

Rainfed integrated farming systems

for arid zone agriculture diversification for resilience

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Arid zone agriculture is endowed with some of the best drought hardy crops, trees and animals and in improved farming systems complementarities among them are exploited to achieve resilience at higher level of production. Integration of diversified cropping with agroforestry trees like khejri and rainfed ber and grasses are some of the enterprises that performed well under meagre rainfall. Less productive land can be used for pasture development with multipurpose trees. These activities increase the livestock carrying capacity of the farmer which are the mainstay of arid zone farming.

Key words: Agriculture, Arid zone, Diversification, Farming system, Rainfed

UNCERTAINTIES in amount and distribution of rainfall and other weather aberrations in arid zone made crop cultivation a risky proposition. Therefore farmers, in this region practised mixed farming to minimize the risk since ages. The components of farming system follow a pattern in accordance with the amount of rainfall (Fig. 1). The areas receiving <250 mm rainfall showed predominance of grasses and shrubs; hence range/pasture development was found with livestock rearing in major proposition. Between 250 and 350 mm rainfall zone besides grasses and shrubs, multipurpose tree species dominate and mixed-farming encompassing agroforestry system, mixed cropping, livestock and pasture management are main livelihood options. Where rainfall is more than 300 mm, crops and cropping system diversification, agroforestry and livestock rearing were major systems of sustenance of arid zone farmers. These sustainable systems were inadequate to fulfill the needs of ever increasing population and their aspirations. Further during drought period, the government facilitates the availability of food to human

population but fodder becomes a rare commodity causing mass casualty of livestock. Therefore, alternate land use systems were developed as per land capability, requirement and weather in farming system mode. These include different combinations of crop, grass and tree-based systems. Addition of horticulture components in farming system increased profitability and resilience of farming systems. A positive aspect of arid horticulture is fine quality of pest free produce.

MAJOR COMPONENTS OF FARMING SYSTEM

Diversified cropping, agroforestry, agri-horticulture horti-pasture system, silvi-pastoral system etc. are major components of farming system and are discussed here.

Diversified cropping

Diversification of crops and cropping systems is the first line of defence to impart resilience in agricultural production system. Conventionally farmers practice mixed sowing of seeds of various dryland crops viz. pearl millet (*Pennisetum glaucum*), moong bean

(*Vigna radiata*), cluster bean (*Cyamopsis tetragonoloba*), moth bean (*Vigna aconitifolia*) and sesame (*Sesamum indicum*) in certain proportion to cushion the adverse effect of drought and uncertainty. If drought commences, pearl millet population is cut down and fed to the animal. However, crop management aspect suffers under mixed-cropping. During timely onset of monsoon pearl millet is grown on more than 60% area and if monsoon is delayed (beyond July 15) *kharif* pulses (moong bean and moth bean) gets the preference. Considering the climate analysis, vulnerability to drought and changing food habits, pearl millet should be grown in about 40% of the area and rest of the area be allocated to *kharif* legumes (30%), oilseeds (15%) and forage crops (15%). Varietal diversification at farmers' level or at village level is also desired for imparting resilience against variations in length of growing season e.g. moong bean varieties GM 4 and IPM 2-3, pearl millet varieties MPMH 14 and HHB 67 improved, moth bean varieties RMO 40 and CZM 2 etc. were sown together.



Fig. 1. Intercropping of pearl millet with moong bean in tree alleys



Fig. 2. *Khejri*- based agroforestry system

Agroforestry

Trees of arid region by virtue of their perennial nature impart stability in production along with improvement in micro-climate and soil fertility. *Khejri* (*Prosopis cineraria*)-based system is the most popular and widespread agroforestry system covering 60% area of arid zone. It has mono-layered canopy, deep root system and being a legume, it also fixes nitrogen in the soil resulting in positive effect on productivity of dryland crops. A bonus yield of dry leaves (25 to 40 kg/tree) and fuel wood (50 to 75/tree) could be obtained from it through annual lopping. Introduction of budded *khejri* for excellent quality *sangri* (pods) made it an important orchard crop also. *Rohida* (*Tecomella undulata*), *Anjan* (*Hardwickia binata*) and *Ardu* (*Ailanthus excelsa*) are the other important tree components that may find place in Integrated Farming Systems. However, newer establishment of natural occurring farm trees ceased

due to uprooting of seedlings and offshoots during mechanized field operations, excessive lopping and insect attack mainly in 200 to 300 mm rainfall zone.

