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Abstract	Arid and semi-arid regions cover more than 50% of the total geographical area in India which is highly populated, water-limited with warm drylands. There is an expectation that the area of drylands will expand under several scenarios of climate change. Maintaining food and nutritional security in this growing rural population of 265 million is a mammoth challenge in the near future. This task can be taken by diversifying the existing scarce resources in a sustainable manner as well as systematic land use management. Indian agriculture sector is dominated by marginal and small farm holdings. Production intensification or land diversification are the keys to agricultural sustainability. After achieving food sustenance for the family, crop intensification/ diversification becomes the mainstay for commercial agriculture. The traditional farming systems are self-contained and show resilience to aberrant weather conditions but yield poorly. An optimization of land usage into cropping, horticulture, livestock, forestry with an objective of food and nutritional security along with profitability holds the key for the future course of sustainable agriculture.
Keywords (separated by " - ")	Integrated farming system - Gender - Livestock - Wasteland development - Nutrition - Food and nutrition security (FNS) - Intensification

Chapter 15
Diversification and Land Use Management Practices for Food and Nutritional Security Under Climate Change Scenario in Arid and Semi-Arid Regions of India

P. K. Pankaj, Mahesh K. Gaur, G. Nirmala, V. Maruthi, Pushpanjali, Josily Samuel, and K. S. Reddy

Context and Setting

In India, rainfed agriculture constitutes 55% of total net cultivable area and contributes to production of major coarse cereals, pulses and oil seeds By comparison, the rainfed and arable area is about 93% of Sub-Saharan Africa, 87% of Latin America, 67% of Near East and North Africa, 65% of East Asia, and about 58% of South Asia are rainfed (FAO 2002). Apart from this, most countries depend primarily on rainfed agriculture for their grain food. The environment of rainfed agriculture is characterized by regular climatic constraints like long dryspells, high intensity rainfall, high evaporation losses, soil degradation, etc. which is becoming more intense with the onset of climate change. Moreover, the annual average rainfall varies from less than 100 mm to 2500 mm in different rainfed agro-ecological regions of the India. Rainfall distribution is erratic with CV varying from 30 to 80% during crop growth period varying in both space and time. The present level of land productivity in rainfed agriculture in India is about 1 t/ha, however, globally it varies from 1–2 t/ha (FAO 2002). In India, the Semi Arid tropics (SAT) spread over 175 districts accounts to 37.2% of geographical area of the country (Map 15.1) supporting 36.9% of the population, covering 42.9% of country's gross cropped area and 46.2%of Net cropped area (Rao et al. 2005). Changes in irrigation percentage, shift in consumption patterns, technology advances have brought change to cropping patterns in arid and semi-arid regions of India (Reddy et al. 2017).

However, the majority farmers own less than one hectare of land that is fraught with problems of frequent droughts, land degradation, soil erosion, infertile soils

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V. R. Squires, M. K. Gaur (eds.), *Food Security and Land Use Change under Conditions of Climatic Variability*,
https://doi.org/10.1007/978-3-030-36762-6_15

Map 15.1 Arid and semi-arid regions of India with state boundaries (Compiled by author)

and poor socio-economic conditions. The Indian hot arid zone occupies an area of 32 million ha (Mha) constituting about 10% of the country's geographical area. It forms a continuous stretch in the north-western states of Rajasthan (61%), Gujarat (20%), Punjab (5%), Haryana (4%) and scattered landmasses in the peninsular states namely, Maharashtra, Karnataka and Andhra Pradesh. Inadequacy in quantum and erratic distribution of rainfall (<150 mm to 400 mm, CV 36 to >65%) coupled with high evaporative demand (1600–1900 mm/year) and light textured soils has made agriculture a difficult proposition. The incidence of poverty found to be the highest in SAT when compared with the other agro-ecological regions. Agricultural output to gross cropped area is lowest in arid and semi-arid areas as 0.77 and 0.86%, respectively when compared with humid area of 1.26 and this is because of low irrigation coverage, marginal soils and low rainfall.

Agriculture plays a vital role in Indian economy, which accounts for 18% of India's gross domestic product (GDP), and 55% of population is dependent on agriculture (Kumar et al. 2015). Hence, any change in the crop conditions, including the fact that nearly 52% of the total cultivated area is being cropped under rainfed conditions, is likely to affect the overall economy of the country (Naresh Kumar et al. 2014; Parmeshwar et al. 2014). The Indian agriculture sector is dominated by marginal and small farm holdings able to consume nearly 80% of the total freshwater (Hochman et al. 2017). In semi-arid tropics, dryland agriculture relies on rainfall as the major source of water (Wani et al. 2012). Indian agriculture currently faces a host of diverse challenges due to the ever-growing population, increasing food and fodder needs, natural resources degradation, higher cost of inputs and climate change (Pankaj et al. 2017). Supplemental irrigation and water harvesting are the most important and proven technologies for improving crop productivity as is the efficient of use of water in the dryland areas of semi-arid tropics. These technologies integrated with crop diversification can increase farmers' income in dryland agriculture systems with improved nutrient availability and food security among the farmers. The monthly per capita expenditure is also lowest in semi-arid areas than when compared to arid and humid regions of the country. As a result, the incidence of poverty is highest in semi-arid areas than in arid areas. About 60 million of India's 147 million rural poor live in the rural semi-arid regions (Rao et al. 2005).

Production intensification or land diversification is the key to agricultural sustainability. After achieving food sustenance for family, crop intensification/ diversification becomes a mainstay for commercial agriculture. To reduce pressure on water resources, better quality rainfed lands could be brought under either limited/ unlimited irrigation during post rainy season (Lu 2003). The traditional farming systems are self-contained and show resilience to aberrant weather conditions, but are low yielders.

The present chapter has been designed to explain the twin benefits of diversification (using cropping systems, livestock and horticulture) as well as land use management (soil management, carbon sequestration) coupled with socio-economic development in the arid and semi-arid region of India to maintain food and nutritional security under a climate change scenario.

Climate Change Scenario in Arid and Semi-Arid Regions

Arid regions cover about 12% geographical area of India, comprising of 31.7 Mha hot arid and 7.0 Mha cold arid region. Nearly 90% of hot arid region of India lies in northwestern states of Rajasthan (19.6 Mha), Gujarat (6.22 Mha), and Haryana and Punjab (2.75 Mha). Some small pockets (3.13 Mha) of hot arid zone are in southern states of Andhra Pradesh, Maharashtra and Karnataka (Table 15.1 and Fig. 15.1). The arid region of northwest India constitutes the major part of the Great Indian Desert or the Thar Desert. About 85% of the Thar Desert lies in northwest India and the remaining part is in southeast Pakistan. The Thar Desert accounts for 89.6% of the total hot arid regions of India. The climate of hot arid regions is characterized by low and erratic rainfall, high potential evapo-transpiration, wide diurnal and annual temperature range, high solar radiation, low relative humidity and high wind velocity. The annual rainfall ranges from about 100 mm in extreme west to 500 mm in the east and southeast side, while the potential evapo-transpiration is about 1650 mm in the east which increases to over 2000 mm in the west. The coefficient of variation of annual rainfall varies from 35% in the east to 65% in the west. Most of the rainfall (80–85%) is received during the southwest monsoon season (June–September) of the Indian sub-continent. However, monsoon rains start in the first week of July and usually withdraw by September beginning in the hot arid zone of northwest India. The region experiences extremes of temperatures. Air temperature increases sharply from April and peaks during May to mid-June. Maximum temperatures during summer season vary from 36 to 43 °C in the eastern and 39 to 45 °C in the western parts but occasionally may reach up to 50 °C. During winter season, the maximum air

Table 15.1 Characteristics of arid and semi-arid ecoregions of India

Climate	Annual rainfall (mm)	Moisture index (%)	Growing period (days)	Physiography	Area (Mha)
Arid					
Cold arid	<500	<−66.7	60–90	Western Himalaya, Jammu and Kashmir	14.3
Hot arid	<500	<−66.7	<90	Western plains & Kutch, Deccan plateau	31.7
Semi-arid					
Dry	500–700	−66.7 to −55.8	90–120	Northern plains, central highlands, Deccan plateau, Tamil Nadu uplands, South Tamil Nadu plains	41.6
Moist	750–1000	−55.7 to −33.3	90–150	Indo-Gangetic plains, Bundelkhand uplands, Malwa plateau, Eastern Gujarat plain, Vindhya hills, part of Maharashtra, Karnataka, Vidharbha, Telangana, Karnataka, Tamil Nadu, Punjab and Rohilkhand	72.2

