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Probable Agricultural Biodiversity Heritage Sites in India: VII. The Arid Western Region

Anurudh K Singh

2924, Sector 23, Gurgaon 122017, Haryana, India (email: anurudhksingh@gmail.com)

Abstract

The arid region of western Rajasthan, parts of southern Haryana, and the Kutch region of Gujarat harbor a unique biodiversity that is adapted to conditions of low water availability. Recognizing the region's chronic scarcity of water, the local communities have developed unique methods for the storage and conservation of water, such as step-wells, khadin, *etc., to sustain themselves and their agricultural activities. The farmers have developed ingenious agroforestry systems that incorporate indigenous multipurpose trees* (Prosopis cineraria)*, exotic drought-tolerant cereals (pearl millet), and pulses (cowpea), in order to facilitate dryland agriculture and to effectively manage the extreme environment. The traditional animal husbandry of nomadic settlements (the phase in human evolution subsequent to that of hunting and gathering) is still practiced, facilitating the sustainable use of grasslands and its development into a profitable proposition. Further, the region has contributed to international agriculture by selecting early-maturing, drought-, heat-, and salinity-tolerant varieties in major crops. The present article illustrates these facts in some detail to justify the proposition of this region as another Agricultural Biodiversity Heritage Site.*

Protohistory reveals that the arid region consisting of western Rajasthan, southern parts of Haryana, and the Kutch region of Gujarat is that part of the Indus Valley civilization where settled agriculture evolved from nomadic herdsmanship. Therefore, rich agriculture has been practiced in this region from a very long time. It has passed through diverse phases of evolution, and being the meeting point of the western and eastern flora, it represents a very unique *mélange* of plant biodiversity. Though the numbers are comparatively small, most species are adapted to the extreme climatic conditions with low water availability. Although agriculture has developed little, the main occupation of the people living in this desert region still remains animal husbandry and agriculture. The traditional nomadic livestock rearing is still practiced in the region sustainably and profitably. Field agriculture is not a dependable activity, as crops often

fail. To succeed in agriculture and support life under such adverse and extreme climatic conditions, the local communities can be credited with the development of some unique and ingenious techniques such as *tankas*, step-wells, and *khadin* for the storage/conservation and efficient use of water. Further, they discovered that animal husbandry, coupled with trees and grasses intercropped with food and vegetable crops or fruit trees, is the most viable model of agriculture for these arid and drought-prone regions. In this regard, the agroforestry systems developed by the local communities involving indigenous multipurpose tree species [*Prosopis cineraria* (L.) Druce., *Tecomella undulata* (Sm.) Seem.] are of significance, and they have played an important role in the amelioration of the conditions in arid and semi-arid lands and in providing livelihood support in the Thar Desert. These innovations have generated significant knowledge regarding the management of the environment and the general welfare of the people living in the desert areas. Subsequently, farmers in western Rajasthan, based on generations of experience, devised criteria for judging the suitability of land for the cultivation of a particular crop and cropping system. They developed various management practices depending on the land quality, which have led to an increase in soil fertility. The indigenous *khadin* system of cultivation not only increases soil fertility, but also conserves water. Other important traditional management practices such as crop rotation, fallowing, crop residue use as manure, addition of pond sediments to fields, and agroforestry are practiced to maintain soil fertility, thereby introducing sustainability into agriculture. As rainfed agriculture is predominant, farmers have adopted drought-resistant exotic crops, particularly cereals (pearl millet, sorghum) and pulses (cowpea) from other parts of the world, and devised several practices for dryland agriculture by growing these crops in non-saline areas, and by identifying early-maturing varieties to beat the short growing period and more drought-resistant varieties of important crops for the efficient use of water. The extremely dry conditions and soil salinity were also favorably exploited for the selection and development of desirable genetic diversity for such traits in important crops. For example, the wheat variety *Kharchia Local* is a unique source of salt tolerance, and *Hindi 62* is a source of heat tolerance. They have been extensively used in breeding programs globally. Similarly, the local *Sanguineum* desi cotton (G7) was used as a source of drought tolerance and fiber quality in the development of the internationally known *Bikanery Nerma* cotton, an important contribution to international agriculture. Thus, because of its contributions to the development of knowledge towards the management of such a harsh environment and landscape, dryland agriculture, and desirable genetic

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diversity responding to prevailing climate in important global crops, the Arid Western Region of India is proposed as another National Agricultural Biodiversity Heritage Site based on the criteria illustrated by Singh and Varaprasad (2008).

Location and extent

The Arid Western Region is one of the twelve biogeographical provinces of India (Rodgers and Panwar, 1988), and one of the twenty-one agroecological zones of India (Sehgal *et al*., 1992). This Agricultural Biodiversity Heritage Site includes the western part of Rajasthan, and parts of the southwestern Haryana and the Kutch peninsula of Gujarat (Fig. 1). It is a hot-arid ecoregion, mostly consisting of desert and saline soils. The extreme climatic conditions, aridity, drought, shifting sand dunes, salinity ingress, and desert storms are hostile for the survival of vegetation in this region. Though the vegetation is scanty, the adaptive strategies of desert vegetation are unique, especially in relation to moisture conservation. Physiographically, the western Rajasthan desert is part of the eastern extension of

Figure 1. Location and extent of the Arid Western Region.

the Saharo–Thar desert, and is covered with shifting sands with rock outcrops in the Barmer–Jaisalmer–Bikaner tract. The Aravalli ranges from Khetri in the northeast and Khed–Brahma in the southwest form a distinct geographical boundary on the eastern side of the arid western plains. The agriculture-dominant areas comprise Sikar, Nagaur, Pali, Hanumangarh, Ganganagar, Jalore, Sirohi, Jodhpur, Jaisalmer, Bikaner, Udaipur, Dungarpur, Churu, and Jhunjhunun districts of Rajasthan, the southwest of Haryana, and the Rann of Kutch.

Landscape

There are three principal landforms in the region – the predominantly sand-covered Thar, the plains with hills including the central dune-free part of the region, and the semi-arid area surrounding the Aravalli ranges.

The Thar Desert is a desolate area, where sand is piled up into huge windblown dunes (known as an *erg*). The sand dunes are of three types: longitudinal parabolic, transverse, and barchans. The first type runs north–northeast to south–southeast that is, parallel to the prevailing winds occurring to the south and west of Thar. The transverse dune is aligned across the wind direction, to the east and south of Thar. The barchans, with the concave sides facing the wind in the interior are predominant in central Thar. On the whole, the Thar Desert slopes imperceptibly towards the Indus plain and the surface unevenness is mainly due to sand dunes. The dunes in the south are higher, rising sometimes up to 152 m, whereas in the north, they are lower and rise up to only 16 m above the ground level.

To succeed in agriculture and support life under such adverse and extreme climatic conditions, the local communities can be credited with the development of some unique and ingenious techniques such as* tankas, *step-wells, and* khadin *for the storage/ conservation and efficient use of water.

The Aravalli range forms the main landmark to the southeast of the Thar Desert. The more humid conditions that prevail near the Aravallis prevent the extension of the Thar Desert towards the east and the Ganges Valley. In the heart of the sand-covered areas, the bare, dune-free area of Barmer, Jaisalmer, and Bikaner present an anomaly.