Agri-horticulture

Growing of arable crops in association with horticulture plants is considered effective strategy for improving productivity, employment opportunities, economic condition and nutritional security in arid regions. Indigenous fruit trees of the region are inherently drought hardy. Interspace of orchards can be utilized for growing suitable intercrops. Suitability of intercrops depends primarily on soil and climatic conditions, however, compatibility aspects deserve primary consideration. If adequately spaced, the alleys in *ber* orchard can be used for growing moong bean without any negative impact on productivity of *ber*. This system provided fruit, fuel wood and round the year employment even in below average

rainfall year. Water harvesting techniques through circular catchments around each tree (1.5 m radius, with 5% slope towards tree trunk and covered with black polyethylene sheet) significantly augment water availability to fruit plants. The other important crops for *ber*-based rainfed system are moth bean, cluster bean and cowpea. *Rabi* crops like wheat and mustard are not found remunerative in *ber* orchards. This system is recommended for the region having rainfall <250 to 300 mm. Pomegranate was found compatible with pearl millet, moong bean, Isabgol and cumin in Jalore district of Rajasthan. During juvenile phase of fruit tree, there were ample opportunities for raising annual, biennial and perennial crops which met diversified need of farmers.

Horti-pasture system

The dried leaves of *ber* (*pala*) forms an excellent fodder for small ruminants (goat and sheep) and forms a robust coping mechanism for



Fig. 3. *Ber*-based agri-horti system



Fig. 4. *Ber*-based horti-pasture system with indigenous Tharparkar cattle

frequent droughts. *Ziziphus nummularia* (*Jharberi*) is top feed species of arid region. The leaves make excellent fodder having high crude protein (13 to 17%) and fiber (15%). It generally dominates the common village grazing lands of Bikaner, Barmer and Jaisalmer districts with a relative dominance of 75 to 90%. Exposed gravelly plains supports a shrub density of 120 to 150 shrubs/ha. In comparatively higher rainfall zone (300 to 500 mm) *desi ber* (*Ziziphus rotundifolia*) also provided good quantity of leaf fodder, fuelwood and fruits found growing in crop lands. Growing of grasses or grass-legume mixtures in the interspaces of *ber* orchard is a suitable proposition in Classes IV and V type of land. In *ber*-grass system, the grass should be sown after two years of establishment because in these initial years, *ber* may not be able to compete with the vigorous root system of grass. No adverse effect of grasses (*Cenchrus ciliaris*) was observed on growth and yield of *ber* in later years. It provided dry grass fodder 1.2 to 1.5 tonne/ha along with 15 to 25 kg dry leaves per plant of *ber*.

Silvi-pastoral system

Such systems are best suited for areas receiving <200 mm rainfall, or in degraded rocky-gravelly areas. The highly compatible trees with grasses are: *Kumat* (*Acacia senegal*), *Israeli babool* (*Acacia tortilis*), *Rohida* (*Tecomella undulata*), *Nutans* (*Dichrostachys nutans*), *anjan* tree

(*Hardwickia binata*), *jharberi* (*Ziziphus nummularia*) and *desi ber* (*Ziziphus rotundifolia*).

Suitable grasses for establishing pasture based systems

The suitability of grass species is region specific. The common grasses of arid zone are *sewan* (*Lasiurus scindicus*), *anjan* (*Cenchrus ciliaris*), *Moda dhaman* (*Cenchrus setigerus*), *gramma* (*Panicum antidotale*) and *kharad* (*Dicanthium annulatum*). These grasses are fast growing, palatable, nutritious and possess high forage yield potential.

Sewan grass is restricted to arid areas receiving 100 to 250 mm annual rainfall. It is the most drought resistant grass of the desert. The common habitats are sandy plains, hummocky plains avoiding sand dune, inter-dunal plains, and exposed rocky surfaces particularly flood plains. *Anjan* grass is a highly palatable grass adapted to be grown even under tree shade. In Rajasthan, Shekhawati region appears to its natural habitat. It can be cultivated on sandy to gravelly soils of arid region (150 to 1,250 mm rainfall) and on sandy to sandy loam soils in semi-arid regions receiving.