Source: Srinivasarao et al. (2013)

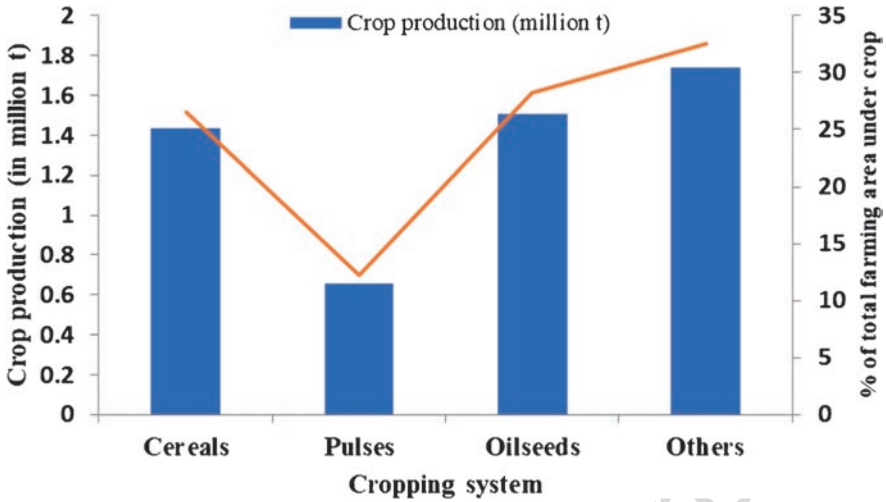


Fig. 15.1 Production and area under different cropping systems in western Rajasthan (2015–16) (Source: Agricultural Statistics, Rajasthan 2015–16)

temperature varies from 24 °C in the east to about 26 °C in the west. Sub-zero temperature is not uncommon and minimum temperature during winter may be as low as −5 °C in sandy terrains. Soil temperature fluctuations reflect the diurnal and annual cycles of the air temperature.

Arid and semi-arid regions cover 30% of the total area in the world and is inhabited by 1.10 billion people (20% of the world population). Arid and semi-arid regions are home to 24% of the population in Africa, 23% in Asia, 17% in the Americas and Caribbean, 6% in Australia and Oceania, 11% in Europe. Highly populated, water-limited and warm drylands are challenging areas for development and are expected to expand overall under several scenarios of climate change (Rajaud and Noblet 2017). A purely climatic definition uses the precipitation (P) over potential evapo-transpiration (PET) ratio (aridity index). Different levels of aridity are distinguished based on consensual thresholds (Yukie and Otto 2011): 0.65 (sub-humid), 0.5 (semi-arid), 0.2 (full arid) and 0.05 (hyper-arid). Projected area-averaged annual mean warming over land regions of Asia is likely to be 1.6 ± 0.2 °C in the 2020s, 3.1 ± 0.3 °C in the 2050s and 4.6 ± 0.4 °C in the 2080s. Similarly, Projected area-averaged annual mean increase in precipitation 3 ± 1% in the 2020s, 7 ± 2% in the 2050s and 11 ± 3% in the 2080s.

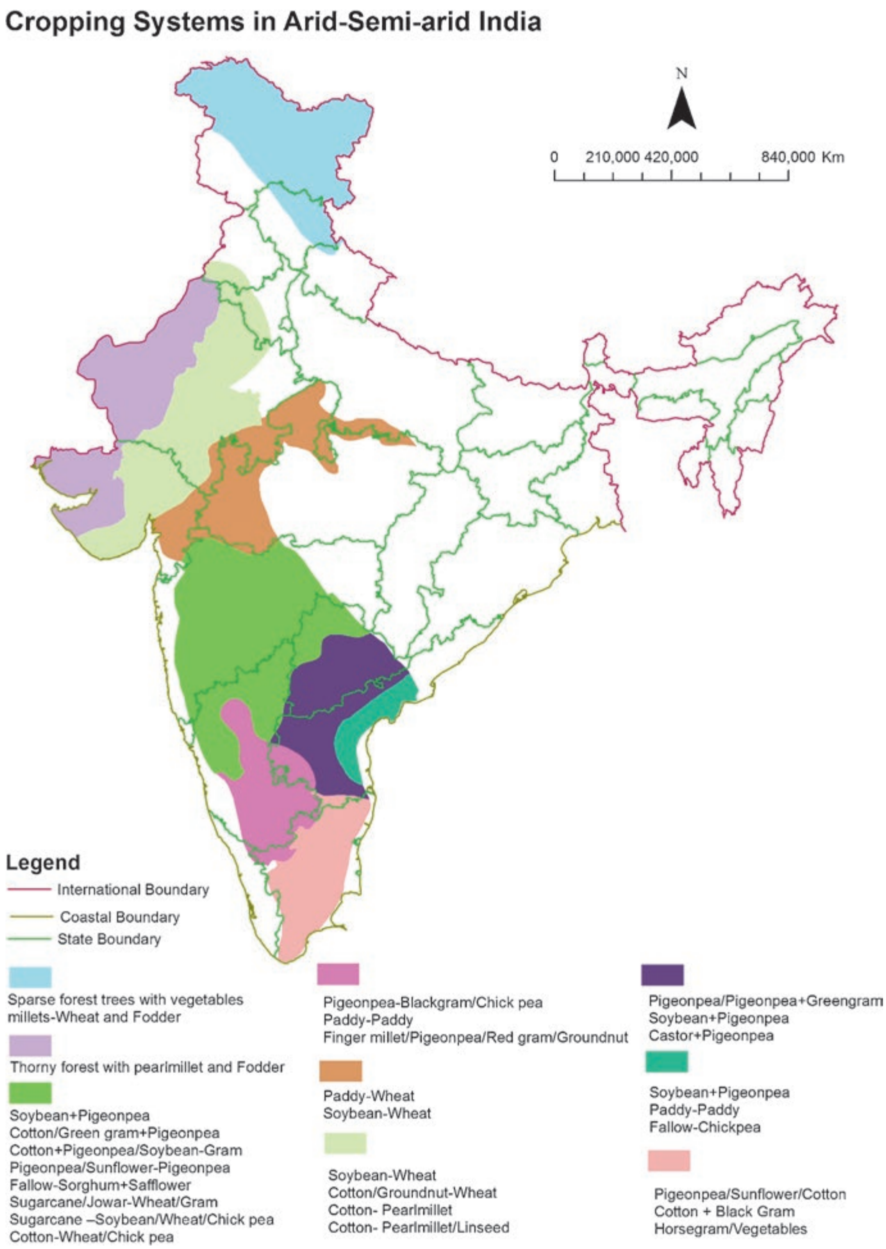
Crops and Cropping System in Arid and Semi-Arid Regions

Although semi-arid tropics (SAT) are typically characterized by low and uncertain rainfall and poor quality of soils, which affect both the quantity and value of the agricultural output, have been defined differently by different analysts. The cropping patterns in this broadly defined SAT region have undergone substantial changes due to increased coverage under irrigation, shifts in consumption patterns, changes in technology and market prices. The Integrated farming system (IFS) approach has been widely advocated for improving productivity, profitability, livelihood and soil health under different agro-ecological settings of India (Gill et al. 2009; Surve et al. 2014; Sahoo et al. 2015; Balamati and Shamaraj 2017; Pankaj 2018).

Improving the productivity of annual crops shall remain the focal point for improving the productivity of any farming system in arid and semi-arid regions. The key elements for improvement of crop productivity envisaged for this region are: efficient rain water management, suitable tillage and sowing operations, selection of improved varieties, appropriate inter-cropping and crop rotation systems, efficient soil fertility management, proper plant protection measures and contingency crop planning. However, positive impact of these interventions on yield are more perceptible only in normal to mild-drought years, causing reluctance of farmers to adopt these improved dryland farming technologies (Bhati 1997; Jodha et al. 2012).

