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Crop diversification opportunities in major rainfed production systems

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Crop diversification is an effort to increase crop diversity by temporal and spatial cropping systems to enhance productivity, sustainability and maintain the ecological balance. It is recognized as one of the most feasible, cost-effective and rational ways of developing resilience to the changing climate. Crop diversification can help to increase the income of smallholder farmers, conservation of natural resources, many agronomic benefits in pest management by breaking insect habitats and disease cycles, reducing weeds and soil erosion, and conserving soil moisture. Inclusion of perennials and high value crops in the system enhances income and also acts as an insurance against complete crop failure under rainfed conditions by providing multiple produce in one time from same piece of land.

Keywords: Agroforestry, Double cropping, Intercropping, Rainfed agriculture

AGRICULTURAL intensification has already aided us in achieving food security, but there is a need to reorient existing agricultural systems to be more sustainable to address household food, nutrition and environmental security. In India, crop diversification is often considered a shift away from less profitable crops toward more profitable crops and from traditionally grown less remunerative crops to more remunerative crops. Crop diversification aims to provide farmers more options for growing a range of crops in climate-resilient areas and reducing the risk of crop failure due to drought or excess rains.

Crop diversification is necessary for reducing risks associated with yield, market and prices; arresting the degradation of natural resources and the environment; and attaining national goals like employment generation, self-reliance in critical crop products and for earning foreign exchange. During the last two-three decades, a shift was noticed in the consumption pattern, wherein the food consumption of cereals has declined in favour of a more varied and nutritious diet of fruits, vegetables, milk, fish, meat and poultry products. The argument is that farmers must be in a position to produce high value crops and with the increase in commercialization, should also be able to maintain the diversity in the cropping pattern to reduce the risk of production losses. Crop diversification and growing of large number of crops are practised in dryland areas to reduce the risk factor of crop failures due to weather aberrations.

Approaches of diversified cropping systems

In All India Coordinated Research Project for Dryland Agriculture (AICRPDA), the crop substitution concept was evolved in which the performance of various new crops was evaluated *vis-a-vis* traditional crops. For example, in Vertisols of Bellary, sorghum was efficient than cotton. The cropping intensity could be increased considerably depending on the soil type and moisture availability period. However, the duration of the crop cultivars influenced the selection of a cropping system. Hence, the research clearly brought out that in high rainfall (> 1,000 mm) regions of Odisha, Eastern Uttar Pradesh and Madhya Pradesh, a second crop could be grown in the residual moisture after a 90 days duration variety of upland rice than 120 days duration. Similarly, in the Vertisols of Malwa (Madhya Pradesh) and Vidarbha (Maharashtra), a change of 140 or 150 days sorghum cultivar to about 90 or 100 days cultivars provided an opportunity to grow chickpea or safflower in sequence. Double cropping was possible only in areas receiving more than 750 mm rainfall with a soil moisture storage capacity of more than 200 mm.

Apart from yield diversity, the adoption of cropping systems focus on year round profitability of small and marginal farmers by integrating livestock through inclusion of fodder/forage crops; maximizing income through inclusion of vegetables such as pointed gourd, brinjal, chilli; reducing the use of costly inorganic fertilizers through inclusion of legumes and biofertilizers and at the same time uplift nutritional security of farm families; and enhancing the agroecosystem services in terms of improving soil quality and resilience through recycling of organic wastes as well as increasing nutrient-use efficiency in cropping systems through balanced/ integrated fertilization. In a nutshell, cropping system diversification focuses on the comprehensive benefits (yield and profitability, nutrient, water and energy budgeting as well as agro-ecosystem services) of more diversified, intensive, energy and water efficient cropping systems.

Types of crop diversification

Temporal crop diversification

A static, rule-based process to optimize crop rotations based on agronomic, economic, social, or environmental indicators.

Crop rotation: Cultivating two or more types of crops in consecutive growing seasons.

Relay cropping: The practice of sowing seeds of one crop into another standing crop. Growing a short-duration, fast growing secondary crop, usually a legume, after the principal crop, is a well-known strategy in rainfed agriculture. In North Gujarat, relay cropping of castor bean in greengram is widely practiced. Castor bean is sown as relay crop either by dibbling manually or by animal drawn seed drill in single row between two rows of greengram, when the crop is 40-45 days old. This system efficiently utilizes the length of growing period compared to cultivation of individual crops alone.