Agroclimate

The Arid Western Region represents a typical hot arid climate, which is characterized by hot summers and cool winters. The mean annual rainfall is around 300 mm, while potential evapotranspiration (PET) is 1,500–1,900 mm due to high solar radiation and wind speed, leading to a prolonged dry moisture regime. This results in a large water deficit throughout the year, reducing the growing period/season to less than 90 days from mid-June to mid-August (Sehgal *et al*., 1992).

The dominant soilscapes representing the area are gentle to very gentle sloping. The dominant sandy soils are represented by the Thar series, which are moderately

calcareous and alkaline in reaction. The soils are generally sandy to sandy-loam in texture. The consistency and depth vary according to the topographical features. The low-lying loams are heavier and may have a hard pan of clay, calcium carbonate, or gypsum. The pH varies between 7 and 9.5. The soils improve in fertility from the west and northwest to the east and northeast. Desert soils are Regosols of windblown sand and sandy fluiratile deposits, derived from the disintegration of rock in the subjacent areas and blown in the form of dust to the coastal region and the Indus Valley. The desert soils occupy the districts of Jodhpur, Bikaner, Churu, Ganganagar, Barmer, Jaisalmer, and Jalore.

Floristic diversity

The region is not very rich in floristic diversity as far as the number of species is concerned, but rich in the uniqueness of plant biodiversity found in the region, which is adapted to extreme agroclimatic conditions, in which agriculture is very little developed, owing to the lack of availability of water and harsh climatic conditions. The region is also unique being at meeting point of eastern and western flora. Therefore, besides, the cosmopolitan and tropical species, it has predominance of western elements, which goes up to 65.8% and eastern elements that are up to 34.2%. There is an overall dominance of the African element, 37.1%, as compared to the Oriental elements, which are only 20.6%. There is a significant percentage of endemic elements, which constitute 9.4% of the total flora. Also present are the Iranian elements (5.5%) and Saharo-Sindian elements (20%), presenting a wide spectrum of genetic diversity. In relation to the number of species, in addition to crop species, the region has around 682 species belonging to 351 genera and 87 families (Bhandari, 1995), of which around 25 are endemic.

The extremely dry conditions and soil salinity were also favorably exploited for the selection and development of desirable genetic diversity for such traits in important crops. For example, the wheat variety* Kharchia Local *is a unique source of salt tolerance, and* Hindi 62 *is a source of heat tolerance.

The natural vegetation comprises of sparse sporadic tropical thorn forests (Champion, 1936). The vegetation is dominated by stunted prickly shrubs and drought-resistant perennial herbs. The trees are few and their distribution is scattered. The important trees are *Acacia senegal* Willd., *A. jacquemontii* Benth., *A. leucophloea* Willd., *Anogeissus rotundifolia* Blatt. & Hallb. *A. pendula* Edgew., *A. sericea* Brandis, *Prosopis cineraria, Salvadora oleoides* Decne., *Tecomella undulata*, and *Tamarix articulata* Wall.

The shrubs occurring in the sandy and gravelly areas are phog (*Calligonum polygonoides* Linnaeus), *Calotropis procera* (Aiton) W.T.Aiton, *Capparis decidua* Edgew., *arni* (*Clerodendrum phlomidis* Linn.), *Acacia jacquemontii*, *Balanites roxburghii* Planch., *Ziziphus zizyphus* (L.) H.Karst., *Z. nummularia*

(Burm.f.) Wight & Arn., *Suaeda fruticosa* Dumort., *Crotalaria burhia* Buch.-Ham., *Aerva tomentosa* Lam., *Clerodendrum multiflorum* G.Don, *Leptadenia pyrotechnica* (Forssk.) Decne., *Lycium barbarum* L., *Grewia populifolia* Vahl, *Commiphora mukul* Engl. [syn. *C. wightii* (Arn.) Bhandari], *Euphorbia neriifolia* L., *Cordia rothii* Roem. & Schult., and *Maytenus emarginata* (Willd.) Ding Hou.

Some of the prominent herbaceous species are *Aerva javanica* Juss., *Citrullus colocynthis* (L.) Schrad., *Farsetia hamiltonii* Royle, *Indigofera argentea* Buch.-Ham. ex Roxb., *I. purpurea* Page ex Steud., *Eleusine compressa* Asch. & Schweinf. ex C.Chr., *Dactyloctenium scindicum* Boiss., *Lasiurus hirsutus* Boiss., *Cynodon dactylon* (L.) Pers., *Dichanthium annulatum* Stapf, *Sporobolus marginatus* Hochst. ex A.Rich., *Saccharum spontaneum* L., *Cenchrus ciliaris* L., *Desmostachya bipinnata* (L.) Stapf, *Cyperus arenarius* Retz., *Eragrostis* Wolf spp., *Ergamopagan* spp., and *Typha* L. spp.

Some of the grass species that bind the sand dunes are *Cenchrus biflorus* Roxb., *C. setigerus* Vahl, *Cymbopogon jwarancusa* (Jones) Schult., *Dactyloctenium aegypticum* (L.) Beauv., *D. scindicum* Boiss., *Lasiurus sindicus* Henrard, *Latipes senegalensis* Kunth, *Panicum antidotale* Retz., *P. turgidum* Forssk. The prominent species that grow in the saline areas are *Chenopodium album* L., *Cressa cretica* L., *Haloxylon salicornicum* Bunge ex Boiss., *Limeum indicum* Stocks ex T.Anderson, *Peganum harmala* L., *Salsola baryosma* (Roem. et Schult.) Dandy, *Suaeda fruticosa* (L.) Forssk., and *Zygophyllum simplex* L. The most characteristic lithophyte in the rocky outcrops, in the Jaisalmer plateau, Barmer hills, Jalore hills, Jodhpur-Mandore plateau is *Euphorbia caducifolia* Haines.

The Thar Desert is a desolate area, where sand is piled up into huge windblown dunes (known as an* erg*).

Agriculture and agrobiodiversity

The Arid Western Region falls in the northwestern region of the Indian subcontinent (Indus Valley), which has seen all four phases of the protohistory. The main occupations of people living in the desert are animal husbandry and agriculture. The region suffers from low rainfall, high temperature, and light-textured soils. Usually, the soil in the region is deficient in nitrogen, low-to-medium in phosphorus, and high in potassium. Therefore, agriculture is not a dependable proposition in this area. After the rainy season, at least 33% of the crops fail. Additionally, the region faces frequent droughts, overgrazing due to high animal populations, wind and water erosion, mining and other industrial development resulting in serious land degradation. Therefore, animal husbandry, cultivation of trees and grasses, and their intercropping with food and vegetable crops or fruit trees, was discovered to be the most viable model for the region. Consequently, agriculture revolved around the available indigenous resources related with this model.

The region is not very rich in floristic diversity as far as the number of species is concerned, but rich in the uniqueness of plant biodiversity found in the region, which is adapted to extreme agroclimatic conditions.