Inter-cropping of cereal and pulse crops is traditionally practiced in Semi Arid Tropic (SAT) regions of India as a risk coping mechanism for minimizing drought impact especially for small and marginal farmers (60% farmers in rainfed areas) and in Arid region having cotton based or pulse-based cropping system (Map 15.2). Inter-cropping has the advantages of maximized rainfall utility both spatially and temporally, minimized risk in terms of crop failures and optimum utilization of weather resources like light to make it profitable and stable (Singh and Reddy 1986; Maruthi et al. 2019). Therefore, inter-cropping is practiced for more total system productivity and economic stability of the farmers (Gliessman 1981). Due to labour scarcity, non-availability of appropriate farm implements (Sanjeeva Reddy et al. 2019) and suitable herbicides, inter-cropped area has been declining. Since the advantages of an intercropping are lost, replaced sole crops have been suffering soil moisture stress, sometimes they may even fail. Further with the shifts from inter-cropping to sole commercial cropping, future food security issues are surfacing up. Consequently, FAO (2012) suggested agro-ecosystem-based crop diversification as well as intensification.

In Western Rajasthan (major Arid region of India), in majority of area, food grains (cereals and pulses) are produced followed by growing oilseeds and other crops (Fig. 15.1). This tells much about the natural resilience of diversification holding the key to low rainfall and high temperature. When the long term trend regarding, intensity of cultivation, cropping intensity and irrigation intensity in western Rajasthan was followed by comparing the data of 2007–08 and 2015–16 (Fig. 15.2), it was observed that installation of a water management system is the vital as it underpins sustainable agriculture even to the arid part of the country. Principal crops



Map 15.2. Cropping systems in Arid and semi-arid regions of India with state boundaries (Compiled by author)

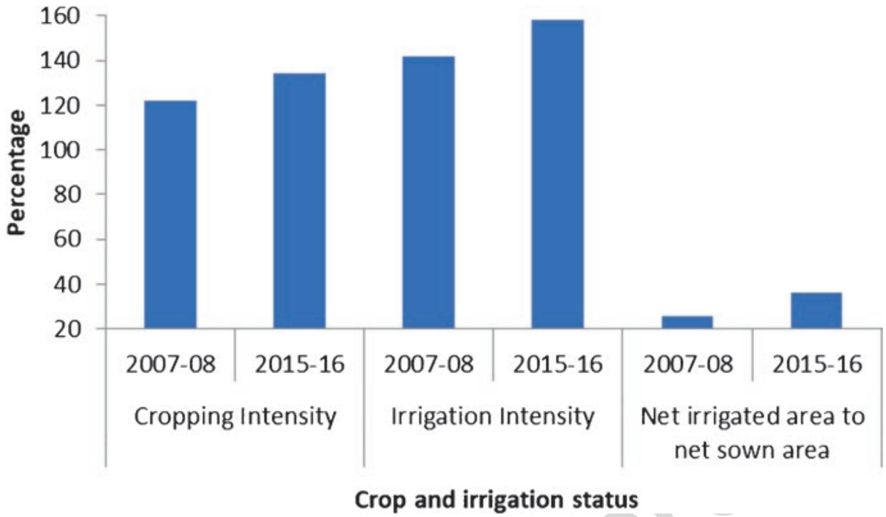


Fig. 15.2 Intensity of cultivation, cropping intensity and irrigation intensity in western Rajasthan (2007–08 and 2015–16) (Source: Agricultural Statistics, Rajasthan 2015–16)

grown in the most arid part of the country, western Rajasthan, the area for pearl millet, pulses, mustard, groundnut and gram were found to be the highest (Fig. 15.3). The most positive jump in the area of production as compared to the year 1970–71, was seen in case of groundnut, mustard and gram, however, all the above-mentioned crop areas in the region were significantly increased. When the production of crops in the same zone was followed, it was found that production of groundnut was tre-

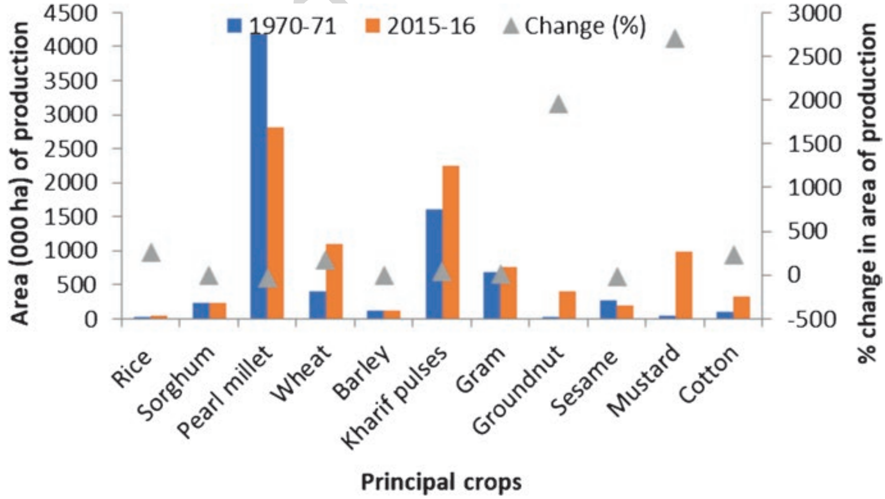


Fig. 15.3 Trend in area of principal crops in western Rajasthan (Source: Agricultural Statistics, Rajasthan 2015–16)

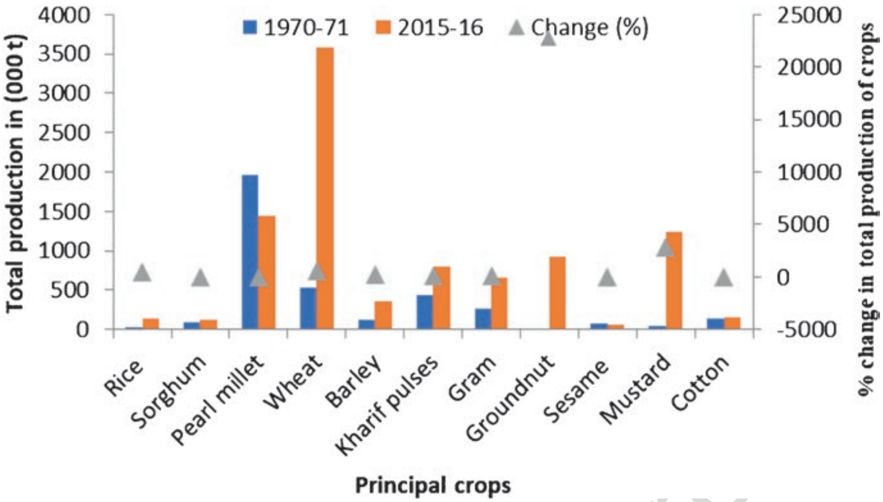


Fig. 15.4 Trend in production of principal crops in western Rajasthan (Source: Agricultural Statistics, Rajasthan 2015–16)

mendously improved (Fig. 15.4), however, production of all other crops (rice, sorghum, pearl millet, wheat, barley, kharif pulses, gram, sesame, mustard, cotton) were also improved -- except pearl millet.

In order to improve productivity of oilseeds and pulses in peninsular India (contribute more than 80% production from rainfed regions), intensification is one option, which has disadvantage of excessive exploitation of natural resources. Sustainable crop intensification can be an effort to intensify cropping system with balanced utilization of land, water, energy and other inputs (agri-ecosystem) which are short in supply (Pretty et al. 2011, Murungweni et al. 2016). Crop intensification as well as integrated farming system approach involves logical blend of both crop and livestock for enhancing crop productivity wherein food security in future can be dealt more with suitable combinations of crop intensification as well as diversification in these areas (Maruthi et al. 2017a).

Changes in Soil Properties Due to Changes in Land Use

Soils under the forest system were used as a control to evaluate the changes in soil properties due to land use and management interventions in the two managed systems. The soils of horticultural systems had the highest pH (6.4) and the agricultural soils had the lowest pH (5.9), indicating that agricultural management interventions increased the acidity of these soils. The pH of the soils tended to increase with depth in all three systems. The average bulk density of the surface soils in the forest system (1.5 Mgm^{-3}) is low due to high SOC when compared to the other two systems.

