stations under the University, which is to be accomplished by upgrading existing stations and campuses or by establishing new ones where none exist (ICAR 1980).

While it appears that the intent of the program is to come to grips with environmentally specific agricultural systems, the thrust is quite different. The research stations in each zone are to conduct basic research on-station to discover what crops, varieties, and combinations are best suited for that zone. The emphasis is on cash crops, new crops, and managing production patterns in line with national priorities. "The appropriate area to be put under each crop will be decided by its demand not only at the state but also at the national level, both for internal consumption and export" (GOI 1977;21).

The plan requires "tremendous efforts" on the part of production scientists to come up with economically attractive recommendations, and on the part of development workers to build infrastructure to facilitate the adoption of recommended cropping patterns (GOI 1977;21). The plans call for seed multiplication, and orchard, oilseed and vegetable production in the arid western areas that have irrigation. For unirrigated farming in this area, emphasis is generally on improving drought resistance and optimal mixes of existing cultivars and increasing the production of certain crops that have industrial uses, e.g. cluster bean. For the higher rainfall area east of the Aravallis the report states that the existing patterns seem appropriate but that farmers in irrigated areas should be encouraged to produce the same cash crops as in the irrigated arid areas (GOI 1977;22).

A number of points stand out here. First, emphasis is on irrigated agriculture which is more amenable to manipulation. Dryland unirrigated agriculture is practically left as a residual category about which little can be done. Second, while indigenous agricultural systems have their use for delineating agro-climatic zones and major features for laboratory research plot experimentation, these systems are seen as having nothing else to offer. This is a recurring theme, not particularly

unique to India but implicit in much development and applied research policy. Traditional systems are by definition backward, unproductive and inefficient. Since they are to be changed and replaced through the application of science, there is no need to interact or understand them except at the extension stage. Recommendations and packages of practices are developed on research stations and taken to farmers who, rational creatures that they are, will accept the self-evident advantages of "scientific" farming.

The basic argument of FSR is to the contrary. There is much to be learned about how resources are combined in traditional systems, in this case dryland rainfed ones that have practical value for research directed to increasing production under such conditions. The associations and relationships of the bio-physical elements that have been brought into being by farmers often hold keys to solutions that cannot be discovered through the **a priori** assumptions and methodologies of conventional on-station disciplinary research.

This is particularly imperative in a state such as Rajasthan where most agriculture is practiced in a fragile environment, where interdependencies are critical and immediate, and where population pressure will lead to attempts to intensify production regardless of what research and development programs are doing. While moisture is the major regulating factor for crop production in a desert environment, rainfed systems should not be sold short for their potential.

Rajasthan's agriculture is predominantly rainfed. Estimates of gross irrigated area as a percentage of gross cropped area are 16 to 18 percent depending on the source (GOI 1977; ICAR 1980); most is concentrated east of the Aravalli Mountains, in their southern range, or in the canal irrigated areas of the northwest. As for the arid to semi-arid zones, particularly west of Aravallis, the main physical and climatological features of rainfed agriculture comprise a rather formidable list of difficulties; sandy to loamy soils with low moisture retention and low organic matter content, high growing season temperatures, dessicating winds, and low and erratic rainfall. Rainfed agriculture is subject to frequent failure and low yields due to these factors.

Combined with these bio-physical features, the human element also provides a set of problems unique to the Rajasthan desert. Of all desert zones, Rajasthan has one of the highest population densities in the world. The 61% of the state's area that lies west of the Aravallis contains 13.39 million people, or 39% of the total population, for an average density of 167 per square mile (GOR 1983). Population increase in western Rajasthan is higher than the rest of the state and exceeds the

all-India average as well. Perversely, there is an inverse relationship between population growth and amount of annual rainfall (Mann 1981;482-483). This population growth exerts increasing pressure on natural resources for food and fuel for humans, and fodder for an animal population increasing at a faster rate than the human population. Intensification of production is the inevitable result, through bringing more marginal lands into production, the use of shorter fallows, and the extraction of resources from common lands that leads to deforestation and pasture degradation. The problem, that is also a crisis, is how to meet these demands without further degrading the environment. An understanding of these systems is crucial.

As is often the case, agricultural systems are not seen usually as systems at all, but only as fractured pieces of a whole (Morrison 1979; 633). This is the case for the rainfed systems of western Rajasthan, although perhaps less so for irrigated areas across the state that have received much more attention. For example Gupta and Prakash's edited volume, **Environmental Analysis of the Thar Desert** (1975), contains exhaustive and very good descriptive accounts of various features of the area from a wide range of disciplines. However there is no analysis linking them together, let alone how natural resources are used, combined and exploited in actual production systems.

