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Traditional Agroforestry Systems in Agro-ecological Zones of Western Rajasthan

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Abstract Farmers of western Rajasthan follow a set of traditional agricultural practices year after year which provide them an assurance towards sustainable crop production in normal rainfall years, while in case of prolonged droughts and famines, they are able to harvest at least top-feeds for their livestock. The pattern of cropping is such that they are able to derive extra economic benefits, through a combination of useful tree and shrub species, which do not compete with the crops grown with them. This paper deals with those traditional systems which are presently known as agroforestry systems and are followed in various agro-ecological zones of western Rajasthan.

Key words traditional agroforestry, economic benefits, sustainable production, top feed

Western Rajasthan experiences frequent droughts and famines. In order to minimize the adverse effects of environment, the desert dwellers have evolved some agricultural practices to boost the production of crops and other related materials like fodder, fuel, fruit and timber. Their centuries-old experiences, passed on from generation to generation, have established a well contained system, which provides maximum benefit, because it integrates woody perennials in the mixed farming system. This system, in the present context, is called agroforestry system.

Considering the climatic and edaphic features of the region, the people selected various suitable drought-hardy and multiple-use species of trees and shrubs for sustainable production under the agroforestry system. During normal rainfall years, this system provides sustainable crop and fodder production, while under adverse conditions, it provides top feed, fuel and fruits. In fact, this traditional desert farming system evolved much before the presently practised fossil-fuel based agriculture came into existence.

Agroecological Zones

Based on the tree and shrub composition, mean annual rainfall and soil types, nine agro-ecological zones have been identified in western Rajasthan (Fig. 1) where different agroforestry systems are prevalent (Table 1). By and large, these zones come under three distinct vegetation belts.

1. Shrublands : The 100-250 mm annual rainfall zone, covering Jaisalmer, western part of Bikaner and Ganganagar districts, and the north-western part of Barmer district, has a preponderance of shrub species. It includes three agro-ecological zones.

2. Tree and shrub zone : The tract with 250-350 mm annual rainfall zone largely has a tree and shrub combination. Here two distinct agro-ecological zones can be distinguished.

3. Woodland : Areas of Pali, Nagaur, Jhunjhunu and part of Churu, Jodhpur and Ganganagar districts, receiving 200-450 mm of annual rainfall, show a clear dominance of woodland. It consists of four agro-ecological zones. The southern part of Barmer district, with 200-250 mm rainfall, is also dominated by woodland.

The natural plant species, in the above three belts, provide many direct and indirect benefits to the inhabitants of the region. These are as follows.

Fruits of trees and shrub like *Prosopis, Cordia myxa* and *Capparis* and of creeper, *Cucumis callosus* are harvested to utilize as vegetable curry during lean period. Seeds of *Acacia senegal, Citrul-*

Table 1 *Agro-ecological zones in western Rajasthan for traditional agroforestry*

	Zone	Rainfall (mm)	Habitat	Districts
A.	**Shrubland**			
	Calligonum polygonoides — Haloxy lon salicornicum	100–150	Sand dunes, interdunes	West of Bikaner, Jaisalmer, NW of Barmer
	Ziziphus nummularia —Capparis decidua	150–250	Rocky, gravelly pediments & buried pediments	NW of Jodhpur, central rocky plateau of Jaisalmer
	Calotropis procera — Calligonum — Clerodendrum phlomoides	200–250	Sandy undulating plains	Barmer (Baytu –Sindri area)
B.	**Trees and Shrubs**			
	Prosopis cineraria — Ziziphus — Capparis	250–350	Alluvial plains with Kankar pan at 80–150 cm	Jodhpur, Nagaur, Bikaner, part of Barmer
	Salvadora oleoides — Prosopis — Capparis	250–350	Alluvial plains with heavy soils but moderately saline	Pali, Jalore
C.	**Woodland**			
	Prosopis cineraria —Tecomella undulata	200–350	Sandy undulating plains and interdunes	Barmer, Sikar Jhunjhunu, Churu
	Prosopis cineraria	300–450	Alluvial plains (unirrigated)	Sikar, Jhunjhunu, Nagaur (north & east)
	Prosopis cineraria — Acacia nilotica	350–400	Alluvial plains (irrigated)	Jodhpur, Nagaur, Sikar, Jhunjhunu
	Acacia nilotica — A. cupressiformis	400–450	Western foothills of Aravalli range, alluvial plains	Pali