To overcome constraints of the desert-like conditions, local communities have developed suitable practices to support life and agriculture, such as *tankas*, step-wells, and *khadins* to facilitate the conservation and efficient use of water (Fig. 2). Recognizing the importance of trees in mitigating dry conditions, the local people have identified indigenous multipurpose trees such as *Prosopis cineraria* (*khejri*) and *Tecomella undulata* (Marwar teak) for cultivation in the agroforestry system (Fig. 3). Based on generations of experience, they have devised criteria for judging the suitability of land for cultivation of a particular crop and cropping systems. Selection of crops and the amount of fertilizer or manure to be used depended upon the quality of land. For example, moth bean is generally grown in poor soils. Better soils are preferred for mung bean and pearl millet, while cluster bean is grown on relatively heavy soil. In sandy soil, pearl millet and mung bean are grown using cow dung manure and camel manure. In the irrigated areas, sheep and goat manure are applied. Farmers follow certain management practices, which help to maintain the soil fertility to some extent. For example, allowing herds of sheep in the field for one or two days and growing *khejri* trees in the field, are some of the practices followed to increase/sustain soil fertility.

The field preparation for *kharif* (rainy season) crops is initiated in May and June by clearing the shrubs and other weeds. The fields are plowed with the arrival of the monsoon in July in the region. Normally, one plowing is done in the case of pearl millet, moth bean, mung bean, sesame, and cluster bean. However, if more than one plowing is practiced, the land is kept fallow for a long time. *Rabi* (winter) crops are usually grown in irrigated areas and in *khadins*. Wheat, mustard, and chickpea, and in some areas, cumin are the crops grown in winter.

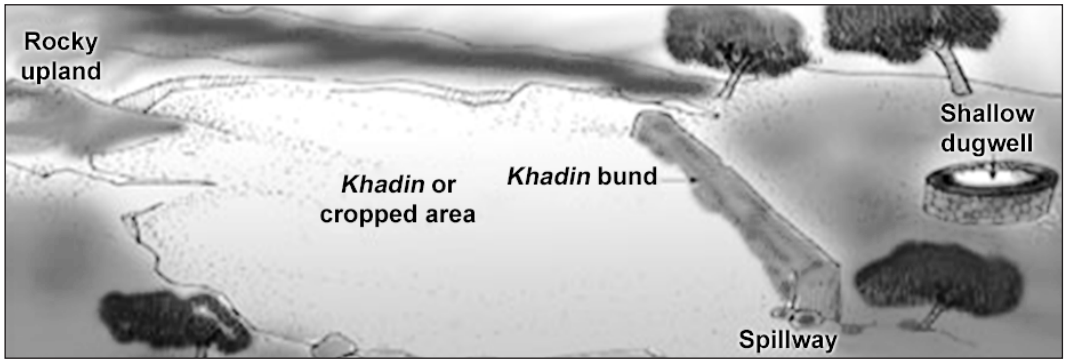

Figure 2. *Khadin,* the traditional system of rainwater harvesting.

Figure 3. Plantation of the multipurpose *khejri* in the field, as part of the agroforestry system.

The traditional agriculture practiced by farmers is rainfed dryland agriculture. Most of the area is under traditional rainfed monocropping with crops like pearl millet, which are well adapted to the region (Fig. 4). The short growing season allows only one crop per year during the rainy season. The farmers grow drought-resistant and short-duration rainy-season crops/varieties, such as pearl millet, sorghum, semi-arid legumes, *chari* (fodder), and other fodder crops in non-saline areas. Pearl millet is the dominant crop grown along with *kharif* sorghum. *Kharif* crops are grown with the onset of rains during July. Other widely cultivated crops are arid legumes such as green gram (mung bean), cowpea, moth bean, and *guar* (cluster bean), and oilseeds such as castor, mustard, and sesame. Some farmers prefer oilseed crops and pulses to pearl millet (Rathore and Gupta, 1991). The yields are low under average management practices. In areas favored by the availability of irrigation water, cotton, sugarcane, mustard, chickpea, and wheat are grown.

Figure 4. Traditional pearl millet monocropping.

The important cropping systems involve pearl millet and cluster bean, and mixed cropping of pearl millet+moth bean, pearl millet+mung bean, cluster bean+sesame, castor+moth bean, castor+mung bean, and castor+sesame are widely practiced. Forage crops are also widely grown. The traditional practices have been further improved through scientific researches in agroforestry, ley farming (field is alternately seeded for grain and left fallow), and in the use of farmyard manure and compost.

The natural vegetation comprises of sparse sporadic tropical thorn forests. The vegetation is dominated by stunted prickly shrubs and drought-resistant perennial herbs. The trees are few and their distribution is scattered.

The Thar Desert is known for nomadic animal husbandry from ancient time. Many nomadic tribes are engaged in animal husbandry, particularly the Raikas/Rabaris (with camel, sheep, and goats) and the Gujjars (with buffalo and sheep). The Raikas live in groups of 4–20 families on the outskirts of villages, and combine crop production during the rainy season with pastoralism during the autumn–spring dry season. They are predominantly non-migratory and live with small herds of a few hundred animals, but with a rich variety of breeds. Camel herding has been their traditional heritage. In this form of agriculture, an indigenous land-use system is practiced, where camels roam freely for much of the year; herded only during the rainy and breeding seasons.

Representative crop species in various crop groups

Cereals, pseudocereals, and millets. Barley (*Hordeum vulgare* L.), crabgrass – a minor millet [*Digitaria cruciata* (Nees ex Steud.) A. Camus.], foxtail millet [*Setaria italica* (L.) P.Beauv.], *ghant ghas* (*Dactyloctenium scindicum*) – grain is eaten mixed with pearl millet, jungle rice [*Echinochloa colonum* (L.) Link], little millet (*Panicum miliare* Lam.), maize (*Zea mays* L.), *Panicum psilopodium* Trin., pearl millet [*Pennisetum glaucum* (L.) R.Br.; syn. *P. americanum* L.], rice (*Oryza sativa* L.) in Ganganagar, sorghum [*Sorghum bicolor* (L.) Moench], wheat (*Triticum aestivum* L.), *Eleusine compressa* Asch. & Schweinf. ex C.Chr., *Echinochloa frumentacea* Link, finger millet [*Eleusine coracana* Gaertn., *E. indica* (L.) Gaertn.], yellow foxtail (*Setaria glauca* Kunth).

Legumes and oilseeds. Black gram [*Vigna mungo* (L.) Hepper], brown mustard/*laha* [*Brassica juncea* (L.) Czern. & Coss], brown sarson (*Brassica campestris* L. var. *dichotoma* Watt), chickpea (*Cicer arietinum* L.), cluster bean (*Cyamopsis tetragonoloba* L.), cowpea [*Vigna unguiculata* (L.) Walp.], green gram [*Vigna radiata* (L.) R. Wilcz.], groundnut (*Arachis hypogaea* L.), horse gram [*Macrotyloma uniflorum* (Lam.) Verdc.], jojoba [*Simmondsia chinensis* (Link) C.K.Schneid.] – a recent introduction, moth bean [*Vigna aconitifolia* (Jacq.) Marechal.], sesame (*Sesamum indicum* L.), *taramira* (*Eruca sativa* Mill.), *toria/lahi* (*Brassica campestris* L. var. *toria* Duth.), yellow sarson (*B. campestris* L. var. *sarson* Prain).