Deforestation and subsequent cultivation result in an increase in soil bulk density (Hajabassi et al. 1977). Bhattacharyya et al. (2007) observed a negative correlation between bulk density and organic carbon in soils of different bioclimatic zones of India. The bulk density in the agriculture and horticulture systems decreased with depth.

Horticulture in Arid and Semi-Arid Regions

In arid regions where livestock is a major component of farming system, horti-pastoral system forms an efficient drought coping mechanism. *Ziziphus nummularia* (Jharberi) is an important top feed species of arid region and almost every part of it has a use. The leaves make excellent fodder having high crude protein (13–17%) and fibre (15%).

Soil erosion by wind is one of the foremost problems in Indian arid zone. Shelterbelts minimize the harmful effects of strong winds and increase farm productivity through moderation of micro-environment at field level. The term shelterbelts and windbreaks are often used inter-changeably, but a distinction can be made. A shelterbelt is a long belt of shrubs and trees for protecting fields, whereas windbreak is a protective planting around farm, orchard or a building. The shelterbelt technology involves raising of porous vegetative barriers comprising strips of trees, shrubs and bushes planted across the direction of prevailing wind. An increase of 305.6% in net returns has been observed by shifting from non-shelter belt to shelterbelt in farms of Jaisalmer district (Gajja et al. 2008). Volumes of data on shelterbelts have been generated addressing designs, composition, suitable tree species, planting technique, etc. (Mertia et al. 2006). Contour vegetative barriers (CVB) may also be designed using locally available fast-growing perennial grasses with extensive root system such as *Cymbopogon jwarancusa, Cenchrus ciliaris* and *Cenchrus setigerus* transplanted 0.3 m apart on contours at 0.6–1.0 m vertical interval forming a dense hedge (Sharma et al. 1999).

Land Use Management Practices in Arid and Semi-Arid Regions

In India, current net sown area is 43% of total geographical area (328 Mha), which has remained constant ever since 1970–71 However, gross cropped area has expanded from 166 Mha to 198 Mha during the same period. India has already lost some of its land masses (30 Mha for ecologically productive area, 19 Mha for infrastructure and housing), however, 25 Mha is still fallow land available for cultivation. Although, area devoted to food grain crops has remained unchanged (~124 Mha), but rice and wheat growing areas have expanded from 56 to 75 Mha, which was at the cost of a fall in the area under coarse grain cereals.

Low and erratic rainfall, extremes of seasonal temperature, high evaporation loss, meager ground water potential, absence of perennial streams, salinity, rocky/gravelly terrains are the major factors affecting the land use in hot arid region of India (Ram and Lal 1998).In order to minimize the adverse effects of environment, the farmers of desert areas have evolved certain well contained systems that follow AU2 a pattern in accordance with the rainfall (Fig. 15.5). Areas receiving <250 mm rainfall have predominance of grasses and shrubs; hence range/pasture development with livestock rearing becomes the major proposition. In 250–350 mm rainfall zone, besides grasses and shrubs, multi-purpose tree species dominate the landscape. Mixed farming encompassing agro-forestry system, mixed cropping, livestock and pasture management are main livelihood options. Where rainfall is more than 300 mm, crops and cropping system diversification, agro-forestry and livestock rearing are the major systems of sustenance of arid zone farmers (Bhati and Joshi 2007). These sustainable systems although resilient to weather aberrations, however, have low production levels, which are now inadequate to fulfill the needs of ever increasing population and their aspirations. Suitable land use models were developed by different authors for different agro-eco-regions of India (Table 15.2).

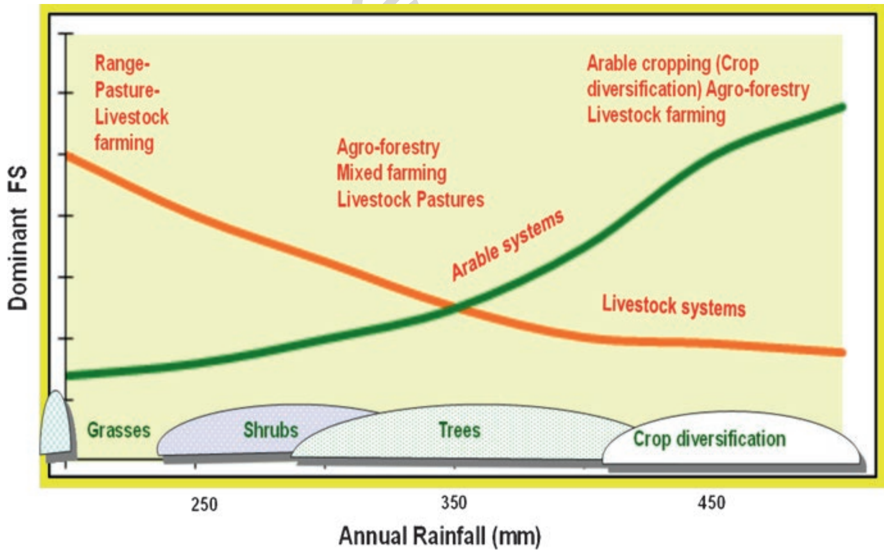


Fig. 15.5 Dominance of various farming systems according to rainfall pattern in arid zone (Source: Bhati and Faroda 1998)

Table 15.2 Suitable IFS models for arid and semi-arid regions of India

Region	Land use IFS model	Reference
Karnataka	Crop (0.74 ha) + horticulture (0.18 ha) + fodder drop (0.02 ha) + livestock (2 cow, 1 buffalo)	Basavanneppa and Gaddi (2017)
Dryland Western zone of Tamil Nadu	Sorghum + cowpea grain, sorghum + cowpea fodder and *C. glaucus* each in 0.33 ha inter-cropped with *Emblica officinalis* + goat (5 + 1)	Radhamani (2001)
Semi-arid Gujarat	Crops: Pearl millet-wheat (0.44 ha), mustard-pearl millet (0.22 ha), cotton-fodder sorghum (1 ha) + horticulture: Papaya (0.04 ha) + dairy buffalo (6)	Patel et al. (2007)
Semi-arid irrigated Punjab	For 2 ha land: Crop (1.14 ha) + dairy (0.22 ha) + fishery (0.56 ha) + piggery (0.24 ha)	Gill et al. (2009)
Arid Rajasthan	IFS for 7 ha land (Table 15.3)	Tanwar et al. (2016)

Land Use Model for Arid Regions

Land use pattern for all farming system in Arid Rajasthan have decreased from 1976 to 2015 except water bodies and forest (Fig. 15.6) which suggests improvement in water harvesting structures and using forest land for agriculture and other activities. A fixed land use model for arid region was developed (Table 15.3) at ICAR-CAZRI, Jodhpur, India for a farmland of 5–7 ha situated in arid zone (rainfall 300–400 mm). For sustainable farming situation in the region, it has allotted area as per its optimal profitability and resource use efficiency. The net returns calculated from this IFS model are Rs. 70,000/ha with a payback period of 5 years at an (IRR) of 33%. This IFS model generates employment to the tune of 130 man-days/ha. This diversification is also equally effective to provide ecosystem services, viz. enhanced biodiversity, carbon-sequestration, fuel-wood production and greenery in the desert. In arid regions where livestock is a major component of farming system, horti-pastoral system forms an efficient drought coping mechanism.