Similarly H.S. Mann, former Director General of the Central Arid Zone Research Institute in Jodhpur, discusses the research program of the institute and the environmental conditions in which the program is working. He describes the various problematic features outlined above, agronomic experiments the institute has conducted, and a few recommendations that have developed for crop mixes, moisture conservation, and cultivation practices. However, the emphasis is on field crops (only part of the system), on-station research and no discussion of what is going on in the region's agricultural systems other than an enumeration of human and livestock populations, crops grown and their low yields, and the dangers of resource degradation. Significantly he does call for interdisciplinary efforts but these are for limited surveys of physical features and interpretation of remote sensing data (Mann 1981). While on-station research is desirable and necessary, there must be an understanding of how people "out there" cope and adapt to such conditions and changes with their production strategies. This also underscores a point that must be made that research stations located in specific zones are no guarantee of an increase in the knowledge and understanding of location specific agricultural systems.

The Farming Systems Case Study

Recently the author was involved in a FSR project with Mohal Lal Sukhadia Agricultural University coordinated through the main campus at Udaipur in the south and with the collaboration of SKN College of Agriculture, a branch campus, located at Jobner in the Northeast Central part of the state (See Figure 11.1). The project was jointly planned and worked out over a space of one and a half years with faculty in the agricultural sciences. Actual fieldwork was conducted through two **kharif** cropping seasons, from 1982 to 1983, in Sikar District close to Jobner. This district typifies the arid and semi-arid characteristics of rainfed agriculture in the state. While space limitations preclude an exhaustive recounting of the project, it is valuable to review the discovery and insights gained from indigenous knowledge and production techniques.

The project was designed to provide: 1) a technical and socioeconomic baseline study of the agricultural system in Sikar District that would be of use in future research programs, 2) linkages between on-station research and off-station agricultural conditions, and 3) farm level sites for adaptive trials and demonstrations under a variety of conditions. Attention was focused on pearl millet and its place in the farming systems of the fieldwork area.

The purpose of the baseline study was to provide a descriptive analysis of predominantly rainfed pearl millet agriculture to identify major agricultural features, associations, and problem domains for research planned for that region. A few years prior to the project the university had received the mandate for all agricultural research in the state, and took over research facilities and moved into regions previously under the jurisdiction of the State Department of Agriculture. This involved some reorganization and strengthening of the university's research wing that is being supported by the already mentioned national Agricultural Research Program. Due to priorities and limitations of previous research and development, dryland regions of the state had not received much attention. Sikar District, along with the other three districts that make up the Shekawati Region, fell into this category. Sikar, however, is the planned locale for a research station under the National Agricultural Research Program and this project was seen as providing a head start for the research agenda.

Although a research station was planned for the district, the program did not provide for off-station investigations. The

lack of such linkages was seen as a lacuna by the scientists with whom the project was to work. Research scientists generally have few direct links to the agricultural systems for which their work is conducted. The flow of information from the field into the research process is indirect, from the state extension services to the directors of research and extension and then to the scientists. Most scientists, unless they happen to come from farm backgrounds in the same region, have little notion of agriculture as practiced off-station. Furthermore they have little opportunity or encouragement to get off-station and if they do, few contacts to approach at the farm level. The project made several contributions in this direction. First, fieldwork was conducted with a sample of farm households of differing socioeconomic characteristics spread across an agro-climatic gradient. Second, logistical support was provided for first-hand investigations and the farm contacts to do so. Third, scientists were able to observe individual problem domains not only in the uncontrolled field situation but also from an interdisciplinary perspective.

Although the university had not done research in the Shekawati region, several scientists had worked on cropping and other problems common to the Sikar area. Research on drought tolerant varieties or pearl millet (**Pennisetum americanum**) and moth bean (**Phaseolus aconitifolius**), had been conducted by scientists at Jobner in the departments of Genetics and Plant Breeding, Plant Pathology, and Entomology. The major constraints for these two crops grown extensively in Sikar are drought for pearl millet and yellow mosaic virus that inhibits plant growth and pod formation on moth beans. Experimental varieties of both crops had undergone a series of on-station and regional trials at other stations. Farm level adaptive trials were next on the agenda. In addition, control measures for a serious insect pest, white grub (main species **Holotrichia consanguinea**), had been developed at Jobner. This beetle is found in sandy regions and in its larval stage severely damages single root crops and in heavy infestations, pearly millet, sorghum, and maize as well. Since this pest is found in Sikar District a control demonstration was in order. The project's sample farmers spread across the district provided sites and the project's field staff posted in each village provided for setting up and monitoring these activities.

Sikar District is situated between 27 degrees 21 minutes and 28 degrees 12 minutes north latitude, at an average elevation of 423 meters above sea level. The district is roughly crescent shaped with an area of 2,985 square miles. The Aravalli Mountains, with peaks up to 1,000 m bisect the district on a southwest-northeast axis starting in the south central

section and roughly demarcate the more arid from the semi-arid tracts. Generally the western part of the district is drier, sandier, warmer in summer, and colder in winter than areas east of the Aravallis. This forms a gradient for a number of features. In the west, soils are sandy with stabilized dunes and to the east soils grade into light loam on a plain sloping to the south. Underground water is present throughout the district but at differing depths and with a wide range of quality. The water table runs from about 150' to 30' on a rough west-east axis. Quality runs from sweet to saline on a north-south axis as one moves toward the Sambhar Basin and its large salt lake. Irrigation is concentrated in pockets, primarily in the eastern part of the district.