Fiber, forage, and others. Fiber: *Agave americana* L., cotton (*Gossypium herbaceum* L.), flax (*Linum usitatissimum* L.), kenaf (*Hibiscus cannabinus* L.), sunn hemp (*Crotalaria juncea* L.); Dyes: *Arnebia hispidissima* (Sieber ex Lehm.) DC., *harmal* (*Peganum harmala*),

Farmers follow certain management practices, which help to maintain the soil fertility to some extent. For example, allowing herds of sheep in the field for one or two days and growing* khejri *trees in the field, are some of the practices followed to increase/sustain soil fertility.

Lawsonia inermis L., *neel* (*Indigofera caerulea* Roxb.), *patalagarudi* (*Cocculus hirsutus*), *Wrightia tinctoria* R. Br.; Forage species: barnyard grass [*Echinochloa crus-galli* (L.) P.B.], a weed, bristle-grass [*Setaria verticillata* (L.) P.Beauv.],*Cenchrus ciliaris,C. setigerus, Crotalaria burhia, Cyperus dwarkensis* Sahni & Naithani, *Dichanthium annulatum, sewan* (*Lasiurus sindicus* Henrard), napier grass (*Pennisetum purpureum* Schum.), *ghamur* (*Panicum antidotale* Retz.). Even trees such as *Salvadora* spp., *Prosopis cineraria, Tecomella undulata*, etc. provide good fodder for cattle and camels during summer, when the vegetation is scarce.

Vegetables and tuber crops. Bitter gourd (*Momordica charantia* L.), bitter melon (*Momordica balsamina* L.), bottle gourd [*Lagenaria siceraria* (Molina) Standl.], brinjal (*Solanum melongena* L.; eggplant), chili (*Capsicum annuum* L.), cluster bean/*guar* (*Cyamopsis tetragonoloba*), cowpea (*Vigna unguiculata*), cucumber (*Cucumis sativus*), *kachari* (*Cucumis melo* var. *agrestis*), and several other wild and weedy forms, *khejri* (*Prosopis cineraria*) – young pods, garlic/*lashun* (*Allium sativum* L.), leafy vegetables – amaranth (*Amaranthus caudatus* L., *A. viridis* L., *A. spinosus* L.), *Chenopodium album* L., *Digera muricata* (L.) Mart., fenugreek/*methi* (*Trigonella foenum-graecum* L.), *Moringa oleifera* Lam., *M. concanensis* Nimmo ex Dalzell & Gibson, mustard greens [*Brassica juncea* (L.) Czern.]; okra (*Abelmoschus esculentus* Moench), onion (*Allium cepa* L.), pumpkin (*Cucurbita pepo* L.), sesame (*Sesamum indicum*), snap melon (*Cucumis melo* var. *momordica* Duthie and Fuller), spine gourd (*Momordica dioica* Roxb. ex Wild.), sponge gourd (*Luffa cylindrica* M. Roem.; syn. *L. aegyptiaca* Mill.), *tinda* (*Citrullus fistulosus* L.), tomato (*Lycopersicon esculentum* L.).

The traditional agriculture practiced by farmers is rainfed dryland agriculture. Most of the area is under traditional rainfed monocropping with crops like pearl millet, which are well adapted to the region.

The important cropping systems involve pearl millet and cluster bean, and mixed cropping of pearl millet+moth bean, pearl millet+mung bean, cluster bean+sesame, castor+moth bean, castor+mung bean, and castor+sesame are widely practiced.

Spices. *Ajwain* [*Trachyspermum copticum* (L.) Link.; syn. *Carum copticum* (L.) Benth. & Hook. f. ex C.B. Clarke.], *Ammi copticum* L., aniseed (*Pimpinella anisum* L.), *Carum carvi* L., *Bunicum persicum* Bioss, chili (*Capsicum annuum* L.), coriander/*dhaniya* (*Coriandrum sativum* L.), fennel/*saunf/sanchal* (*Foeniculum vulgare* Mill.), cumin/*jeera* (*Cuminum cyminum* L.), *kalongi* (*Nigella sativa* L.), fenugreek/*methi* (*Trigonella foenum-graecum*).

Fruits. *Aonla* (*Emblica officinalis* L.), *ber* (*Ziziphus mauritiana*; syn. *Z. jujube* Lam.), fig (*Ficus carica* L.), guava (*Psidium guajava* L.), Indian fig/opuntia/ barbary fig [*Opuntia ficus-indica* (L.) Mill.], *kair/karel* [*Capparis decidua* (Forssk.) Edgew.], *khejri* (*Prosopis cineraria*), *karonda* (*Carissa carandas* L.), *lasura* (*Cordia myxa* L.), musk melon (*Cucumis melo*), *phalsa* (*Grewia oppositifolia* Roxb.), *pilu* (*Salvadora oleoides* Decne.; syn. *S. stocksii* Wight), pomegranate (*Punica granatum* L.), watermelon [*Citrullus lanatus* (Thunb.) Mansf.].

Timber and agroforestry species. *Acacia nilotica* (L.) Del., *A. senegal* (L.) Willd., *Anogeissus pendula* Edgew., *A. rotundifolia* Blatt. & Hallb., *Boswellia serrata* Roxb. ex Colebr., *Cordia gharaf* (Forssk.) Ehrenb. & Aschers., *Faidherbia albida* (Delile) A.Chev. (syn. *Acacia albida* Delile; naturalized), *khejri* (*Prosopis cineraria*), *Salvadora indica* Royle (syn. *S. oleoides* Decne.), *Tamarix aphylla* (L.) Karst., Marwar/Barmer teak (*Tecomella undulata*), neem (*Azadirachta indica* Juss.), *vilayati babul* (*Prosopis juliflora*) (naturalized).

The Thar Desert is known for nomadic animal husbandry from ancient time. Many nomadic tribes are engaged in animal husbandry, particularly the Raikas/Rabaris (with camel, sheep, and goats) and the Gujjars (with buffalo and sheep).

Other economic plants. Minor vegetables – *Caralluma edulis* (Edgew.) Benth. & Hook., *Clitoria ternatea* L., *Portulaca oleracea* L., *Talinum portulacifolium* (Forssk.) Asch. & Schweinf. ex Schweinf., and fruits – bitter apple (*Citrullus colocynthis*), *Grewia tenax* (Forssk.) Fiori, *jungal jalebi* [*Pithecellobium dulce* (Roxb.) Benth.; introduction], *pilu* (*Salvadora persica* L.).