Land Use Model for Semi-Arid Regions

A long-term investigation (2004–2011) was carried out on an Alfisol watershed model (Picture 15.1) at ICAR-CRIDA Research farm, Hyderabad, India covering an area of 1.65 ha having three pediments consisting of upper soil depth of 8.0 ± 4.3 cm (D_1) with low water requirements of grasses (19% of area), middle basin of depth 15 ± 4.4 cm (D_2) with arable crops and cropping systems as sorghum + pigeon pea (2:1) and castor + cluster bean (1,1) (48% of area) and lower basin of depth 30 ± 12 cm (D_3) with agro-forestry systems (25% of area) and vegetables (8% of area), respectively (Maruthi et al. 2017). A farm pond of 650 m^3 capacity was dug at the lowest point of the watershed for rainwater harvesting and recycling as

Table 15.3 Synthesized rainfed IFS model for arid zone (Tanwar et al. 2016)

System	Component	% area allocation
Arable cropping	Diversified cropping of pearl millet, greengram, clusterbean in 4:1:1 ratio. Replace 30% pearl millet with dew gram under delayed monsoon	20
Agroforestry	*Prosopis* + crops	30
Agri-horticulture	Ber + crops	20
Silvi-pasture	*Hardwickia* + grass (*Cenchrus ciliaris*)	10
Horti-pasture	*Ziziphus* + grass (*Cenchrus ciliaris*)	10
Boundary plantation	*Acacia*, *Hardwickia*, *Dalbergia* + trenching after 3 year of plantation	10
Cattle	Tharparkar breed	0.75 ACU/ha
Goat and sheep	Marwari breed	3 animals/ha

supplemental irrigation to vegetables. The plants of glyricidia were grown along the graded bunds to be used as mulch-cum-manure. The teak, henna and subabul plants were planted alternatively to create an asset in the watershed area. The horticulture plants like papaya and drumstick were planted around the periphery of the farm pond. Rainfall characteristics, seed and fodder yields of arable crops, agro-forestry systems, grasses, bushes and other perennial crops along with their economics, rainfall use efficiency was collected for all years (2004–11). The rainfall was categorized as deficit (<20% of normal as in 2004, 2009 and 2011), normal (750 mm long term rainfall as in 2006 and 2007) and excess (>20% of normal as in 2005, 2008 and 2010) and evaluation of farming system in different categories of rainfall years were carried out based on net income (Rs.), B:C ratio, availability of food grains,

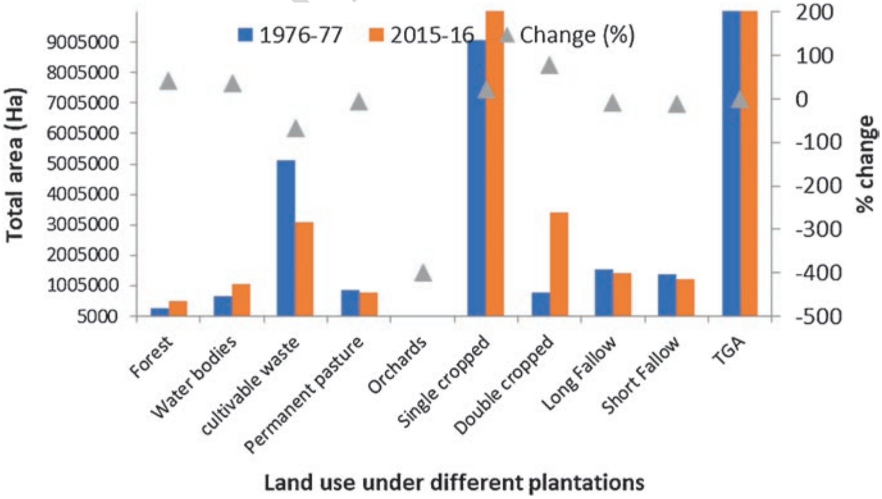


Fig. 15.6 Land Use in Arid Rajasthan (1976–77 and 2015–16) ((Source: Gaur 2016))

Picture 15.1. On Farm Resource (OFR)-based farming system at ICAR-CRIDA, Hyderabad

estimated fodder security for livestock, etc. Cost of production (Rs.) of farming system (FS) module was two times more in deficit rainfall years (Rs. 21,239) than during normal rainfall years (Rs.10,419) due to gestation period required by the agro-forestry (Rs. 10,019) component.

Net income from FS was highest in excess rainfall years (Rs. 22,142) as compared to normal (Rs.9420) and deficit rainfall years (Rs.243). Similar trend in B:C ratio was also observed where it was almost doubled during excess rainfall years (2.46) as compared to deficit rainfall years (1.27). Family food security was estimated through crop component in watershed-based farming system which suggested that cereals, oilseeds and pulses produced during excess rainfall years could be sufficient for 3, 1.24 and 8 persons in a year whereas during normal and deficit rainfall years, requirement could be fulfilled for 2, 0.79 and 4 persons in a year. The number of dairy animals and small ruminants which can be supported with this farming system was almost 1 and 3, respectively during all rainfall years, but during deficit rainfall, external inputs would be required for procuring deficit legume fodders. Scaling-up of such models is necessary to address the livelihood security of small farmers in rainfed areas.

Land Use as Green Fodder Belt for NRM Conservation

Soil erosion is a common problem in arid and semi-arid regions of slope varying from 3% and above. A green fodder belt technology has been experimented at ICAR-CRIDA, Hyderabad for 5 years of experiments (2015–2019) to prevent sheet erosion in rainfed farming situations with option of life saving irrigation, if required which can be applicable to the semi-arid and sub-humid agro-ecological regions. A permanent bed of *Brachiaria ruziziensis* of 2 m width need to be established at every 15 m across the direction of slope (Picture 15.2 (a) and (b)). This technology is not a hindrance to the mechanization at farmers' fields. This bed can be maintained

Picture 15.2. (**a**). *Brachiaria ruziziensis* fodder strip (**b**). *Stylosanthes hamata* fodder strip

for several years and has the potential to prevent the sheet erosion apart from providing forage to the ruminants. Cutting of green fodder should be done at 90 days after establishment and subsequently every 60 days. Thus, a minimum of five cuts can be harvested from the grass belt.

First year of the experiment will be able to establish the permanent bed (2 m width) of *Brachiaria ruziziensis*. For establishment of 2 m x 2 m bed, 150 saplings will be required. Thus, for 1 hectare of land, 7000 saplings will be required. This technology provides green fodder of 10–15 t ha^{-1} on yearly basis which can sustain the green fodder requirement of 15–20 small ruminants or 1–2 cattle. Thus, it is a very good technology for the small and marginal farmers without affecting the growth of other crops taken in between the green belt. The NRM benefits include prevention of soil and nutrient loss, increase infiltration opportunity time inside the standing crop field, biomass yield of 10–15 t ha^{-1} apart from the concurrent crop/grain yield (CRIDA Annual Report 2016-17).

Livestock Component as Model of Diversification in Arid and Semi-Arid Regions

Livestock Farming Systems

The farming systems in arid zone are quite diverse with a variety of crops and cropping systems, agro-forestry, and livestock production. The changes in the quantity of rainfall received and its distribution pattern are leading to intermittent droughts during the crop period resulting in crop failures leading to debts and migration. Droughts occur once in 3–5 years either due to a deficit in seasonal rainfall during the main cropping season or from inadequate soil moisture availability during the prolonged dry spells between successive rainfall events. Several farming systems involving trees, fruits, grasses and crops have been studied by ICAR-CAZRI, Jodhpur for their suitability in arid agro-ecosystem and compatibility of selected farming system components in agro-forestry, silvi-pasture, agri-silvi-pasture, agri-horticulture, horti-pastoral systems. Feed resources provide a direct link between crops and animals and the interaction between the two largely dictates the development of such systems. It has been observed that the areas falling in <250 mm rainfall zone have predominance of grasses and shrubs (Fig. 15.5); hence range/pasture development with livestock rearing is the major proposition for such areas. Areas in 250–350 mm rainfall zone are suitable for agroforestry and mixed farming; while areas receiving more than 300 mm rainfall are suitable for agroforestry, arable crops, crop diversification and livestock rearing. The crop productivity is low mainly due to aberrant weather conditions and poor soil fertility. Livestock gives much more stable income than crop farming since the possibility of out-migrating avoids localized scarcity conditions, making it much more adapted to uncertain and erratic climatic conditions. Even in terms of rentability of investment, livestock farming surpasses crop farming. In general, pastoralism is predominant practice in arid regions and arable farming receives less importance with few exceptions. With the increase in aridity from irrigated tract to dry farming to pastoral, the households owning sheep, goats, and camels have increased. In spite of frequent droughts and famines, there is an increasing tendency among the farmers to keep large number of animals as walking capital.