Spatial crop diversification

Spatial crop diversification can be achieved by growing different crop cultivars and species in different configurations at the same time in a given field.

Intercropping systems: The important contribution of rainfed farming research has been to scientifically modify the mixed cropping systems to the level of intercropping where in two crops of different durations are planted in definite row ratios as a system. It ensures the greater efficiency of resource utilization in a wide range of environments. Research on intercropping systems has focused on identification of potential crop combinations for increased productivity, profitability and risk minimization. Groundnut + pigeonpea intercropping system in 7:1 proportion is one of the most successful intercropping system adopted by farmers in scarce rainfall zone of Andhra Pradesh. About 70% of the total groundnut area of 0.85 million ha in this zone is under groundnut + pigeonpea intercropping system. The system is also adopted on a large scale by farmers in southern Karnataka. Similarly, sunflower + pigeonpea (2:1) system is practiced in more than 6,000 ha covering 30% of cropped area during rainy season in Solapur district and pearl millet + pigeonpea (5:1) is practiced in 80,000 ha covering 35% of cropped area during post-rainy season in Ahmednagar, Pune and Dhule districts of Maharashtra.

Castor + cowpea (1:2) intercropping system is recommended to cope with aberrant weather situation in North Gujarat. This system is practiced in more than 55,000 ha, and has potential to be upscaled in other castor areas of this region. In eastern plain zone of Uttar Pradesh, intercropping of pigeonpea and sesame (30/90 cm) gives 85% higher productivity over farmers' practice of sole pigeonpea cropping. Wheat + raya (2:1) is a popular intercropping system in Kandi region of Punjab. The area under this system is more than 40% wheat area in Nawanshahar and Hoshiarpur districts, and is gradually extending in other parts of the region. Further, production technologies involving defining of base and companion crop combinations, plant population, nutrient management, etc. have been standardized for intercropping systems suitable for different agro-climatic conditions.

Double cropping systems: Multiplicity of cropping systems has been one of the main features of Indian agriculture and it is attributed to rainfed agriculture and prevailing socio-economic situations of farming community. With the available dryland technologies like rainwater management, choice of crops, short duration varieties, and other agronomical practices, a greater portion of drylands can be put under intensive cropping systems including relay cropping and double cropping. In areas having sufficient rainfall (usually more than 750 mm) with a soil storage capacity of more than 150 mm of available soil moisture, double cropping is possible. Double cropping is also possible with rainwater harvested in farm ponds which is used for establishing

Fingermillet + pigeonpea (8:2) intercropping system

Cotton + cowpea (1:1) intercropping system

Table 1. Efficient diversified cropping systems for different rainfed areas in India