Medicinal plants. *Aak/dhatura* [*Calotropis gigantea* (L.) R. Br., *C. procera* (Ait) R.B.], *Abutilon indicum* (Linn.) Sweet, *adusa/arusha* (*Justicia adhatoda* L.), *Alhagi maurorum* Medik., aloe [*Aloe barbadensis* Miller.; syn. *A. vera* (L.) Burm.f.], *Anticharis glandulosa* var. *caerulea* Blatt. & Hallb. ex Santapau, *ashwagandha* [*Withania somnifera* (L.) Dunal], *bada-gokhru* (*Pedalium murex* L.), *bajradanti* (*Barleria prionitis* L. var. *dicantha* Blatt. & Hallb.), *barchi-buti* (*Leonotis nepetifolia* L.), *bhangari* (*Blepharis sindica* T. Anders.), *bhrangraj* (*Eclipta prostrata* L.), *Cassia auriculata* L., *chapari* (*Barleria acanthoides* Vahl.), *chinawari/santhi* (*Boerhaavia diffusa* L.), *chota-gokhru* (*Tribulus terrestris* L.), *Marwadi gokhru* (*Tribulus rajasthanensis* Bhandari & Sharma), *guggul* [*Commiphora wightii* (Arn.) Bhandari; syn. *C. mukul* and wild *C. caudata* (Wight & Arn.) Engl.] – sometimes identified with ancient bdellium, and gum obtained from bark, *gundi* [*Cordia gharaf* (Forssk.) Ehrenb. & Aschers.], *harmal* (*Peganum harmala* L.), *hatjod* (*Cissus quadrangularis* L.), *hingot/hingan* (*Balanites aegyptiaca* L.), *kaligari/ kalihari/karihari* (*Gloriosa superba* L.), *koyalri/aparajit* (*Clitoria ternatea* L.),

lunwo (*Zygophyllum simplex* L.), *madhio* (*Cleome vahliana* Fresen.), *nwal* (*Senna auriculata* L.), *paneer bandh* [*Withania coagulans* (Stocks) Dunal], *patharchur* (*Coleus amboinicus* Lour.), *phok* (*Calligonum polygonoides* L.), *pilu/jhak/ kharjal* (*Salvadora persica* L.), *ratanjot* [*Convolvulus auricomus* A. Rich. var. *volubilis* (C.B. Clarke) Bhandari], *rota bel* [*Convolvulus auricomus* A. Rich. var. *ferruginosus* Bhandari], *rudrawanti* (*Cressa cretica* L.), *salaran/salai gugal* (*Boswellia serrata* Roxb. ex Colebr.), *satyanashi* (*Argemone mexicana* L.), *shankhpushpi* (*Convolvulus microphyllus* Choisy), *undhokanto* (*Achyranthes aspera* L.) (Singh, 2004). Other medicinal plants are *babachi* (*Psoralea corylifolia* Linn.), *Fagonia cretica* L., gum guaiacum (*Guaiacum officinale* L.), *jharber* [*Ziziphus nummularia* (Burm. f.) Wight & Arn.; syn. *Z. rotundifolia* Lam.], *khodhab* [*Cadaba fruticosa* (L.) Druce], *Pedalium murex* Linn., *Wrightia tinctoria* R. Br.

Ornamentals. *Agave americana* L., *Azima tetracantha* Lam. (syn. *Monetia barlerioides* L'Her.) (edible fruits), *Barleria prionitis* L. var. *dicantha* Blatt. & Hallb.

Multipurpose species. *Acacia catechu* (L.f.) Willd., *A. jacquemontii* (Benth.) Willd., *A. leucophloea* Roxb., *Acacia nilotica* subsp. *indica*, aloe (*Aloe barbadensis*), *Balanites aegyptiaca* (L.) Delile, *Commiphora wightii*, *khejri* (*Prosopis cineraria*), Marwar teak/*rohida* (*Tecomella undulata*), neem (*Azadirachta indica*), *siris* [*Albizia lebbeck* (L.) Benth.].

Wild relatives of crop species. *Acacia nilotica* (L.) Delile, *Aegle marmelos* (Linn.) Corr., *Balanites aegyptiaca* (syn. *B. roxburghii* Planch.), *Capparis decidua* (Forssk.) Edgew., *Citrullus colocynthis* (L.) Schrad., *Commiphora wightii* (wild form), *C. caudata*, *Crotalaria burhia* Buch.-Ham., *Cucumis prophetrum*, *Ipomoea cairica* (L.) Sweet var. *semineglabra*, *Momordica balsamina* Linn., *Psoralea corylifolia* L., *Salvadora oleoides* Decne., *Sorghum bicolor* (weedy forms), *Sorghum halepense* (L.) Pers., *Withania coagulans*, *Ziziphus nummularia* (syn. *Z. rotundifolia* Lam.), *Z. mauritiana* (Arora and Nayar, 1984).

Endemic species. *Abutilon bidentatum* Hochst. ex A. Rich. var. *major* (Blatt. & Hallb.) Bhandari, *A. fruticosum* Guillemin & Perottet. var. *chrysocarpa* Blatt. & Hallb., *Alysicarpus monilifer* (L.) DC. var. *venosa* (minor vegetable), *Barleria prionitis* var. *dicantha*, *Cenchrus prieurii* (Kunth) Maire var. *scabra* Bhandari (forage), *Cenchrus rajasthanensis* K.C.Kanodia & P.C.Nanda (forage), *Ceropegia odorata* Nimmo, *Citrullus colocynthis*, *Cleome gynandra* L. var. *nana* (Blatt. and Hallb.) Bhandari (medicinal), *Commiphora wightii*, *Cucumis prophetrum*, *Cyperus dwarkensis*, *Digitaria pennata* Hochst. (as brush), *Ipomoea cairica* (L.) Sweet var. *semineglabra*, *Pavonia arabica* Hochst. ex Steud. var. *massuriensis* Bhandari, *Pavonia arabica* var. *glutinosa* Blatt. & Hallb., *Salvadora persica*, *Tamarix kutchensis* B.V.Shetty & R.P.Pandey, *Tecomella undulata*, *Withania coagulans*, *Ziziphus truncata* Blatt. & Hallb., *Z. williamsii* (Nayar, 1996). Table 1 presents the details of species endemic to the region.

Table 1. Representative agriculturally important species endemic to the Arid Western Region.

Species	Family	Habit	Distribution	Use
Abutilon bidentatum var. *major*	Malvaceae	Undershrub	Western Rajasthan	Medicinal
Abutilon fruticosum var. *chrysocarpa*	Malvaceae	Undershrub	Western Rajasthan	Medicinal
Alysicarpus monilifer var. *venosa*	Fabaceae	Perennial herb	Western Rajasthan	Vegetable
Barleria prionitis var. *dicantha*	Acanthaceae	Thorny undershrub	Western Rajasthan, Alwar, Tonk	Medicinal, *Vajradanti*
Cenchrus rajasthanensis	Poaceae	Caespitose annual or biennial	Western Rajasthan	Forage, wild relative
Ceropegia odorata	Asclepiadaceae	Twiner	Western Rajasthan	Medicinal, ceropegine
Citrullus colocynthis	Cucurbitaceae	Climber	Western Rajasthan	Wild relative on sand dunes
Cleome gynandra var. *nana*	Cruciferae	Dwarf annual herb	Western Rajasthan	Medicinal
Commiphora wightii	Burseraceae	Shrub	Western Rajasthan	Gum and resin, medicine
Cucumis prophetrum	Cucurbitaceae	Climber	Western Rajasthan	Wild relative, on hillocks
Ipomoea cairica var. *semineglabra*	Convolvulaceae	Perennial twiner with tuberous rootstock	Western Rajasthan	Food
Pavonia arabica var. *glutinosa*	Malvaceae	Undershrub	Western Rajasthan	Medicinal, fruit and flower
Pavonia arabica var. *massuriensis*	Malvaceae	Undershrub	Western Rajasthan	Medicinal, fruit and flower
Salvadora persica	Salvadoraceae	Tree	Western Rajasthan	Medicinal, fruit eaten
Tecomella undulata	Bignoniaceae	Tree	Western Rajasthan	Timber wood
Withania coagulans	Solanaceae	Undershrub	Western Rajasthan	Relative of *W. somnifera*
Ziziphus truncata	Rhamnaceae	Small shrub	Jaisalmer, Jodhpur	Fruit
Ziziphus williamsii	Rhamnaceae	Small shrub	Rann of Kutch	Wild relative