The climate is dominated by the June-September monsoon with average rainfall varying on a west-east gradient from 14 to 28 inches. The main cropping season is **kharif**. Winter showers are more frequent in the east where with loamier soils unirrigated crops can be taken during **rabi** season. One meteorological feature which is particularly problematic in the western part is the hot dry wind, called the **jhola**, that blows from the west near the end of the **kharif** season as the monsoon retreats down the Gangetic plain. These winds come during the grain filling stage of most crops and can dessicate a stand in a matter of days. Temperatures peak during the pre-monsoon period of May-June and are at their nadir in December-January. At Sikar weather station average maximum temperature is 43.7 C, average minimum 1.4 C, and mean temperature is 20.8 C, based on the 1978-79 data. Many areas are subject to frost.

Given the environmental conditions, agricultural productivity is generally low and erratic, particularly during the **kharif** season that is predominantly rainfed. Indicative of this are the yields for major crops during the cropping years 1977/78 to 1979/80 presented in Table 11.1.

Although temporal and spatial patterns are not indicated, the district as a whole received 235% of its average rainfall of 18.4 inches during 1977, 165% during 1978, and 64% in 1979. Too much rain damages **kharif** crops, leaches sandy soils of nutrients, damages seed beds, and/or silts over newly emerging seedlings. Too little rain results in drought. The yearly variability in yields is most striking with **kharif** crops as opposed to **rabi** crops that are grown predominantly with irrigation.

For project purposes, the district was divided into three zones on the basis of agro-climatic characteristics (See Figure 11.2). The agro-climatic gradient these zones present is illustrated in Table 11.2. The decreasing dependency on the single rainy season as one moves from Zone 1 to 3 is a function

of rainfall, irrigation and also loamier soils found toward the east.

The cropping pattern across the zones shifts from almost exclusively pearl millet and pulses grown during the **kharif** season in Zone 1 to a more diversified double-cropped, irrigated regime in Zone 3 as indicated in Table 11.3. The pulses included under the monsoon crops are green gram (**Phaseolus aureus**), cowpea (**Vigna sinensis**), cluster bean (**Cyanopsis tegragonolobe**), and moth bean. The first two are consumed as lentils. Cluster bean is used for fodder although its young tender beans are used as a vegetable food and the crop is becoming an important commercial crop for the extraction of gum with several industrial purposes. Moth bean is the most drought resistant of the pulses and is found primarily west of the Aravallis as a sole crop. Moth bean is used as a lentil and also as a flour base for a deep fried vermicelli used in popular snack foods. Under rainfed conditions, however, cereals and pulses are most often grown mixed rather than as sole crops. Similarly gram, or chickpea (**Cicer arietnum**), is often intercropped with mustard during **rabi** on unirrigated land. The significant features are, however, the overwhelming preponderance of pearl millet as the **kharif** cereal under all conditions, rainfed and irrigated. Very little area is under commercial grains or horticultural crops.

Table 11.1
Sikar District
Yields (in lbs./acre) of Principal Crops, 1977/78 - 1979/80.

Year	Monsoon Kharif Crops				Winter Rabi Crops		
	Millet	Sorghum	Maize	Pulses	Wheat	Barley	Gram
77/78	100	119	84	37	1,277	1,614	862
78/79	273	272	279	41	1,283	1,432	893
79/80	165	131	43	6	1,268	1,208	671
Average	179	174	135	28	1,276	1,418	809

Source: Statistical Abstract(s), Rajasthan. Directorate of Economics and Statistics, Government of Rajasthan, 1979 & 1980.

Sikar District has a number of social features significant for agriculture and the farming systems practiced there. Historically the district was linked to the former princely state of Jaipur and until the 1950's was ruled and administered by a feudal regime that at the local level took the form of lords controlling all aspects of land and natural resource use. As with the rest of Rajasthan after Indian Independence in 1947, Sikar underwent a series of politico-administrative and land reforms into the 1960's. These reorganized and integrated the various princely states into the Indian Union, conferred land ownership on former peasant tenants, and formed elected village councils as the lowest level of democratic institutions to govern village affairs, including common lands. A concomitant change has been the demise of localized systems of subsistence production, exchange, and consumption based on patron-client structures with the inroads of commercial markets, modern transportation and closer links with wider state and national institutions (Michie 1981).

Table 11.2
Sikar District
Select Agroclimatic Features by Zone and Tehsil.