Soil zone and region	Water availability period (days)	Intercropping system	Double cropping system
Vertisols and related soil zone			
Malwa plateau (Madhya Pradesh)	210-230	Soybean + pigeonpea (4:2) Sorghum + pigeonpea (2:2)	Soybean-chickpea/safflower Maize/sorghum-safflower/chickpea
Baghelkhand (Madhya Pradesh)	210-230	Soybean + pigeonpea (3:1) Wheat + mustard (2:1)	Rice-wheat/chickpea Soybean-wheat/chickpea
Bundelkhand (Uttar Pradesh)	190-220	Sorghum + pigeonpea (2:1)	Sorghum-chickpea Blackgram-mustard/safflower
Vidharbha (Maharashtra)	190-210	Cotton + sorghum (6:1) Sorghum + pigeonpea (2:1) Cotton + greengram (1:1)	Greengram-safflower Sorghum-safflower
Southern Maharashtra	160-180	Sunflower + pigeonpea (2:1) Pearl millet + pigeonpea (2:1)	Pearl millet-sunflower Pearl millet-chickpea Greengram-sorghum
Southern Rajasthan	160-180	Maize + blackgram (2:2) Groundnut + sesame (6:2) Chickpea + mustard (4:1) Chickpea + safflower (2:1)	Sorghum/maize-mustard Sorghum-safflower Backgram/greengram-mustard
Northern Karnataka	130-150	Pearl millet + castor bean (3:1) Pearl millet + pigeonpea (2:1) Chickpea + safflower (4:2) Sorghum + chickpea (2:1)	Greengram-sorghum Greengram-sunflower Greengram-safflower
Saurashtra (Gujarat)	130-140	Groundnut + castor bean (3:1) Groundnut + pigeonpea (3:1) Pearl millet + pigeonpea (4:1)	
Southern Tamil Nadu	120-130	Cotton + blackgram/ greengram (2:1)	
Inceptisols and related soil zone			
Sub-montane region (Punjab)	260-280	Wheat + raya (1:1) Wheat + chickpea	Maize-wheat/mustard/chickpea Pearl millet-wheat/barley
South-western dry zone (Haryana)		Greengram + pearl millet (3:1) Pearl millet + cluster bean (2:1)	Pearl millet-chickpea/raya Greengram/cowpea-raya
Eastern plain zone (Uttar Pradesh)	200-230	Maize + pigeonpea (1:1) Chickpea + mustard (4:1) Pigeonpea + sesame (2:1) Pearl millet + pigeonpea (2:1) Maize + blackgram (1:3)	Rice-chickpea/lentil Pearl millet-chickpea/lentil Sesame-chickpea Blackgram-mustard/chickpea
Western plain zone (Uttar Pradesh)		Pearl millet + pigeonpea (2:1) Pearl millet + greengram (2:1) Chickpea + lentil (4:1)	Greengram-mustard Pearl millet + cowpea-chickpea + mustard
Western plateau (Jharkhand)		Pigeonpea + rice (2:3) Pigeonpea + soybean (2:2) Safflower + chickpea (2:1)	Rice-niger/toria
Bastar plateau (Chattisgarh)		Maize + cowpea (2:2)	
Jammu region (Jammu and Kashmir)		Cowpea + blackgram + maize (2:2:1) Wheat + chickpea (4:2) Chickpea + mustard (4:1)	Maize-wheat/barley/rapeseed Pearl millet-wheat Greengram/blackgram-wheat
Oxisols zone			
Eastern Ghat zone (Odisha)	200-220	Maize + pigeonpea (2:2) Finger millet + pigeonpea (4:2)	Rice-horsegram/toria Maize + cowpea-toria Rice-linseed/safflower Rice-greengram/castor bean
Alfisols and related soil zone			
Southern Karnataka	190-220	Groundnut + pigeonpea (8:2) Finger millet + pigeonpea (10:2) Groundnut + castor bean (8:1)	Pearl millet (fodder)-chilli Greengram-finger millet Blackgram-finger millet Sorghum-horsegram
Telangana (Andhra Pradesh)	140-160	Sorghum + pigeonpea (2:1) Castor bean + cluster bean (2:2)	
Rayalaseema (Andhra Pradesh)	110-130	Groundnut + pigeonpea (7:1) Groundnut + castor bean (7:1)	
Arid soil zone			
North-western Gujarat	100-120	Castor bean + cowpea (1:2) Pearl millet + cluster bean (2:1)	

winter crop. Out of the two crops, one could be of short duration of 60-70 days (usually legume), and another crop could be long duration of 110-120 days (usually cereal).

Pulses in rice fallows: On an average, 30% of the area under rice production during *kharif* season in India remains fallow in the subsequent *rabi* due to a number of biotic, abiotic and socio-economic constrains. A large area (11.6 m ha) of rice fallows under rainfed conditions can be brought under pulses provided available land and water resources (soil moisture, crop residue, water harvesting structures, etc.) are scientifically and innovatively managed. Out of 10.5 mha rice fallows of eastern (Uttar Pradesh, Bihar, West Bengal, Assam), Central (Chhattisgarh) and southern states (Andhra Pradesh, Karnataka, Tamil Nadu), 2.5 mha can be utilized by expanding lentil, greengram and blackgram cultivation.

Strip cropping: Strip cropping is a method of farming which involves cultivating a field partitioned into long, narrow strips which are alternated in a crop rotation system. It is used when a slope is too steep or when there is no alternative method of preventing soil erosion. Strip cropping can improve crop yields by encouraging infiltration and thereby increasing soil moisture.