Threatened economic species. Nayar (1996) reported the following species to be under threat: *Abutilon bidentatum* var. *major, A. fruticosum* var. *chrysocarpa, Anogeissus sericea* Brandis var. *nummularia* King ex Duthie (around lake Kailana, Jodhpur), *Barleria prionitis* var. *dicantha, Cenchrus prieurii* var. *scabra, C. rajasthanensis, Ceropegia odorata, Cyperus dwarkensis, Indigofera caerulea* Roxb. var. *monosperma* (Sant.) Sant., *Indigofera constricta* (Thw.) Trimen, *Tamarix kutchensis,* and *Ziziphus williamsii*. A survey conducted by Singh (2004) recorded the following additional species to be under threat as per the perception of local scientific community and other stakeholders: *Anticharis glandulosa* var. *caerulea* Blatt. & Hallb. ex Santapau, *Calligonum polygonoides, Caralluma edulis, Psoralea odorata* Blatt. & Hallb., *Commiphora wightii, Portulaca oleracea* L., *Salvadora indica* Royle (syn. *S. oleoides* Decne.), *S. persica, Sarcostemma acidium* (Roxb.) Voigt., *Schweinfurthia papilionacea* (L.) Merill., *Tecomella undulata,* and *Withania coagulans*. Recently, the Government of India's Environmental Information System ENVIS program has further listed *Ephedra foliata* Boiss. & Kotschy, *Farsetia macrantha* Blatter & Hallberg, *Tephrosia falciformis* Ramasw, *Tribulus rajasthanensis* Bhandari & Sharma, and *Ziziphus truncata* Blatt. & Hallb. to be under threat (Rawat, 2008). The details of species under threat are given in Table 2.

Associated cultures and tribes

The region is inhabited by Indo-Aryan and Dravidian races with dominant influence of the Indo-Aryan culture and Hindu religion. The main tribes of Rajasthan are the Bhils and the Minas, who were the original inhabitants. But they were forced into the Aravalli range by the Aryan invasion. Smaller tribes include the Sahariyas, Garasias, and the Gaduliya Lohars.

The tribes share common traits, which seem to link their past together, but it is the differences in their costumes and jewelry, fairs and festivals that set them apart from one another. Over time, the region was frequently visited by people from Africa, the Middle East and Central Asia, making a good impact on the culture and agriculture of the region. This is clearly reflected in the predominance of western plant species in local flora, and cultivation of species domesticated in Africa and Central Asia as major staple food crops. The Muslim religion has also made significant impact, which is visible in the prevalence of a composite, colorful culture rich in traditions. The people have a great passion for music and poetry. In the desert region, the small population is mostly pastoral, and hide and wool industries are prominent.

At present, the Indian Desert is mainly inhabited by Hindus, Muslims, and Sikhs. The portion in Pakistan is inhabited primarily by Sindhis and Kolhis. The tribes associated with agriculture are Bhils, Rabari, Minas, Garasias, and Bishnois. The Sahariyas Bishnoi community is known for the conservation and protection of the *khejri*

Table 2. Representative agriculturally important species under threat in the Arid Western Region.

Species[1]	Family	Habit	Threat level[2]	Use
Abutilon bidentatum var. *major*	Malvaceae	Undershrub	I	Fiber used for making rope
Abutilon fruticosum var. *chrysocarpa*	Malvaceae	Undershrub		Fodder value
Anogeissus sericea var. *nummularia**	Combretaceae	Tree	R	Hardwood tree species, good for tool handles
Barleria prionitis var. *dicantha*	Acanthaceae	Shrub	EN	Medicinal, ornamental
Capparis decidua	Capparidaceae	Shrub	VN	Fruit for food
Cenchrus rajasthanensis	Poaceae	Herb	I	Forage
*Ceropegia odorata**	Asclepiadaceae	Twiner		Medicinal, ceropegine
Citrullus colocynthis	Cucurbitaceae	Climber	VN	Wild relative
Commiphora wightii	Burseraceae	Shrub	EN	Gum and resin, medicine
Cucumis prophetrum	Cucurbitaceae	Climber	I	Wild relative
*Cyperus dwarkensis**	Cyperaceae	Herb	EN	Forage
Indigofera caerulea var. *monosperma**	Fabaceae	Shrub	R	Medicinal, green manure
*Indigofera constricta**	Fabaceae	Shrub	R	Medicinal, green manure
Salvadora indica (syn. *S. oleoides*)	Salvadoraceae	Tree	EN	Wood
Salvadora persica	Salvadoraceae	Tree	VN	Fruit
Tecomella undulata	Bignoniaceae	Tree	VN	Timber
Tamarix kutchensis	Tamaricaceae	Undershrub	EN	Fuelwood
Withania coagulans	Solanaceae	Undershrub	VN	Relative of *W. somnifera*
Ziziphus williamsii	Rhamnaceae	Small shrub	EN	Wild relative

1. * = Also listed by the Ministry of Environment and Forests, Government of India.
2. EN = Endangered; I = Indeterminate; R = Rare; VU = Vulnerable.

tree (*Prosopis cineraria*), a life-supporting multipurpose 'keystone species' for the agroclimate of the region, which has become part of the social and cultural life. *Prosopis cineraria* provides wood for construction and house-building, Persian wheels, agricultural implements and shafts, spokes, felloes, and yoke of carts. Also, the wood, which is reported to have a high calorific value, provides high-quality fuelwood. It is much valued as fodder, as the tree provides most important top feed, which is nutritious and highly palatable green as well as dry fodder readily eaten by camels, cattle, sheep, and goats, meeting a major feed requirement of desert livestock.

The Raikas of Rajasthan, also known as the Rebaris or Dewasis, are an indigenous group of animal breeders and livestock raisers. Anthropologists have documented that the Raika people came at least 500 years ago from Persia or Baluchistan. Traditionally, they lived a semi-nomadic life tied to the arid and semi-arid desert/savanna region on the fringes of the Thar (or Great Indian) Desert. Contemporarily, they are regarded highly for their extensive ecological and veterinary knowledge, as well as for their ability to manage large herds of animals in the harsh Rajasthan environment. This relationship with animals is exhibited in their semi-nomadic lifestyle. Traditionally, the Raika people managed and bred animals, as well as supplied camels for the maharajahs and rajahs (kings) of the vast feudal states of the region. In this role, the Raikas were strongly identified with the camel, and the region has relied on them for several hundred years for their availability. Presently, the Raikas combine field agricultural production (pearl millet, wheat, and arid legumes) and pastoralism (animal breeding and wool products). The forests of India have historically been held in reserve by the state, but for the Raikas, these forests are an essential resource for dry-season grazing (www.indigenouspeoplesissues.com/index.php?, 2008).