Zone	Tehsil**	Average Rainfall	% Gross Cropped Area Irrigated *	Average Cropping Intensity*	% Gross Cropped During Monsoon*
1	Fatehpur	13.8	0.3	100.17	99.7
1	Lachmangarh	23.1	1.9	101.15	98.2
2	Sikar	22.2	8.4	105.21	91.6
2	Danta Ramgarh	29.6	27.0	110.59	77.4
3	Shri Madhopur	21.9	31.9	122.96	62.2
3	Neem ka Than	28.3	29.1	123.78	52.8
1-3	All District	18.4	18.0	109.90	79.0

* Based on averages of cropping years 1977/78 through 1979/80.
** A "tehsil" is an administrative unit below the level of the district similar to a township in the US, but larger.
Source: District Statistical Handbook(s), Sikar. (In Hindi). Directorate of Economics and Statistics, Government of Rajasthan, 1980 & 1981.

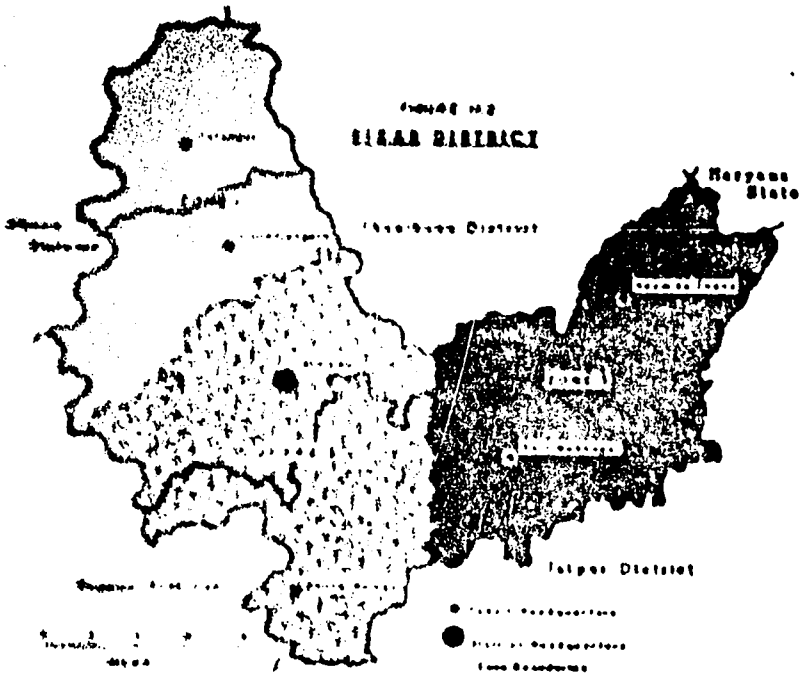


Table 11.1
Sikar District
Average Gross Cropped Area and Specific Crops
as Percentage of Gross Cropped Area by Zone and Tahsil, 1977/78 - 1979/80.

Zone	Tahsil	Gross Cropped Area (Acres)	Summer Monsoon Kharif Crops: Millet (%)	Sorghum (%)	Maize (%)	Pulses (%)	Groundnut (%)	Winter Dry Rabi Crops: Wheat (%)	Barley (%)	Gram (%)	Mustard (%)
1	Fatehpur	[illegible]	[illegible]	---	*	11.4	*	0.1	*	*	*
1	Lachmangarh	[illegible]	[illegible]	*	---	34.6	---	1.1	0.4	0.1	0.1
2	Sikar	[illegible]	[illegible]	*	*	17.6	*	4.6	1.7	1.2	0.4
2	Dhoda Ramgarh	[illegible]	[illegible]	*	*	41.5	0.1	9.1	7.1	4.4	0.9
3	Dhri Madhopur	[illegible]	[illegible]	[illegible]	*	27.2	1.2	11.5	8.4	15.3	0.9
3	Neem ka Thana	[illegible]	[illegible]	0.1	0.1	17.3	1.2	13.5	7.4	22.7	1.5
1-3	All Tahsils	[illegible]	[illegible]	0.7	0.1	32.2	0.5	7.2	4.6	7.6	0.6

Note: * [illegible] but less than 0.1%.
Source: [illegible] for years 1977/78 through 1979/80.
Source: [illegible], Sikar. (In Hindi). Directorate of Economics and Statistics, [illegible], 1980 & 1981.

Demographic changes have occurred as well. The district as a whole has had a slightly more than 100% increase in population from 1951 to 1981. In 1981 the population was 1,377,000 of which 80% was rural. Rural densities, while not high by Indian standards, run from 238 per square mile in the dry northwest to 487 in the irrigated tracts (Table 11.4).