Moda dhaman is also a very palatable perennial grass adaptable to be grown in a wide range of agro-climatic conditions. It grows luxuriously on sandy soils, as well on heavy textured and gravelly soils receiving rainfall between 150 and 1,250 mm.

Kharad is comparatively a shallow



Fig. 5. Boundary plantation

rooted grass, occurs mainly in moderately high rainfall areas with annual precipitation of 350 mm and more or in low lying places in arid regions. In sub-humid regions, it is a grass of uplands and adapted well to heavy soils. Among the pasture legumes *Clitoria ternatea* and *Lablab purpureus* showed good compatibility with *sewan* and *anjan* grass.

Strip cropping and boundary plantations

Soil erosion by wind is one of the foremost problem in Indian arid zone. Wind strip cropping is a method of farming in severely erosion prone areas where perennial grass or other plants were established in the field at right angle to the prevailing wind direction and crops were grown in between these strips. Grasses like *sewan* and *Moda dhaman* are suitable for strip cropping. However, *Saccharum munja*, *Panicum antidotale* and *Panicum turgidum* can also serve the purpose effectively. Where farmers are reluctant to adopt grasses, strips of *Ziziphus nummularia* (*pala*) would be readily acceptable. Shelterbelts and windbreaks of trees were also effective. The purpose of

Table 1. Different farming systems of arid zone (300 to 400 mm rainfall)

Farming systems	Components	Spacing	Production (Pearl millet equivalent yield, q ha ⁻¹)	Net return (₹ ha ⁻¹)	B:C ratio	Employment (mandays ha ⁻¹)	Animal carrying capacity (ACU ha ⁻¹)
Diversified cropping	Pearl millet + moong bean + mothbean + Cluster bean allocated to field in 3:1:1:1 ratio	-	17.65	12,000	1.46-2.05	75	0.5 ACU
Agroforestry	Crops as above + <i>khejri</i>	15 m × 10 m	29.5	25,000	2.02-2.41	96	1 ACU (0.5 cattle + 3 small ruminants)
Agri-horticulture	Crops as above + <i>ber</i> (<i>Ziziphus mauritiana</i>)	10 m × 5 m	75.5	66,000	2.36-2.42	175	1.5ACU (0.5 cow+ 5-6 small ruminants)
Agri-silviculture	Crops as above + <i>Anjan</i> tree (<i>Hardwickia binata</i>)	2m × 2m/ 20 m	25 q	21,000	1.52-2.31	98	1.5 ACU (0.5 cow+ 5-6 small ruminants)
Horti-pasture	<i>Ber</i> + grass	6 m × 6m / 13 m	32.5	26,000	1.56-2.4	105	2.5 ACU (1.5 Cow + 5-6 small ruminants)
Silvi-pasture	<i>Anjan</i> tree (<i>Hardwickia binata</i>) + grass	2m × 2m/ 20 m	28.5	21,000	1.52-2.31	105	1.5 ACU (0.5 Cow+ 5-6 small ruminant)

these plantations is to create a mechanical obstacle to the free sweep of wind and to reduce its velocity, which ultimately helps in controlling erosion. A more acceptable way is to grow trees around the field boundaries. The suitable trees are *Israeli babool*, *desi ber*, nutans, *kummat*, *anjan* trees, *karonda* and *gonda*. Along with soothing of micro-climate they provide some economical products e.g. gum from *kummat*, leaf fodder from *anjan* tree, fruits from *gonda* and *ber*.

Animal husbandry

Arid zone animal husbandry is endowed with some of the best breeds of livestock. These breeds acquired characters to withstand the arid climate over generations but their productivity in spite of genetic potential is limited due to lack of proper nutrition. Therefore, providing year round fodder to these animals remains a fundamental objective of the farming systems. Major cattle breeds in the hot arid region are: Tharparkar, Rath, Nagori and Kankrej. Amongst small ruminants Marwari, Jaisalmeri, Chokla, Nali, Magra, Pugal and Sonadi are major breeds of sheep; and Marwari, Kutchi and Parbatsari are major breeds of goat. Mainly two breeds of camel Bikaneri and Jaisalmeri are found in the region.