Some of the common traditions, such as rituals like fasting, where traditional families would eat only *sama* (*Echinochloa colonum*) during the day of the fast (usually on '*Amavasi*'), have generated an institutionalized demand for *sama* grains, thereby promoting its cultivation and use as alternate food, facilitating conservation.

Technology and products

Recognizing the difficulties of human survival and agriculture under the extreme conditions, because of scarcity of water, the local communities probably concentrated first on the development of practices for the conservation and efficient use of water that is precipitated annually. They developed some ingenious methods for the storage and conservation of water to facilitate life and agriculture. *Tankas* are small underground tanks found traditionally in most Bikaner and some Jodhpur houses. They are built inside the main house or in the courtyard. Essentially, these are circular pits dug in the ground and lined with fine lime and polished, in which the rainwater is collected. *Tankas* were often beautifully decorated with tiles, which helped to keep the water cool. The water was basically used only for drinking. In this way, the people were able to meet their water requirements. The *tanka* system has been in existence for centuries, and is still used in residential areas, temples, *dharamshalas*, and hotels.

Another system of rainwater harvesting and storage was the traditional step-well, called '*Vav*' or '*Vavadi*' in Gujarat, or '*Baoli*' or '*Bavadi*' in Rajasthan. They were used both for drinking and irrigation purposes. Generally, they were built by the nobility usually for strategic and/or philanthropical reasons. The construction of step-wells dates from four periods: Pre-Solanki period (8th to 11th century CE); Solanki period (11th to 12th century CE); Vaghela period (mid-13th to end-14th century CE); and the Sultanate period (mid-13th to end-15th century CE). Sculptures and inscriptions in

step-wells demonstrate the importance of these structures to the traditional social and cultural lives of the people. Step-well locations often suggested the way in which they would be used. When a step-well was located within or at the edge of a village, it was mainly used for utilitarian purposes and as a cool place for social gatherings. When step-wells were located outside the village, on trade routes, they were often frequented as resting places. When step-wells were used exclusively for irrigation, a sluice was constructed at the rim, to receive the lifted water and lead it to a trough or pond, from where it ran through a drainage system and was channeled into the fields. A major reason for the breakdown of this traditional system is the pressure of centralization and intensification of agriculture.

The *khadin* (*dhora*) is an ingenious construction designed to harvest surface runoff water for agriculture, practiced since the 15th century (Prasad *et al.*, 2004). Its main feature is a long (100–300 m) earthen embankment built across the lower hill slopes lying below gravelly uplands. Sluices and spillways allow excess water to drain off (Fig. 2). The *khadin* system is based on the principle of harvesting rainwater on farmland and the use of water-saturated land for crop production. This practice also makes the soils fertile due to regular settlement of fine sediments brought down by the runoff water and ensure a dependable harvest. Historically, *khadins* were designed by the Paliwal Brahmins of Jaisalmer, western Rajasthan, in the 15th century (www.rainwaterharvesting.org/Rural/thar-desert_tradi.htm, 2008). Their origin may be part of the influence of neighboring cultures, as it has great similarity with the irrigation methods of the people of Ur (present-day Iraq) around 4500 BCE, and later of the Nabataeans in the Middle East. A similar system is also reported to have been practiced 4,000 years ago in the Negev desert (southern Israel).

The local people also realized that agroforestry can help in the amelioration of semi-arid and arid land conditions and fulfill the basic need for food, fodder, feed, fuel, and shelter. Therefore, agroforestry systems were evolved using indigenous resources, particularly the incorporating of local multipurpose trees. The most important tree species, in agroforestry, that provides livelihood support in the Thar Desert, is the *khejri* (*Prosopis cineraria*) (Fig. 3). The description of the *khejri* is mentioned in ancient Indian scriptures, reflecting the abundance of *khejri* in Rajasthan about 10,000 years ago, when it enjoyed a high ecological status. Probably because of its adaptation to the desert ecosystem and multiple uses (food, fodder, fuel, etc.), the local people discovered it as part of agroforestry (Vishnu Mittre, 1975). *Tecomella undulata* is another multipurpose tree locally known as *rohida*; it produces quality timber with the trade name of Desert teak or Marwar teak. The wood is excellent for firewood and charcoal. Cattle and goats eat leaves of the tree. Camels, goats, and sheep consume the flowers and pods. Being soft, *Tecomella* is very suitable for wood-carved furniture. Also, the tree plays an important role in the ecology, because of its wind-breaking capacity and soil-binding properties; it helps in stabilizing the shifting sand dunes. Its shady canopy offers a

nesting habitat for birds and provides shelter for other desert wildlife. *Tecomella* has medicinal properties: the bark is used as a remedy for syphilis and for curing urinary disorders, enlargement of the spleen, gonorrhea, leucoderma, and liver diseases. Seeds are used to treat abscess.

Further, the region has evolved several practices for dryland agriculture, particularly with the identification of early-maturing varieties to beat the short growing period and ensuing drought. Pearl millet is the staple food of the region and contains a great deal of variability for the desired features; the local landraces have shorter and narrow leaves, small or long spike and early maturity. Extra-early (60 to 65 days) lines have been identified in pearl millet, which are being used globally (Gupta and Bhatnagar, 2006). In bread wheat, the region is known for variability in spike maturity, spike density, tiller number, whereas in the case of durum wheat, there is variability for initial growth habit, spike emergence, plant height, 100-grain weight, grain yield, grain color, etc. (Singh *et al.*, 2006b). The extreme dry conditions and soil salinity have resulted in the identification/ evolution of genetic diversity in most crops with resistance to drought and salinity. For example, *Kharchia Local* varieties of wheat are being used as source of salt tolerance and *Hindi 62* for heat tolerance. They are extensively cultivated and used in breeding programs for drought and salinity tolerance. In barley, genetic variability for tolerance to saline and alkaline conditions has been collected (Verma *et al.*, 2006).

The region is known for variability in arid legumes such as cluster bean, moth bean, cowpea, horse gram, etc. In cluster bean, the highest gum contents (33.9%) and also highest and lowest protein contents (29.4% and 22.4%) have been recorded in collections from Rajasthan. In moth bean, the region provides useful variability for growth habit, branching pattern, leaf lobation, pod and seed color, early maturity, yield, and resistance to diseases. Varieties like PLM039, PLM055, and IC8551 have been developed by the National Bureau of Plant Genetic Resources (NBPGR), Regional Station, Jodhpur; whereas varieties like *Jadia Jwala*, from Bikaner (Dabas *et al.*, 2006) using local landraces. Variability for seed size, shape, color, and maturity period exists in pea, and the variety RPG3 has been derived from a local landrace (Singh *et al.*, 2006a). In mung bean, the region is known for variability in greater number of seeds per pod, and in *urd* (black gram) for bold seed.

Among oilseeds, variability exists in *Brassica tournfortii* and niger, and the variety *Durgamani*, in the case of *B. juncea*, and *Karan Tara*, in the case of *taramira* (*Eruca sativa*) have been developed from local landraces of Ganganagar (Kumar *et al.*, 2004). Also, in sesame, the region represents the maximum variability, and the variety *Pratap* has been developed from a local landrace of Kota.