These changes have implications for agriculture, natural resource use, and the strategies people pursue in making a living from the land. Given the fragile ecology, a decreasing per capita land base, and increased demand for agricultural products from both local and national markets, attempts at intensification are inevitable but also run the risk of ecological degradation. Irrigation is the most resource enhancing of intensification techniques but given water quality and depth, and capital and power constraints, it is possible only in limited areas. Expansion on previously uncultivated lands entails the loss of village common lands used for pasture, fodder, and fuelwood. In any event there is not much new land that can be brought under cultivation; 80% is already put to agricultural use and the rest is unavailable due to hilly terrain or government forest reserves (Table 11.5). Common lands are highly degraded from uncontrolled tree felling and overgrazing due to population pressure. The new socio-political arrangements on one hand have freed people from the old feudal order but have also effectively destroyed traditional institutional control at the local level over common resources.

Despite all these problematic features of the environment and the processes enumerated the situation is not hopeless. To the contrary there are some rather interesting developments that suggest solutions to many of these problems.

Desert Agroforestry

For the adaptive trials and demonstrations carried out in the project, results were rather mixed. In the first season untimely rains that came two months early upset the planting schedule, washed out seed beds, and ended in a severe drought that burned up all the pearl millet trials. The second year had good and evenly spaced rainfall that did not allow the trials to be conducted under drought conditions. For moth bean, the first year proved successful with the varieties performing near to expectation. The second year disease incidence was much heavier, forcing some re-evaluation of the resistance mechanism, whether bio-chemical or due to the hairy physiology of the

Table 11.4
Sikar District
Population, Density and Decadal Variation, 1981.

Zone	Tehsil	Population 1981			Population Density per sq. mile			% Decadal Variation 1971 - 1981		
		Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
1	Fatehpur	97,745	70,654	168,399	238	4,816	396	+30.51	+41.32	+34.84
1	Lachmangarh	146,913	29,215	176,128	308	9,455	367	+29.21	+31.85	+29.64
2	Sikar	211,780	102,970	314,750	368	13,675	539	+31.73	+45.05	+35.81
2	Danta Ramgarh	191,620	14,232	205,852	368	517	376	+16.91	-----	+25.59
3	Shri Madhopur	256,297	46,599	302,896	488	2,370	555	+25.30	+104.44	+33.23
3	Neem ka Thana	193,954	15,266	209,220	425	2,636	452	+31.59	+31.47	+31.68
1-3	All District	1,098,309	278,936	1,377,245	370	3,565	453	26.96	57.10	32.09

Source: District Census Handbook, Sikar. Census of India 1981. Series 18, Parts XIII-A&B, Government of Rajasthan, 1983.

Table 11.5
Sikar District.
Land Use as Average Percentage of Total Area, 1977/78 - 1979/80.

Zone	Tehsil	Forest (%)	Pasture (%)	Groves & Orchards (%)	Non-Cultivable (%)	Cultivable Waste (%)	Fallow (%)	Net Sown Area (%)
1	Fatehpur	3.9	5.6	---	3.0	0.5	20.4	66.6
1	Lachmangarh	1.3	6.3	---	2.7	0.4	17.2	72.1
2	Sikar	0.6	5.4	---	9.0	0.8	16.6	67.6
2	Danta Ramgarh	0.3	5.9	---	7.6	1.2	25.9	59.1
3	Shri Madhopur	1.3	7.1	+	9.8	2.7	13.3	65.8
3	Neem ka Thana	3.4	7.0	0.1	32.1	5.3	9.4	42.7
1-3	All District	1.7	6.2	+	10.6	1.8	17.2	62.5

Note: + equals presence but less than 0.1%.
Based on area and cropping data for years 1977/78 through 1979/80.
Source: District Statistical Handbook(s), Sikar. (In Hindi). Directorate of Economics and Statistics, Government of Rajasthan, 1980 & 1981.

varieties that vectors were learning to overcome. Similarly, the white grub control demonstration did not go as expected. The early rains in the first year completely upset the adult beetle's normal emergence and reproductive behavior, the only life phase in which they are exposed for control measures. They did not emerge from the ground in their characteristic swarms at any time. The controls, spraying of host trees, were not done. Crop damage, however, was noticeable later in the season. The same thing happened at the Jobner campus where much to everyone's chagrin many research plots were destroyed. What this underscores is the difficulty of research under erratic desert conditions where seasons are very dissimilar. A much longer time frame is necessary.

While the trials and demonstrations had their value, the most significant findings of the project came from enquiry into how farmers combine their resources and separate farm activities into a system. What was discovered was an indigenous agroforestry system incorporating trees on crop land, under rainfed conditions. The basic outlines of this system are a number of associations and interdependencies between trees, field crops, and animal husbandry that are also linked to fuel and timber concerns (Figure 11.3). Trees, crops and animals are a tripod which farmers have adapted to the fluctuations in their environment with trees serving as the stabilizing element for both crops and livestock. The spread and development of this system also allows for the intensification of production on a long term sustainable basis.