The diversity of livestock resources in arid areas is very wide, both in variety and variability in terms of species, breeds, populations and unique genotypes. This diversity has been recognized as a vital resource for sustenance of mankind. Judicious utilization and enhancement of the quality of these resources is important to ensure their sustainability to meet future demands. The nature has endowed arid areas with some of the best breeds of cattle (Tharparkar, Rathi, Kankrej, Red Sindhi, Nagouri), buffalo (Murrah, Surti, Mehsana, Banni), sheep (Marwari, Magra, Nali, Pugal, Chokla, Jaisalmerti, Kheri, Patanwadi), goats (Marwari, Sirohi/Parbatsari, Jhakarana, Kachehhi), camel (Bikaneri, Jaiselmeri, Kuchchi and Mewati and lesser known breeds Marwadi, Mewadi, Sindhi, Shekawati) and horses (Marwari (Malani), Kathiawad, Bikaneri, Jaiselmeri). Livestock breeds in the region have been developed and owned by local people over many generations and are the product of local knowledge about animal breeding. Indigenous breeds from an arid environment are not only heat tolerant but are able to survive, grow and reproduce even with poor seasonal nutrition, high parasite and disease pressure.

More than half (57.73%) of total livestock population of Rajasthan are in the arid district of the state with a larger number of small ruminants. The ratio of livestock and human is equal in the western arid parts and is about 0.8 in the semi-arid parts of Rajasthan. The number of livestock in the arid zone increased by 41% between 1951 and 1961 and by 15% between 1995 and 2012. The density of livestock increased from 50 animal per 100 hectares of grazing land in 1951–52 to 154 during 2012. There are three major categories of livestock-keepers in arid zones of India:

- ***Labor-pastoralists*** (the landless or near-landless who depend mainly on wage labor, but keep a few animals); and

- ***Agro-pastoralists*** (large, small and marginal farmers who keep livestock as secondary income generating activity);
- ***Landless livestock-specialists*** (people with little or no land but for which livestock production is the main livelihood activity).

In arid areas, the contribution of livestock is as high as 50% and goes up to two third of the total earning to the farmers' income during drought years. This value increases with a shift from subsistence agriculture to the more open market economics, to include specialization and intensification of the production systems. For landless livestock specialists, livestock may be the principal livelihood activity and source of income. However, these people are heavily dependent on common grazing resources including farmers' field for grazing at certain times of the years (Pankaj et al. 2017). Agro-pastoralists, particularly small and marginal farmers are relatively more dependent on livestock than large farmers. This means that for them livestock are relatively more important as a source of planned income and as a buffer to poor crop yields. Large farmers are less dependent on common grazing resources, as they produce larger quantity of crop residues and also have access to large areas of private wastelands.

The farming system research that began in early eighties derives its tools from rich indigenous knowledge accumulated over the ages for resilience and amalgamated it with the scientific innovation to achieve higher levels of production, while managing the fragile resource base. Owing to risky crop production, land is put to alternate uses with perennial components like agro-forestry, agri-horticulture, agri-pasture, horti-pasture, farm forestry, etc. (Table 15.2). Major part of the Rajasthan is an arid region and there is inadequate availability of fodder and feed resources due to frequent drought and famines. Still, it ranks first in wool, second in per capita milk production and availability, and fourteenth in egg production in the country.

Impact of Livestock on Sustainable Agriculture

Owing to dryland technologies, except wool production, all livestock product output has been increasing since 1995–96 (Fig. 15.7). Impacts of livestock on soil fall into two broad categories: firstly, the physical impact of the animal on soil as it moves around and secondly the chemical and biological impact of the feces and urine that the animal deposits to soil. Physically damaged soil can be even more susceptible to the chemical and biological impact of feces and urine. These factors are important in arid and semi-arid regions of India as livestock is dependent on common pool resources for grazing and getting nutrient out of it (Pankaj et al. 2014). Heavy livestock such as cattle compact soil structure and destroy vegetation on parts of a field that they tread most often. This is visually apparent around drinking water troughs, entrances to fields and other parts of the land where the animals congregate. Destruction of soil structure in this way is known as 'poaching' and can be seen to be harmful because restoration of vegetation does not always occur

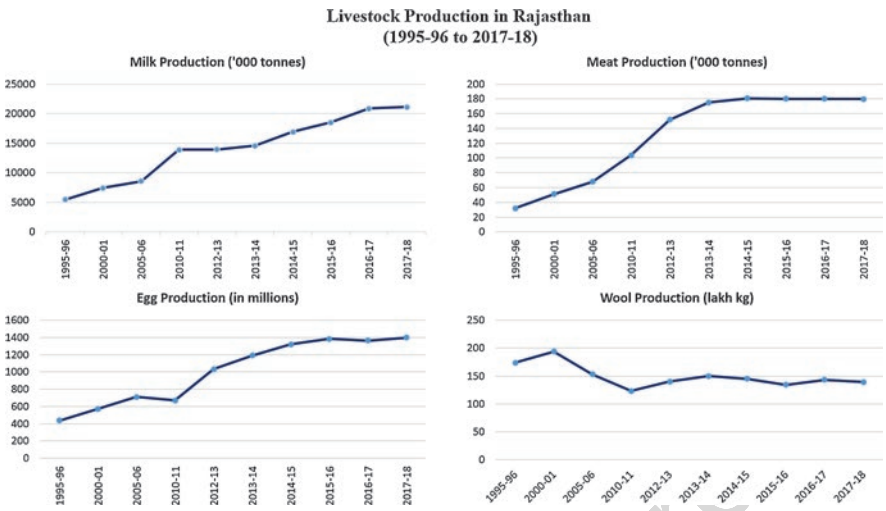


Fig. 15.7 Livestock production in Rajasthan state
(Source: State wise estimates of value of output from agriculture and allied activities with new base year 2004–2005 (Published in 2013), Ministry of Statistics and Programme Implementation, Govt. of India)

spontaneously once the grazing animal is withdrawn. Sheath and Carlson (1998) found losses of 5–10 kg dry matter ha^{-1} d^{-1} where up to 50% of an area was affected by cattle treading but recovery occurred within a few months. Compacted soil becomes strong making it difficult for new shoots to penetrate the soil and emerge; structureless soil is unlikely to drain well and will pond after moderate rainfall. Soil particles from these zones will be susceptible to erosion carrying particles, organic matter and phosphorus to surface waters (Warren et al. 1986). Anaerobic zones in waterlogged soils will encourage denitrification which implies a loss of nitrogen and pollution of the atmosphere with N_2O if conditions for denitrification are sub-optimal in the compacted zone. Problems with soil structure are not limited to cattle farming. Sheep grazing is largely extensive on upland rough grazing. In some farms, however, sheep are used to graze root cover crops (such as turnips) in the late winter and all but sandy soils are likely to be susceptible to damage. At equivalent (i.e. metabolic weight) stocking densities on wet soils, short-term treading by sheep is less damaging than treading by cattle (Betteridge et al. 1999).

Although many of the impacts of animal wastes on the environment concern losses to water or the atmosphere, soil is an intermediary and as such these impacts deserve space here. The amount of urine delivered to soil by a grazing cow is of the order of 2 litres applied to an area of about 0.4 m^2 (Addiscott et al. 1991). This represents an instantaneous application of 400–1200 kg N ha^{-1}. Such an amount burns vegetation and is often toxic to plant roots which cannot immediately recover to take up the N (full recovery can take up to 12 months and the problem is obviously worst in areas where animals congregate). Urea in soil is quickly hydrolyzed and given that grass can take up perhaps 400 kg N ha^{-1} annually without loss, pollution of groundwater or the atmosphere is almost inevitable whenever urine is applied to soil. Both Calcium and Magnesium are also lost in substantial amounts from urine patches on pasture soils (Early et al. 1998). Compaction of and damage to soil also limits the growth and use pasture can make of available nutrients. Douglas and Crawford (1998) found between 1.7 and 2.1 t ha^{-1} reduction in dry matter production in a compacted sward and reduction in recovery of N from 71% to 55% of that applied in the uncompacted and compacted swards, respectively.

The amounts of nutrients in manure are equally a source of waste, a missed opportunity and a potential pollutant. Manure is partly microbial in composition derived from fermentation during digestion and partly composed of recalcitrant components of the feed. As such it is rather less decomposable than fresh plant material and does not supply N to soil as rapidly or damagingly as urine. It does, however, block light and grass growth underneath manure will be temporarily retarded. Some regrowth occurs with penetration where the pasture is well enough established, some with reseeding directly into the manure.

Development of irrigation system has impacted the number of cultivation as well as improved the total cropped area (Fig. 15.8). However, change in livestock population over seven decades are not much in the arid regions, however, inland drainage plain was changed significantly in the region due to upscaling of watersheds.