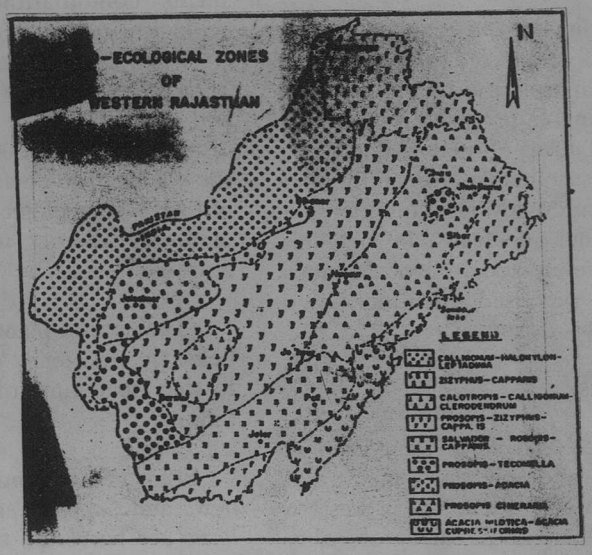


Fig 1 Agro-ecological zones of western Rajasthan

lus colocynthis and *C. lanatus* are collected for vegetables, snacks and oil.

Dried leaves of plants like *P. cineraria* (loong), *Ziziphus nummularia* (pala) and *Calligonum polygonoides* (lasu) are collected in large quantity and consumed by livestock during the lean period.

Green forage is made available to sheep and goat from *Ailanthus excelsa* (arru), *Z. mauritiana*, (ber), *Azadirachta indica* (neem), *Acacia nilotica* (babool), *A. cupressiformis* (khajoor babool) and *P. cineraria* (khejri).

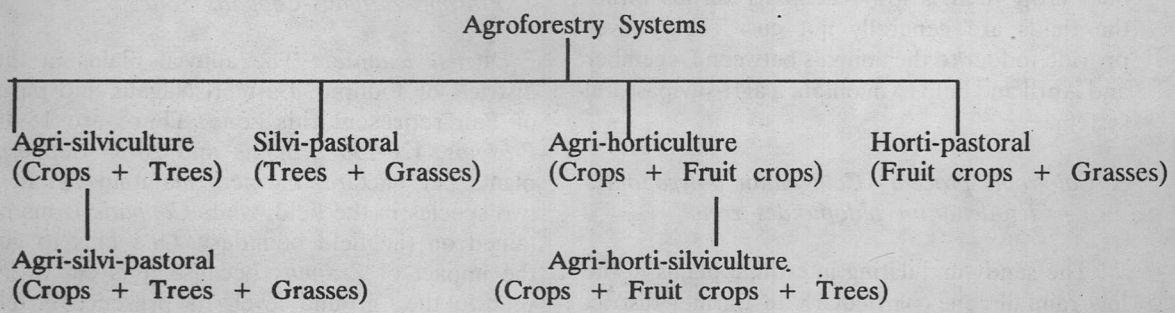
Green twigs of *C. decidua* (kair) and *C. polygonoides* (phog) are browsed by cattle, sheep and goat during the lean periods.

Wood of *Prosopis* (khejri) and *Tecomella* (rohida), sticks of *Calotropis* (ak), dried plants of *Leptadenia* and *Crotalaria* and dried stems of pearl millet (*Pennisetum americanum* L.) are utilized for construction of huts.

Wood of *Tecomella, Capparis* and *Prosopis* are utilized in making agricultural implements and local household furnitures. Lopped wood is also used as fuelwood or for fencing. The plants are also used for fibre, gum and medicinal purposes.

Present Agroforestry

In India, four main agroforesty systems are practiced:



Presently, agroforestry is conceived as a sustainable land management system for practicing agriculture, forestry and animal husbandry, on a long term basis, for the benefit of local people, for improving their economy and also for the environmental conditions.

Prevailing Agroforestry Systems in Western Rajasthan

1. Calligonum-Haloxylon-Leptadenia zone

This zone covers the western and north-western parts of Jaisalmer and Barmer districts and western part of Bikaner and Ganganagar districts. Here, the average annual rainfall is 100-150 mm. This zone is very dry and is infested with high sand dunes. Fresh sand activities on these dunes and interdunes, often create chains of barchan and do not allow any vegetation to establish. Only some annual species come up on them during the monsoon. Interdune plains support scrub vegetation.