The most important tree, and the most numerous perhaps as a result of social selection, is a native mesquite (**Prosopis cineraria**) locally called the **khejri**. This tree occurs in loose to dense volunteer stands on cropped and other land. The khejri does well on deep sandy soils in low rainfall areas and withstands extremes of heat and cold. It grows to a height of 45 feet with spreading branches that provide light shade. Its central root penetrates up to 60 feet (Singh 1982).

A common observation by both farmers and agricultural scientists is that crop stands and yields are better under and around the **khejri** canopy than out in the open. Possible, and highly researchable, reasons for why this happens are many. The **khejri** is evergreen and leguminous with heaviest shedding of leaves during the summer before the **kharif** season. This adds organic material and nitrogen to the soil. The deep root system does not compete for moisture with crops in their root zone. Shade reduces soil temperatures and conserves moisture, both problems for crop germination in sandy soils. Later in the growth cycle this micro-environment protects against heat and moisture stresses that inhibit photosynthetic activity in crops.

The canopy acts as an umbrella, protecting pearl millet seedlings from heavy cloudbursts shortly after emergence. Pearl millet seedlings are particularly susceptible to damage at that stage; seedlings are easily beaten down and silted over by light soils during heavy rainfall. The **khejri** also provides protection against the dessicating dry winds near the end of the **kharif** season.

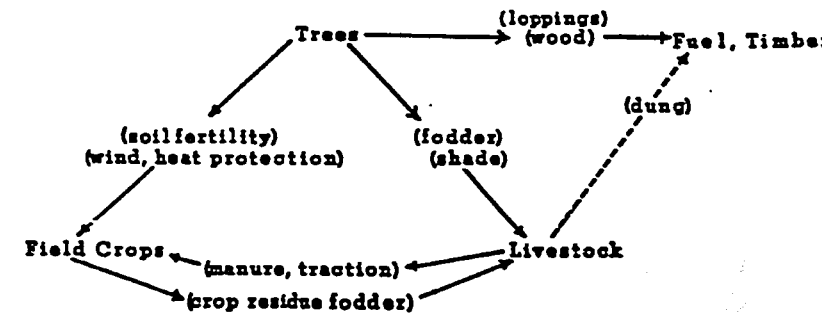
There are some possible problems with these associations. Trees attract birds that may damage crops although they may also attract beneficial ones. The **khejri** is a preferred host of the adult white grub beetle. The shaded micro-environment may increase soil pathogens and insects that would be neutralized by the baking action of the sun during the hot season. Mechanization of field operations is problematic since trees are volunteers and appear in random patterns. The **khejri** is slow growing and particularly susceptible to livestock grazing seedlings to the ground. Given the long maturation period it is less attractive in comparison to some exotics that have been introduced for fodder purposes.

The **khejri** is managed and harvested like a crop, the activities and sequencing of which are neatly integrated with farm operations, labor availability, animal and human needs, and natural cycles. First, the random spacing of trees presents no difficulty for animal powered operations. Draft animals, usually water buffalo and camels, are yoked singly and can plow straight tight furrows through a thick stand with ease. Second, bean like pods are produced during the hot pre-monsoon season when vegetables are scarce. The young tender beans are a supplementary, and free, vegetable, particularly for the poor. Third, harvest occurs after **kharif** is over. This creates an extra month to month and a half of employment and wage labor during an otherwise slack season, particularly where a second crop is not taken. Fourth, the **khejri** is harvested by lopping its leaf bearing branches. These are dried and the leaves beaten off. The leaves are slightly less nutritious than alfalfa and coincidentally their crude protein is highest during the cool season (Singh 1982; 272-274), the time of harvest, during November and December. Fifth, the woody loppings are used as a domestic fuel and for other purposes such as firing bricks. This frees animal dung from use as a fuel, allowing most to go into compost. Sixth, management practices dovetail with agro-meteorological cycles for the two cropping season. This is significant if a winter **rabi** crop is taken. The removal of the canopy opens the area to warmth and solar radiation during the cool winter season when it is needed.

The yearly loppings can present problems, however, due to the natural propagation of the **khejri**. Seed pods form only on

Figure 11.3

Agroforestry System Schematic



second year growth and if the tree is lopped completely year after year it will not reproduce. Most farmers do leave a few branches to allow trees to spread. In fact some farmers carefully shape their trees to make as full a canopy as possible, although this is highly variable. In any event an assured source of seed is associated with religious practices. Shrines to field gods found on most farmers' fields are always shaded by a **khejri**, which is never lopped or cut.