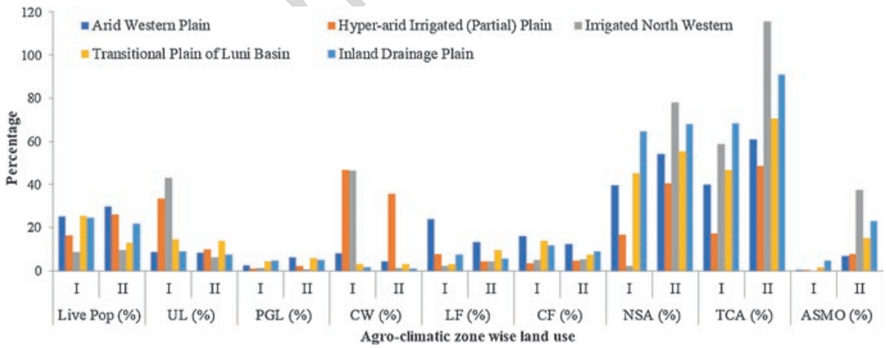


Fig. 15.8 Agro-climatic zone wise land use and livestock population in arid zone of Rajasthan
Live Pop = Livestock Population, UL = Uncultivable Land, PGL = Pasture and other Grazing Land, CW = Culturable Land, LF = Long Fallow, CF = Current Fallow, NSA = Net Sown Area, TCA = Total Cropped Area, ASMO = Area Sown More than Once
I = 1956, II = 2012
Source: Animal Husbandry Department and District Statistical Handbooks, Government of Rajasthan

Food and Nutritional Security (FNS) in Arid and Semi-Arid Regions

India's population of 1.3 billion is around 18% of the world's which is further estimated to reach 1.6 billion by 2030. Thus, Indian agriculture systems have a huge responsibility to ensure secure access to food and nutrition by every one of its citizens, now and for the future. FNS need to be linked to various socio-economic factors for perfect implementation in arid and semi-arid regions of India.

Linking Poverty, Nutrition and Food Security for Sustainable Development

To estimate poverty in a region it is not only household income level that is taken into consideration for determining extent of poverty but also variables like consumption, expenditure and nutrition standards included for estimation of poverty in semi-arid tropics and arid regions. In a longitudinal study carried out in Andhra Pradesh and Maharashtra states, both located in semi-arid tropics, it was inferred that on an average the total calories consumption by a person in rural household was found to be 2135 and 49 gms of protein when compared with recommended dietary standards of 2000 calorie consumption and 50 gms protein per head. More than 50% households in these states are deficit in protein consumption than total calorie intake (Rao 2000). Protein intake may be correlated to cultivable area of pulses in the region and Maharashtra State has less acreage under pulses than in Andhra Pradesh.

Any change in population, income, technologies bring corresponding changes in poverty, inequality and food security. The World Bank Report, 2015 proclaimed the efforts of UN in achieving the Millennium Development Goals which has significantly reduced global poverty from 12.7% in 2012 to 9.7% by 2015.There is significant reduction in poverty levels across most of the regions of the world except in Sub-Sahara African countries where poverty seems to increase from 350 million in 1990 to 60 million more in 2015. In South Asian countries- Sri Lanka, Bangladesh, China and India have possessed the highest number of undernourished populations to the extent of 281 million as per 2014–2016 estimates. Bangladesh achieved its MDG goal of (MDG – Goal-1 of eradicating hunger), achieved mainly for its promising National food policy. India is still housing the second highest undernourished population.

Drivers Promoting Food and Nutrition Security

Many International organizations based on experiences of working with food security issues have suggested four ways to reduce poverty, hunger and malnutrition of rural poor in Semi-arid areas. These are increasing economic growth, mostly referred to inclusive growth by involving poor, disadvantaged and marginal population; and by improving resource productivity of small and marginal farm families. Because agriculture is a major occupation in rural areas that have the highest percentage of malnutrition; implementation of safety net program; and political stability in the region is called for (FAO, IFAD and WFP 2015).

Increasing economic growth is considered the best strategy to reduce poverty. However economic growth should be inclusive in nature which implies embracing of the poor and marginal population, including the poor rural families who need to be brought into the development pathway. They should be provided with all best possible opportunities to access resources, develop skills and improve income for livelihood development. The possibility and scope for achieving inclusive growth is high in agriculture field where livelihood for the majority of the rural population is derived from a small holding having scarce resources. The majority of the farmers with small holdings usually depend on their own land, labor and capital. Their inclusion is crucial to increase economic growth rate by adopting practices like diversification and intensification of farming.

Rural women constitute a major workforce and contribute to the rural economy. By virtue of their roles and responsibilities of farm and family in context of social norms and culture of the society, they are being pushed to a secondary position in society. Given the extreme workload and long hours of work they remain withdrawn from policy and development activities. Inclusive growth, here, implies that rural women be given recognition of their contribution to economic growth. It is necessary to provide a greater number of equal opportunities to develop skills, improve assets and enhance livelihood and increase resilience at times of climate adversities.

Improving productivity of resources of small landholdings has great scope for achieving food security. For instance, investment in infrastructure and institutions: improvement of institutional credit, timely supply of seed, fertilizer and pesticides and extension services and ensuring congenial environment for better farming and marketing constitute important sources for eradicating hunger and poverty.

Another significant and viable important strategy proposed by Governments, these days, is to sanction safety nets schemes and social protection programs having potential to promote adaptation. These are mostly found effective during occurrence of natural hazards (droughts, floods) when crops and livestock are severely affected. For example, in Semi-arid and Arid areas of India the government introduced an Employment Guarantee Act called MGNREGA program to provide employment for 100 days per annum during lean period to rural poor comprising laborers, wage workers, small farmers and women. Studies conducted on impacts of MNREGA indicated that program enhanced equity, improvement of resilience of small landholders and the downtrodden to withstand drought or any other natural calamity.

Gender Equality Implications in Agriculture for Achieving FNS

In developing countries of the world most of the women of rural households play a significant role in safeguarding nutritional security of the family. In adverse conditions of drought women feel the burden of fulfilling the task of feeding children and other family members. Women adopt varied strategies to reduce impact of weather risk both on food production and meeting food consumption needs of family despite social constraints in access to resources and social norms. Decisions on selling of land, livestock and assets to withstand drought lies usually with men but selling of a small number of chickens, fruits and vegetable from farm yard and often reduced food intake rests with women. Women's education levels, social status interact with social norms, cultural context in a rural household also influence extent of food intake within a family. Food and nutritional security issues vary with class, marital status and gender. For example, unmarried woman and widowed woman face differential and more severe impacts of climate change on food availability than married women, owing to the different dependency status and economic conditions. Women are totally dependent on their assets owned or accessed and on prevailing economic conditions.

Gender equality in agriculture is expressed in terms of access to land, water and resources. Women play important roles as producers and provide relief to the most vulnerable for attaining FNS in rural areas. Women are key providers of unpaid care work in rural households poor in the growth process through better access to and communities. However, despite decades of efforts to education, health and proper nutrition, all of which expand address gender inequalities, many rural women continue to and strengthen human potential. Removal of gender-based constraints that limit their capacity to social protection can establish a virtuous circle of progress contribute to growth and take advantage of new opportunities. Involving the poor to improve livelihoods through increased income-generating opportunities such as, employment can shape national economies for the better.

Institutionalization of Diversification and Land Use Management Practices Models for Food and Nutritional Security

Achieving global food security remains a key challenge for the future, particularly given continued population increases, dietary shifts, and global climate change. Focus on agricultural intensification as a mechanism for producing more has been a major mean to achieve food security (Hazell and Wood 2008). Farmers in arid and semi-arid regions have adapted to climatic and other risks by diversifying their farming activities (Ebi 2011) and spreading the risk among different crop and livestock types (Antwi-Agyei et al. 2014) or by increasing the range of agricultural products for markets or subsistence (McCord et al. 2015).