Silvipastoral system : The zone being deficient in rainfall, supports naturally grown shrubs. Widely scattered shrubs and under-shrubs like *Calligonum polygonoides, Leptadenia pyrotechnica, Clerodendrum phlomoides, Calotropis procera, Haloxylon salicornicum, Aerva persica* and *A. pseudotomentosa* are prevalent. In Jaisalmer sector, *Calligonum* occurs in asssociation with *Haloxylon*, whereas, the Bikaner-Ganganagar tract is covered with *Leptadenia-Calligonum*, and/or *Acacia jacquemontii* and *Calligonum*. Barmer sector is dominated by *Calotropis procera* and *Clerodendrum phlomoides,* associated with *Calligonum*. *Lasiurus sindicus* and *Panicum turgidum* are the two main perennial grasses. Due to low and erratic rainfall the tract is largely utilized for animal grazing.

Kharif crops are cultivated only in good rainfall years, and hence, once in five years the agri-silvi-pastoral system is followed. Moth bean, cluster bean and local varieties of pearl millet, which can withstand prolonged droughts, are grown. In the crop fields, sown crop varieties can be noticed along with bushes and grass clumps. Ploughing is done through camel, donkey or bullock.

2. *Ziziphus nummularia–Capparis decidua zone*

This zone includes the gravelly and rocky plains, the buried Nagaur district also has similar vegetation.

The rocky uplands of Jaisalmer support widely scattered shrubs like *Leptadenia pyrotechnica, Ziziphus nummularia, Calotropis procera, Euphorbia caducifolia, Commiphora wightii* and *Capparis decidua*. Large bushes of *Salvadora oleoides, Maytenus emarginatus, Lycium barbarum, E. caducifolia, C. procera, L. pyrotechnica, Z. mauritiana* and *Z. nummularia* occur along the buried channels.

Silvi-pastoral system : Larger parts of the gravelly plains have good stand of *Ziziphus nummularia* and *Capparis decidua* with varying density (250-350 plants ha^{-1}). Many common village grazing lands also support similar vegetation components with clumps of grass like *L. sindicus* and serve as a silvi-pastoral system. In the areas of soil accumulation, *kharif* crops like cluster bean, moth bean and pearl millet are grown, but crop yield is low. *Ziziphus* shrubs within the fields are generally not cut. Their leaves provide fodder to the animals between December and April and help to maintain a agri-silvipastoral system.

3. *Calotropis procera – Calligonum polygonoides – Clerodendrum phlomoides zone*

The sandy undulating interdune plains in the low rainfall zone, particularly in Barmer district i.e., Sindri-Baytu tract, and around Phalodi and Shergarh in Jodhpur district, support these shrub components. Here, *Calotropis* is the dominant species with a density of 200-400 plants ha^{-1}. This density remains undisturbed when fields are left as long fallows. Before cultivation, majority of *Calotropis* shrubs are cut to the ground level, or many of them are given the shape of *Calotropis* trees. Other associated species are mainly *Calligonum* and *Clerodendrum*. At many places, *Lasiurus sindicus* and/or *Panicum turgidum* exhibit good stand. During long fallows, these tracts largely serve as grazing grounds for the stock when the farmers follow a silvi-pastoral system.

Agri-silvi-pastoral system : Kharif crops like cluster bean, moth bean and pearl millet are grown once in three or four years, depending upon rainfall. The crops provide low yield, but farmers grow them for their immediate requirement. In some fields, the density of *Prosopis-Tecomella* is 1-5 plants ha^{-1}.

Economic benefits : During scarcity and famine periods the *Calotropis* leaves are cut, dried in the field and given to sheep, goat and cattle. One year old stems of *Calotropis* are the most suitable for making huts. Other sand loving species like *Crotalaria burhia, Aerva persica, A.pseudotomentosa* and *Leptadenia pyrotechnica* are largerly utilized for thatching of the huts. Stem fibre, extracted from dry stalks of *Calotropis,* is converted into fine rope for cots.

Stands of *Lasiurus* and *Panicum* also provide good forage. During famine, *Aerva* and *Crotalaria*, are mixed with normal forage feed.