The associations and interdependencies found in this system are apparently long recognized by farmers. However as a dominant practice it appears to be a relatively recent phenomenon, gaining greater currency over the past thirty years. This conclusion is tentative at this writing and requires further investigation. Nevertheless there is some evidence to support this. Tree stands appear to be young, although this may be due to selective felling practices. A mature tree can bring several hundred rupees as firewood when the need for cash is immediate. Farmers practicing rainfed agriculture do report, however, that they now have more trees than previously, and they want more. They also report that they actively encourage and protect **khejri** seedlings that appear in their fields whereas previously they ignored or uprooted them during field operations. The practice also appears more prevalent with those farmers who, for more intensive land use and to shorten fallows, erect boundary walls to protect their crops from grazing animals. In the process tree seedlings are also protected from grazing that destroys or retards the reproduction of trees.

The apparent increase of agroforestry also appears linked to the social changes that have occurred over the past thirty or forty years. Population increase, institutional changes affecting natural resource use, and the linkage to wider markets all push for the intensification of production. However, the way in which agroforestry has come into its own is through a rather circuitous route. It appears to be a private response initially to the ecological degradation and/or disappearance of village common lands, the major traditional source of fuel and fodder. If sufficient quantities are no longer available from common lands then attention turns to tree resources on one's own land. Farmers also realize the direct benefits to crops and are encouraging the **khejri** on that account as well. In effect, farmers are reinterpreting and integrating trees into their rainfed farming to enhance their personal resource base and intensify the production of crops, fuel, fodder, and timber. In the process they are also decreasing the risk of degrading their own land.

Significance of Findings for Research

The significance of these findings for research on and development of rainfed agriculture should be clear. This project delineated what might be termed mega-relationships among differing farming activities in this region's farming systems that form a list of researchable problems. The findings also point to the close interdependence of these activities. The development of a package of practices would most likely have to include more than inputs and techniques relevant to the growth, management, and yield of a particular cultivar or even crop mixes. These would have to include recommendations on tree species which produce fodder, fuel and timber. The delineation of these mega-relationships does provide some guidelines and directions to that end.

First, agroforestry is a production strategy with a widespread use among the region's farmers. A research focus on this strategy would; 1) fit both the agro-climatic environment and agricultural practices already followed, and 2) most probably generate recommendations acceptable to farmers. Such a focus could be on the crop-livestock-horticultural associations already in place, as well as farm forestry, horticultural tree crops, and/or silvo-pastoralism. Some work has already been done in these directions. The studies by Singh and Lal (1969) on tree-soil relationships and by Gupta and Mohan (1982) on tree and grass combinations for silvo-pastoral systems are examples. However, such studies are few and far between. Most published research is confined by disciplinary boundaries with little analysis crossing those lines.

Second, solutions to specific problems may lie not only within one research discipline or system element but in associated disciplines and elements. As an example, drought resistance can be approached either by breeding more resistant cultivars or by research on micro-environments and their effect on physiological processes.

Third, returning to Farming Systems Methodology, the off-station environment sets the parameters within which solutions to problems are to be found. This is particularly important where targeted production systems are relatively unknown, unfamiliar, or not fully understood. The understanding of off-station parameters brings to the fore some rather crucial relationships and processes that would otherwise go unnoticed in conventional disciplinary enquiry confined to the experiment station. Conventional research sees crops as separate from animals and separate from trees. In fact most literature on the

khejri recommends that it be grown on waste and uncultivated land (e.g. Verma 1975). Furthermore the dichotomy between trees and field crops is a pervasive one that on the face of things appears to follow common sense. A good example is the otherwise excellent study presented in Gupta and Mohan's **Economics of Trees Versus Annual Crops on Marginal Agricultural Lands** (1982) with specific reference to arid lands of Rajasthan. Their methodologically sophisticated and rigorous simulation study examines numerous tree-grass combinations and juxtaposes them against field crops. While silvo-pastoralism comes out ahead in terms of monetary return, the examination of tree-crop combinations is barely considered. In fact nowhere has this author found a reference, let alone a study, of this agroforestry system as a system.

Conclusions

This case study illustrates one of the strongest assets of the FSR approach, the appreciation of locally developed agricultural practices. Numerous studies had been directed toward the problems of arid land production in Rajasthan, focusing on crops, crop combinations and infrastructural development, without realizing the potential value of the existing agroforestry techniques. In fairness, it can be noted that conceptually the system described is highly unlikely; grain crops are virtually always grown in full sun due to their physiological needs, and the scarcity of moisture would suggest that associated plants would directly compete for the little moisture available.

The techno-economic "fit" was another factor in the use of the **khejri** agroforestry combination. The farmers' needs for new sources of fuelwood and off-season food supplies contributed to the appropriateness of the technology, as did their reliance on animal rather than mechanical traction for crop cultivation. This technology, then, had been developed by the producers themselves to meet the needs of relatively poor farmers working on agriculturally marginal lands. Equally important is that the system is based on locally available low cost materials to meet needs not only for shade, but for fuel, fertilizer, and food. One of the major problems faced in agricultural development has been the differential access to improved inputs according to socioeconomic status, and this sort of agricultural technology helps overcome the unequal distribution of agricultural development benefits.