Table 2. Efficient strip cropping systems

State	Location	Efficient strip cropping system
Punjab	Ballowal Saunkhri (Punjab)	Maize (4.8 m) + cowpea (1.2 m)
Rajasthan	Arjia (Rajasthan)	Maize (2/3 area) + blackgram (1/3 area) (8:4)
Maharashtra	Parbhani (Maharashtra)	Soybean + pigeonpea (5.4 m) (6 & 3 rows/strip)
Karnataka	Bengaluru (Karnataka)	Finger millet + cowpea (21:21)

Agroforestry: Agroforestry system is a land management system, which optimizes the land productivity by harnessing positive interactions between tree-crop-grass-livestock system in a unit area and time.

Maize (4.8 m strip) + cowpea (1.2 m strip) cropping system

The objective of agroforestry is to take advantage of the complimentary relationships between trees, crops and livestock in such a way that the productivity, stability and sustainability of the total system exceed individual component. In India, combined (irrigated and rainfed) total area under agroforestry is 7.45 million hectares and can be extended to a potential of 21.56 million hectares in rainfed area alone through adoption of improved and diversified agroforestry systems. Continued adoption of agroforestry systems in rainfed areas will enhance farm productivity and the livelihoods of small and marginal farmers substantially.

Crop diversification opportunities

Economic status of farmers: Crop diversification helps to increase income of small land holding farmers and they can better tolerate the ups and downs in price of various farm products and may ensure economic stability of farming products. To overcome this, existing cropping patterns must be diversified with high value crops such as maize, pulses, vegetables etc.

Balance food demand: Most of the Indian population suffers from malnutrition. Crop diversification including crops like pulses, oilseeds, horticulture and vegetable crops can improve socio-economic status by adding quality to the food basket and also improve soil health

Table 3. Different agroforestry systems in relation to the arable cropping systems in varying rainfall regimes

Agroforestry system	Tree density/ha	Rainfall (mm)	Tree age (years)	Extent of yield improvement/ reduction over sole crop (%)	Extent of improvement in profitability over sole crop (%)
Acacia tortiles + *Cenchrus ciliaris*	200	400	7	-16*	+30
Acacia tortiles + *Cenchrus ciliaris*	100	400	7	-12*	+75
Acacia Senegal + Sorghum	625	500		+81	+64
Albizia lebbeck + Sunflower	625	750	4	-21	+64
Leucaena + Blackgram	3.75 × 0.25 m alleys	1000		-34	+117
Eucalyptus + Intercrop	3 × 2 m	1000	4.5	-41	+318
Leucaena + Intercrop	3 × 0.75 m	1000	4.5	-55	+287
Leucaena leucocephala + *Gobhi sarson*		1100		-31	+205
Grewiaoptiva + *Gobhi sarson*		1100		-41	+275
Leucaena + Maize	600	1116	6	-38	+ 29

*Comparison over sole tree

Tamarind based horti-pastoral system

with the aim of food safety and nutritional security.

Employment generation: Employment generation is a significant role of agriculture. There is a serious problem of seasonal unemployment in different regions of the country, which leads to seasonal migration of labours/farmers to nearby cities/towns in quest of contractual work. Crop diversification helps rural households to have more opportunities of full-time employment.

Conservation of natural resources: Adoption of crop diversification helps in conservation of natural resources like introduction of legume in cereal based cropping system has the ability to fix atmospheric nitrogen to sustain soil fertility and also reduce soil erosion.

Risk reduction: Crop diversification is very much responsive to climatic and biotic vagaries, particularly in fragile ecosystems by expanding locally adapted or introducing novel varieties and related production systems will help resource-poor farmers to improve their food security and income generation while also protecting the environment. Under sudden adverse weather conditions like erratic rainfall, drought, hail, incidence of insect and pest disease, crop diversification through mixed cropping may be useful.

SUMMARY

Rainfed agriculture is challenged by many abiotic and biotic constraints, particularly weather aberrations in cropping season. Crop diversification plays a vital role in ensuring stable/higher income and also climate risk resilience. Crop diversification with intercropping, double/strip cropping systems enhances resource use efficiency, and overall system productivity and income per unit area to the small holders. Further, crop diversification provides variety of products enabling farmers to grow surplus products or sell at market and thus help to obtain increased income to meet other needs related to household well-being. Diversifying from the monoculture of traditional staples can have important nutritional benefits for farmers. Diversification can also manage price risk, on the assumption that not all products will suffer low market prices at the same time and increase the profitability of the farming community. Thus, crop diversification contributes to achieving food and nutritional security, income growth, employment generation and sustainable rainfed agriculture.

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