Although the climatic conditions are harsh in arid region but at the same time it is endowed with drought hardy species many of them giving low volume high price products. Another advantage as the size of operational holdings are large (usually >4 ha), so a portion of it can be put to alternate uses besides growing of annual crops. This may be the reason that even when per ha production of annual crops is low a decent income per farm family can be achieved through the developed integrated farming systems. Besides, traditional value addition activities and handicrafts utilized a good amount of family labour during lean months. Grazing in rangelands for a considerable period, collection of some herbs like *phog*, *brahmi*,

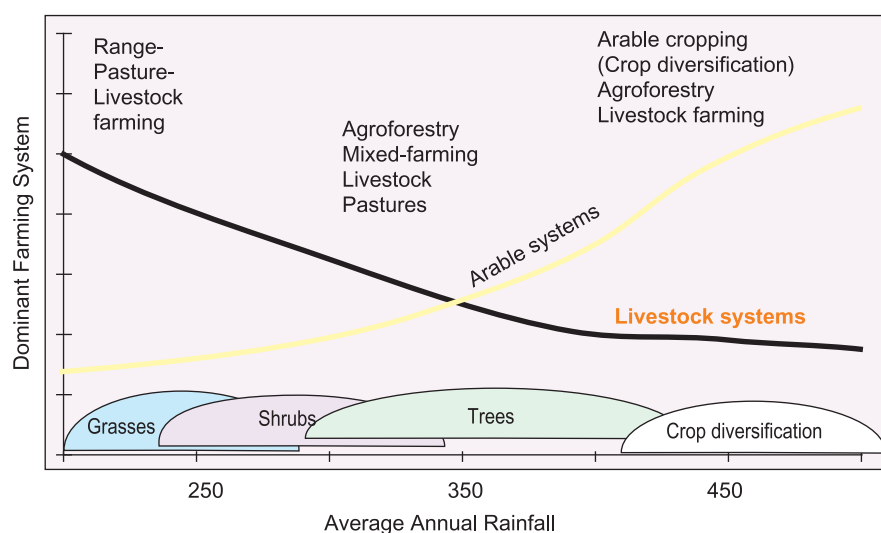


Fig. 1. Dominance of various farming systems according to rainfall pattern in arid zone

ashwagandha etc. are some of the ways of harvesting the vast stretches of wastelands in an efficient way. This showed the arid wastelands are not wastelands but the life savers of people and animals. They must be considered as an integral part of farming systems of arid regions. Hence, it may be concluded that only those improved farming systems will survive that harmonizes the existing synergies between the desert dwellers and their efficient ways of utilizing the meagre available resources.

Integrated farming system model for rainfed situations (> 4 ha)

The average size of operational holdings under rainfed farming in western Rajasthan is more than 4 ha. CAZRI developed an integrated farming system for such holdings in the rainfall zone of 300 to 400 mm. In this model annual crops, multipurpose trees, shrubs and grasses were grown in a proper combination to meet food, fodder, fruit, fuel and cash flow requirements of a household. The model is as follows:

- Diversified cropping as pearl millet-legume rotation needs to be adopted. Crops can be diversified even at varietal level.
- Trees like *khejri*, *ber*, *Hardwickia* were grown in the field along with the intercropping of annual *kharif* crops. Both *bajra* and legumes perform better under *khejri*. No adverse effect of moong bean was

noted on the production of *ber*.

- The less productive parts of field may be converted to silvi-pastoral system. For this develop 24, 15 and 20 m wide alleys of *anjan* tree, *desi ber* and *urd* tree. Grasses i.e. *anjan*, *dhaman* and *sewan* were grown in their alleys.
- Boundary plantation of *Israeli babool*, *kummat* and *anjan* tree should be done at a distance of 3 to 5 m to save crops from dry and desiccating winds. This plantation would also provide fuelwood, fodder (loppings), timber, gum etc. After 6-7 years of plantation a 4 feet (1.2 m) deep trench may be dug to avoid any adverse effect of trees on crops. The trench also act as a water recharging structure.

SUMMARY

This model provided fodder for 1.5-2 ACU/ha (1 ACU= 1 cattle or 6 small ruminants). Tharparkar cattle and Marwari breed of sheep and goat were reared. The proportion of land allocated to crop, trees and grasses was 50:20:30. This can be adjusted as per quality of land and requirement of the farmer. It took about 5 to 6 years for establishment and thereafter gave an annual income of more than ₹ 50,000/ha. It also generated >130 man-days/ha⁻¹ wages which were additional to the net returns.

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