The interdisciplinary team approach to agricultural

research permits the inclusion of anthropological methodologies for the detection of existing systems which may be objects of investigation for their improvement or further propagation.

Notes

1. This discussion is based on material derived from the project "A Farming Systems Approach to Semi-Arid Agriculture in Rajasthan, India", supported by the USAID Title XII International Sorghum and Millet Program, contract no. DSAN/XII-G-1049. While the author wishes to thank the program for its support and acknowledges the invaluable contributions of others on the project team, responsibility for the views expressed herein is entirely his own.
2. Formerly the University of Udaipur.
3. An autonomous council that advises the Government of India on agricultural policy, coordinates national research and controls research funding. It acts much like the United States Department of Agriculture.

Bibliography

Chambers, R. and John Harriss. 1977. "Comparing Twelve South Indian Villages: In Search of Practical Theory." In B.H. Farmer (ed.), **Green Revolution.** New York: Cambridge University Press.

GOI. (Government of India). 1976. **Climate and Agriculture: National Commission on Agriculture** Report. Part IV. New Delhi: Ministry of Agriculture and Irrigation.

—. 1977. **Rajasthan: Rainfall and Cropping Patterns Report.** Vol. XIII. New Delhi: Ministry of Agriculture and Irrigation.

GOR. (Government of Rajasthan). 1983. **Basic Statistics, Rajasthan,** 1982. Jaipur: Directorate of Economics and Statistics, Government of Rajasthan.

Gupta, R.K. and I. Prakash. 1975. **Environmental Analysis of the Thar Desert.** Dehra Dun: English Book Depot.

Gupta, T. and D. Mohan. 1982.
Economics of Trees Versus Annual Crops on Marginal Lands. New Delhi: Oxford and IBH Publishing Co.

ICAR. (Indian Council of Agricultural Research). 1980.
Report of the ICAR Research Review Committee for University of Udaipur. New Delhi. ICAR.

Jodha, N.S. 1978.
"The Operating Mechanism of Desertification and Choice of Interventions". Discussion Paper #5, Economics Program, ICRISAT. Hyderabad, India: International Crops Research Institute for the Semi-Arid Tropics.

Mann, H.S. 1981.
"Management of Arid-Land Resources for Dryland and Irrigated Crops". In D.W. Goodall and R.A. Perry (eds). **Arid-Land Ecosystems: Structure, Functioning and Management.** Cambridge: Cambridge University Press.

Mencher, Joan. 1966.
"Kerala and Madras: A Comparative Study of Ecology and Social Structure". **Ethnology** Vol 5; 135-171.

Michie, Barry H. 1981.
"The Transformation of Agrarian Patron-Client Relations: An Illustration from India." **American Ethnologist** Vol 8, #1.

Morrison, Barrie M. 1979.
"The Persistent Rural Crisis in Asia: A Shift in Conception". **Pacific Affairs** Vol 52, #4; 631-646.

Nair, Kusum. 1979.
In Defense of the Irrational Peasant. Chicago: University of Chicago Press.

Singh, K.S. and P. Lal. 1969.
"Effect of 'Khejari' **Prosopis spicigera** [Linn] and 'Babool' **Acacia arabica** Trees on Soil Fertility and Profile Characteristics". **Annals of the Arid Zone.** Vol 8,#1.

Singh, R.V. 1982.
Fodder Trees of India. New Delhi: Oxford and IBH Publishing Co.

Verma, S.C. 1975.
"Forestry and Afforestation Practices." In R.K. Gupta and I. Prakash (eds). **Environmental Analysis of the Thar Desert.** Dehra Dun: English Book Depot.

12

Applying the FSR/E Approach in the Management of an AID Agroforestry Project

Edward Robins

Agroforestry is a land use strategy commonly employed by small farmers to maximize land use intensity and permit the joint production of forestry products and other agricultural or animal products. This chapter[1] reports on the Communal Afforestation Project in Rwanda where the author has been serving as Social Science Advisor to the AID mission since 1983, under the Joint Career Corps program. This innovative program permits faculty members from selected U.S. universities to serve AID as advisors for a period of 2-3 years in an overseas bureau. Thereafter, the faculty member returns to the university as a base of operations from which yet other field tours, both short and long term, ensue. The analytical know-how of university faculty is applied to activities in the field in this fashion; AID benefits from the expertise of individuals current in their discipline, and the individual participants and their universities gain from first-hand exposure to actual conditions in the field.

Setting

The afforestation program advanced by the joint Rwanda-USAID forestry project focuses on the introduction among the rural populace of agroforestry ideas and practices as a fundamental means of promoting reforestation and improving the farming system. Agroforestry is viewed in Rwanda as a basic intervention especially suitable on small parcels and under conditions of wood scarcity. Average farm size is just under 1 hectare; population density is the highest in Africa, at about 230/km². In the project zone population density reaches 325/km². Land is farmed intensively in this small, mountainous country.