Climate change and sustenance of food security are main challenges of twenty-first Century. In arid and Semi-arid areas rainfed agriculture play a significant role contributing to 40% of food basket of the world. Majority of food crops are cultivated in rainfed areas. Rainfed agriculture is mainly affected with availability and access to water which form critical resource that directly impact land use, land cover and livelihood pattern of people of the region. Looking at past history of rainfed areas worldwide a huge shift in land use and land cover change is found visible. The predominant changes range from grazing of sheep in rangelands to dominant irrigated intensive agriculture (Hole. 2007). It was reiterated that these changes brought about with government policies; intensive bore (well) irrigation; subsides for farm inputs; adoption of modern technologies such as use of fertilizers and pesticides; farm machinery, use of diesel pump sets etc., Land use management practices are influenced by soil climate and other factors like labor shortages, land ownership, economic and political factors, that many times impose constraints for higher productivity (Nuhu et al. 2007).

Intensive agricultural practices followed over a few decades resulted in depletion of fertile soil, decreased groundwater levels and sparse vegetation on the ground and farmers' attitude for getting quick returns has left a negative impact on livelihood and food security. Given current climate visibilities' resulting in temperature changes and occurrence of frequent droughts and floods further deteriorated the crop productivity, increasing hunger and poverty. Revamping farming to meet food security needs, eradicate hunger, alleviate poverty entails conserving natural resources while improving productivity of rainfed agriculture in semi-arid areas in sustainable manner is warranted (Nirmala et al. 2019).

Experts, scientists, policy makers, and learned experts from countries that focused on agriculture have taken steps (after realization of fallacies of farm policies leading to food insecurity) and devised tools and methods to mitigate damage to environment and food needs of country. Different models adopted and institutionalized in countries are discussed here in this section to gain insights on extent of diversification and various land use management practices followed and also to gain firsthand knowledge changing scenarios in semi-arid and arid regions of the world. Some successful models prevailing in countries of SAR are discussed here.

Integrated Farming System (IFS) Development for Food Security and Livelihood Development in India

An Integrated Farming systems approach is multifunctional, contributing to food security and livelihood enhancement. Promotion of IFS model particularly in agriculture sector through effective combination of one or more enterprises with crop component such as livestock, poultry, duckery, fishery, goatery, mushrooms, beekeeping depending on the availability of resources and effective recycling of waste for sustainable natural resource development found to be more profitable and environmentally sustainable. In semi-arid areas, with a predominance of small and marginal farmers, with limited and limited access to resources: land, water, inputs, credit and technology; are now encouraged to adapting to IFS model on a small scale to earn decent income from each of the enterprise sufficient to meet livelihood needs. In India, farmers quite often face challenges of volatility of markets, climate variability impacts leading to loss of crop and income (Reddy et al. 2018). Integration of small-scale enterprises along with the crop which involves low investment, more profit and only family labor are more appealing. The National Sample Survey Organization (NSSO) data (2003), the value of output per hectare was Rs 14,754 for marginal farmers, Rs 13,001 for small farmers, Rs10,655 for medium farmers and Rs 8783for large farmers. It could be inferred from NSSO data the small farms can be operated more effectively in terms of income generation than large farms due to paucity of resources, the small farm holders often suffer from social maladies such as poverty, malnutrition, unemployment and migration.

For example, in a study reported by farm science centre in Chattisgarh State in India an IFS model practiced by a marginal farmer in 1.5 acre of land has earned four times of net return over traditional practice of monocropping, getting employment generation of 316-man-days per year instead of 165 days in the same area. Duckery and backyard components contributed to nutritional security. Green fodders and straw produced were consumed by the milch cattle to produce more milk earning more to income to farmers. (Sujit et al. 2016).

Farmer FIRST Approach in India

It is an approach that focuses on the Farmers, farmers' innovations, farmers' resources and knowledge and science and technology termed as 'FIRST', a participatory approach followed to integrate all components of a farm to develop farm beyond productivity and profitability. The program launched by ICAR as a frontline extension system in 2016. Local knowledge is dynamic and its use over a period leads to innovation and key to sustainable development. This concept has driven the conception and operationalization of Farmers FIRST project. It concentrates on all aspects of farm such as crops and cropping systems, natural resource development like soil and water, horticulture component, small farm mechanization and socio-economic aspects utilizing convergence and institutional linkages. The objectives and aims of the approach aim at strengthening farmer – scientist interface which otherwise found weak in present extension system; technology assemblage with emphasis on diversification (crop, livestock, horticulture, mechanization); partnership and institutional development. The approach has adequately created impact benefitting farm families to achieve nutritional security with inclusion of eggs into diet with Srinidhi, a backyard poultry breed intervention.

Development of organized poultry has masked the contribution of backyard poultry or household poultry in rural areas of Telangana, a prominent semi-arid region of India where rural poultry constitute about 27% of the total poultry population. In order to improve nutrient availability of poor households in rural areas of Vikarabad district, Telangana, low input technology backyard poultry farming using Srinidhi breed was introduced under farmers first project for supplementing the earnings of poor farmers and landless labourers. Srinidhi variety of birds each 25 were given to geo-tagged, pre-trained fifty landless and small farmers from Pudugurthy village (17.18° N, 78.02° E), Pudur Mandal, Vikarabad District, Telangana, India for rearing. For comparison, performance of 100 birds of local variety were monitored. The nutritional status pre-and post-intervention was assessed and as per the production and reproduction performance data obtained on Srinidhi poultry, their role in reducing the nutritional deficiency in the area was demonstrated to the farmers. At 20 wks of age, the body weights of birds of local varieties were only 1.36 kg, whereas Srinidhi variety at village level has achieved a body weight of 2.35 kg with survivability of 60% and 80%, respectively. On adult unit basis, diet was deficient in energy as well as protein and it had energy levels only to meet their Basal Metabolic Rate (BMR) requirements. After the intervention, as the farmers did not sell their produce outside and used the produce for their home consumption only, the energy deficiency in diet was reduced to 33.52% and protein% in diet has become excess to the requirement by 13.21%. The diet chart revealed that females and children were more deficient in diet than males in both types of families. After the intervention, the diet was excess in protein to the tune of 23.2, 6.8 and 76.7% in the male, female and children, respectively. The study revealed significant higher production performances of Srinidhi variety over the Indigenous poultry birds has a better support system to livelihood and nutritional security under backyard poultry production in dryland region (Pankaj et al. 2019a).

Sheep farming is the strength of South India (a major semi-arid region of India) where chevon is preferred species for meat, but in some of the area of Telangana, its farming has been discontinued due to forage unavailability. Rural masses are already suffering from food and nutritional deficiencies. In order to improve nutrient availability of poor households in rural areas of Telangana, low input technology sheep farming coupled with improved forage production has been introduced under Farmers First project for supplementing the earnings of poor farmers. Deccani and Nellore sheep breeds each five female and one male were given to geo-tagged, pre-trained six small farmers from Gangupalle village (17.30° N, 77.98° E), Pudur Mandal, Vikarabad District, Telangana, India for rearing. For comparison, performance of 14 non-descript goats were also monitored. The nutritional status pre-and post-intervention was assessed and as per the revenue generated from selling of sheep, 50% of money were allocated for egg, chicken and chevon purchases for family consumption. On adult unit basis, diet was deficient in energy as well as protein and it had too low energy levels to meet their Basal Metabolic Rate (BMR) requirements. After the intervention, the energy deficiency in diet was reduced to meet out BMR requirement in all categories of people in the family. The diet chart revealed that females and children were more deficient in diet than males in an typical family of six people. After the intervention, the diet was excess in protein to the tune of 14.27, 3.73 and 63.02% in the male, female and children, respectively. The study revealed significant higher production performances of indigenous sheep (76.4% better body weight) over the non-descript goat has a better support system to livelihood and nutritional security in the dryland region (Pankaj et al. 2019b).

Strategies for Achieving FNS in Arid and Semi-Arid Regions

The following strategic points should be pondered to achieve FNS in arid and semi-arid regions of India:

- increase in institutional credit and irrigated areas,
- improvement of marketing infrastructure and revitalization of the agricultural extension system.
- There is also need to ensure that agricultural inputs such as seeds and pesticides are of proper quality.
- In arid zones, agriculture has to be horticulture and livestock driven. Semi-arid zones also require horticulture and livestock farming, but they can also take an annual crop during the three months when they have more water.

Acknowledgement The authors are thankful to Indian Council of Agricultural Research and ICAR-Central Research Institute for Dryland Agriculture (CRIDA) authorities for all the financial help rendered to generate different datasets useful for this chapter.

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