Among fiber crops, *Bikanery Nerma* cotton, which is derived from a cross between American cotton (F414) and the local *Sanguineum* desi cotton (G7), is

internationally known and is being used as a source of drought tolerance and fiber quality.

Among horticulture crops, this region represents a significant amount of genetic diversity for cucurbitaceous vegetables and arid fruits. The region is rich in diversity for drought hardiness and sweetness, better shelf life for most crops, but particularly for *Citrullus lanatus* and *Cucumis melo* var. *momordica*. In *Cucumis sativus*, specific variability has been recorded for small (tender) fruit size, drought tolerance, and yield. Using this genetic variability a number of varietal products have been developed through selection from local landraces; for example, in watermelon, Durgapura Kesar and Durgapura Madhu; in musk melon, Durgapura Madhu, Akra Rajhans, Pusa Madhu; in *Momordica charantia*, Pusa Do Mausmi (Sirohi *et al.*, 2005).

Among fruits, the region is known for variability in mandarin (*Citrus reticulata*) with Keenow mandarin, sweet orange (*C. sinensis*) with *mosumbi*, in Malta with Blood Red. In addition, the region is very rich in diversity for fruits, which can be referred to as 'arid fruits', well adapted to the dry conditions. Some common ones with important variability are cactus pear, *Opuntia ficus-indica*, *Capparis decidua*, *Cordia myxa* (*lasoda*), which are eaten and used for preparations like pickles, etc. *Ziziphus mauritiana* is another important fruit, with local cultivars like Gola, Seb, and Mundia. *Khejri* (*Prosopis cineraria*) is another local fruit with wide diversity for vegetative growth, yield, and quality attributes such as cluster bearing, larger pod size, sweet taste and precocity, etc. *Phalsa* (*Grewia subinaequalis*) is another arid fruit known for its use in the preparation of fresh juice, whereas in *Punica granatum* (pomegranate) the varieties like Jodhpur Red with wider spread, and Jalore Seedless with greater fruit size and yield, reflect the level of variability available (Vashishtha *et al.*, 2005). The date palm, believed to have been introduced in the 4th century BCE by a soldier of Alexander, and at the beginning of the 8th century CE by Muslim invaders is cultivated in Kutch and Bikaner.

In seed spices, the region is very rich in genetic diversity of crops such as coriander, cumin, and fennel, and several varieties have been developed from local landraces/ cultivars. For example, in coriander, through recurrent selection in locals, varieties like Rcr41, Rcr435, Rcr436, and through mutation in Rcr20, variety Rcr 684 have been developed. Similarly, in cumin, RZ19 through recurrent selection in UC-19; in fennel, RF101 through recurrent selection in a local germplasm, and in fenugreek, RMt1 through pure line selection in Nagpur local, and RMt303 through mutation in RMt1 (Ravindran *et al.*, 2005).

The region is known for variability in arid legumes such as cluster bean, moth bean, cowpea, horse gram, etc. In cluster bean, the highest gum contents (33.9%) and also highest and lowest protein contents (29.4% and 22.4%) have been recorded in collections from Rajasthan.

The region can also be credited for the development of dehydrated products from arid fruits and vegetables, like *chhuhara* from date palm, *sangria* from *khejri*, *anardana* from pomegranate, Chinese date from *ber*, and dried *methi* from fenugreek for offseason and round-the-year use. In addition, pickles and powder are prepared from almost all fruits for use as culinary supplements.

There are several common practices followed in the region for sustainability of agriculture, productivity and environmental balance, such as planting of multipurpose *khejri* (*Prosopis cineraria*) at the rate of 40 to 100 trees per hectare in order to develop woodland. In mixed cropping, *Citrullus lanatus* is planted mixed with pearl millet to ensure availability of diverse food crops.

Carved furniture made from Marwar teak (*Tecomella undulata*), which is under threat because of over-exploitation, is a popular handicraft product from the region. The Bishnoi tribe from the Jodhpur region is known for their determination to protect life-supporting species like *khejri*, and they are legendarily known for sacrificing their lives for protecting such multipurpose species that provide food, fuel, and shelter to the community.

The people of the region are known for their nomadic life and livestock rearing and breeding as a sustainable occupation. Tribes like the Raikas, responding to the vagaries of nature, have developed resilient indigenous breeds, and maintained them within restricted social groups. Their memorization of the pedigree lineage for 7 to 8 generations is worth appreciation, as also their role as guardians of agrobiodiversity, which has led to recognition of their system under the Globally Important Agricultural Heritage Systems (http://www.fao.org/sd/giahs/other_india2.asp). They are known for as many as 11 *Bikaneri* sheep breeds. Additionally, despite the global trend being toward settlement, the incidence of pastoral nomadism is on the rise in the Marwar region of Rajasthan, because producers have increased access to markets. Also, the reproductive rate of their herd improves through long, annual migration. Therefore, nomadism is a general adaptation to changes in the socioeconomic conditions of the region; however, differential resource endowments accounting for the range of strategies are confined to wealthy herders and are not being enjoyed by the more marginal producers (Paul Robbins, 2004).

Future perspective

The recent statistics indicate drastic losses in the forest areas in the Arid Western Region, because of indiscriminate deforestation causing severe losses of biodiversity, including agrobiodiversity.

Among horticulture crops, this region represents a significant amount of genetic diversity for cucurbitaceous vegetables and arid fruits. The region is rich in diversity for drought hardiness and sweetness, better shelf life for most crops.

Further, the invasion of aggressive foreign plant species such as Mexican mesquite (*Prosopis juliflora*) and lantana (*Lantana camara*) have rendered large areas of traditional pasture lands useless. This has created an ecological crisis and threatens whatever pasturage remains in the region. Therefore, it is necessary to develop continuous afforestation programs using local tree species diversity, and pasteurization programs to promote the local grass and forage leguminous species.

The erratic rainfall leading to water deficit and acute soil salinity is causing physiological drought, and is thus making cultivation of crops difficult. Therefore, appropriate hybridization programs for breeding drought and salinity resistance cultivars using local elite genetic resources and remedial programs for soil salinity are necessary. Also, acute drought conditions at the grain-filling stage have to be circumvented by breeding for extra-early varieties.

The deficiency of soils in nitrogen, phosphorus, zinc, and iron, resulting in nutrient imbalance, requires attention in order to develop methods that can contribute to enrichment of soil through integrated nutritional management programs.

The decrease of pastures due to reasons like enclosure of forests, expansion of irrigated agriculture, breakdown of village institutions governing the use of common pasture, deterioration of pasture land due to disappearance or reduction of traditional grasses, and invasive species adversely affecting the species composition, have been causing damage to the traditional animal husbandry of the region. Animal husbandry has also been adversely affected because of little or no access to veterinary care, and the lack of infrastructure for processing and production of value-added livestock products (for instance, chilling plants necessary for collection of camel milk from pastoralist herds) and needs immediate attention. These are some of the areas requiring attention to further promote the profitable land-use of this Arid Western Region.

Among fruits, the region is known for variability in mandarin* (Citrus reticulata) *with Keenow mandarin, sweet orange* (C. sinensis) *with* mosumbi*, in Malta with Blood Red. In addition, the region is very rich in diversity for fruits, which can be referred to as 'arid fruits', well adapted to the dry conditions.

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