4. *Prosopis-Ziziphus-Capparis zone*

Agri-silviculture : The alluvial plains in the districts of Jodhpur, Barmer, Nagaur and parts of Pali represent this zone. There are 15-40 *Prosopis*, 120-250 *Ziziphus* and 20-35 *Capparis* plants per hactare. Farmers maintain the first two species in the field, while *Capparis* is maintained on the field boundary. One fails to get the impact of *Ziziphus* because it is cut every year to the ground level. Its presence is felt only after the *kharif* crop is harvested. This system provides two storeys, i.e, one of the trees and the other of the shrubs. The association

of these species is largely for the livestock and to some extent, for farmers' own use. Here the cumulative return from the crop, fodder, fuel and fruit is quite high, while the total input is low. This combination covers the largest area of arid western Rajasthan. The *kharif* crops grown are pearl millet, mung bean, moth bean, sesame and cluster bean. These crops are generally harvested by the end of October.

Economic benefits : Ziziphus grows during the monsoon through coppicing and root suckers. It is harvested by the end of November. The branches are heaped for 5-7 days and then threshed to remove the air dried leaves (pala) for storage. About 200-250 kg ha^{-1} of pala may be obtained from 400-500 plants in a hectare during normal rainfall year. The trees of *Prosopis* are lopped during December and January to get dry leaves (loong) for storage. Lopped branches are heaped for 8-10 days and then the leaves are removed. Small twigs/ branches are used for fencing, while larger ones are used as fuel/timber.

Prosopis trees resprout in March and continue to develop new leaves till the onset of monsoon. During drought years, small twigs laden with green leaves (loong) are harvested and given to animals. This tree favours the growth of crops under its canopy. Aggarwal *et al.* (1976) and Shankar *et al.* (1976) reported higher biomass production of crops/grasses grown under it.

5. Salvadora-Prosopis-Capparis zone

This zone lies in the flat alluvial plains of Jalor and Pali, with medium to heavy textured soils and moderate salinity, in 350-450 mm annual rainfall zone. The water table is 10-12 m deep and the water is either brackish or saline. The tract has both irrigated and unirrigated areas. *Salvadora* density is 10-20 plants ha^{-1} in unirrigated areas and 5-10 plant ha^{-1} under irrigated condition. The density of *Salvadora* and *Prosopis* in the cultivated fields was better earlier, but with the introduction of tractor, the farmers are now compelled to remove the *Salvadora* trees. However, *Prosopis* trees are least disturbed. Shrubs of *Capparis* or *Ziziphus*, as the main component of this system, are generally maintained on the field boundaries.

Agri-silviculture : Rainfed *kharif* crops include mung bean, moth bean, cluster bean, sesame, cowpea and pearl millet. Fallow system is also practiced. Irrigated *rabi* crops include wheat, barley, cumin and mustard (raida).

Economic benefits : Large scale fruit collection of kair is carried out for domestic consumption. Plant species like *Acacia nilotica, A. leucophloea* and *Z. mauritiana* provide top feed to sheep and goats (foliage) during lean periods. Ripe pods of P. *juliflora* provide proteinaceous diet to the grazing animals. *Salvadora* fruits (pillu) are used by the local population. Its seeds contain 45% non-edible oil and hence, the dried fruits are fed to milch animals to get milk rich in fat. Presently, seeds are sold to the soap manufacturers for extra revenue.

Here *P. cineraria* tree is generally not lopped. The green twigs are directly fed to sheep and goats during summer months. Many of the irrigated fields in Jalor have pomegranate orchards. In the early stage of orchard establishment, leguminous crops like mung bean and cowpea are taken, while in later stages, only grass is grown and is either harvested or grazed by animals once the fruits are harvested. Thus, this zone practices agri-horticulture, agri-horti-pastoral and agri-silviculture systems.

6. Prosopis cineraria - Tecomella undulata zone

In western Rajasthan, two distinct zones of *Prosopis, Tecomella* are found. One is in the less than 200 mm rainfall zone in Barmer district and the other in more than 350 mm rainfall zone of Lachmangarh and Fatehpur Tehsils of Sikar district. Both the areas have high sand dunes. The interdune plains of south-western Barmer are well wooded with these species. The density is as high as 60 trees ha^{-1}. In recent years *Tecomella* trees are being removed for industrial use. However, in some fields, the coppice shoots developed from the root suckers were counted as 100-140 ha^{-1}.