

Crop diversification options for enhancing sustainability in irrigated ecosystems

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Crop diversification is an effort to enhance crop productivity and sustainability by growing a variety of crops in a particular area, instead of focusing on a single crop. It aims to improve crop productivity and soil health, maintain the ecological balance and reduce risk of crop failure due to pests, diseases, ecological and environmental factors. Crop diversification serves as an opportunity to augment the income of small landholder farmers and employment generation for rural communities. It has many agronomic benefits in pest management by breaking insect habitats and interrupts the disease cycle, reducing weeds and soil erosion, promotes the interaction of beneficial soil bacteria and conserving soil moisture and natural resources. Maximum cropped area of the country is under rainfed, with inadequate supply of seeds and plants materials of improved varieties, fragmentation of land holding and inadequate post-harvest infrastructure being the major challenges for the adoption of crop diversification. Farmers are shifting from low-value crops with low yields to high-value crops with high yields by exploiting the benefits of crop diversification. Thus, crop diversification has the sound capacity for accomplishing the objectives of food and nutritional security, income growth, job creation and sustainable agriculture development.

Keywords: Crop diversification, Cropping pattern, Productivity, Sustainability

IN many developing countries additional food, fiber, and oil supplies are required due to ever-increasing worldwide population, posing a serious challenge to produce more and more from limited resources. Climate change, extreme weather and urbanization are big challenges to agricultural sustainability. It is expected that the global population will increase upto 50% by 2050, thereby doubling grain demand. As per the vision 2030 documents of ICAR, the food grain demand of the country will increase to 345 Mt by 2030, which will have to be met from a stagnated net cultivated area. The irrigated production systems of the country are mainly cereal dominated, where recent evidences show that continuous cereal-cereal production systems are now facing severe problem of sustainability along with degradation of soil quality resulting in fatigue in production and deterioration of soil health. Since the last 2-3 decades, fast declining water table and factor productivity in rice-wheat cropping system of Indo-Gangetic Plains (IGP) are the results of over-exploitation of natural resources. Crop diversification with pulses and oilseeds is given priority as a potential means for improving sustainability and minimizing

over-exploitation of natural resources in existing cereal-cereal production systems.

Crop diversification is the solution and a key strategy for achieving agricultural sustainability and ensuring long-term productivity in irrigated cereal-cereal production systems. Crop diversification is one of the most environmentally feasible, cost-effective, and reasonable approaches aimed at achieving sustainable productivity, while lowering input costs and thus increasing farmer's income and reducing uncertainty in agriculture, particularly in the face of climate change. Crop diversification is the inclusion of new diverse group of crops or cropping patterns that is best suited to a particular region for ensuring increased productivity and profitability. There is a need to reorient existing agricultural systems to be more sustainable, which continue to address household food, nutrition and environmental security. Crop diversification aims to provide farmers more options for growing a range of crops in climate resilient areas and helps in minimizing soil degradation, soil salinity, soil and environmental pollution, nutrient imbalance, insect-pest and disease incidence, decline in farm profit reducing the risk of

crop failure due to drought or excess rains and also helps in minimizing ill effect of climate change.

Cropping systems in irrigated areas of the country

In India, the existing socio-economic situations of the farmers results in multiple cropping systems. The philosophy behind cropping system is to maximize the crop production per unit area of land within a year or unit time with minimum degradation of natural resources. Cropping systems remain dynamic in time and space and therefore, it is difficult to determine their spread over a large territory. However, it has been estimated that more than 250 double cropping systems exist in the country. Based on the area of spread and importance, 30 cropping systems were identified under the irrigated agro-ecosystem. Among them, cereal-cereal systems like rice-wheat, maize-wheat, rice-rice, sugarcane-wheat, sorghum-wheat and rice-sorghum are commonly observed in the larger area. Further, the cereal-based systems like rice-wheat (10.5 million ha), rice-rice (5.9 million ha) and coarse grain-based systems (10.8 million ha) are major contributors to the total foodgrains production of the country.

Benefits of diversification

Food security: Crop diversification is a critical strategy for achieving food security by growing a variety of crops instead of relying on single/mono cereal-cereal cropping systems. Thus, farmers can produce all kinds of crops like vegetables, pulses and oilseeds along with cereals.

Nutritional security: Nutritional security and quality of life can be improved by growing nutrient-rich crops like fruits, vegetables, legumes, oilseeds and biofortified crops. Diversified crops can provide year-round availability of essential nutrients and offers nutritional food security by enriching diets.

Employment generation and poverty alleviation: Adopting the conventional cropping system generally leads to lack of employment during off seasons. Crop diversification is a sustainable strategy for employment generation and alleviating poverty. Different crops have varying requirements for labor and growing diverse crops can spread out labor demands across seasons, ensuring consistent employment. It helps to increase farmer's income and may ensure economic stability of farming products. By crop diversification, farmers reduce dependency on a single crop and protect themselves from market or climatic risks. Existing cropping patterns must be diversified with high value crops, that fetch better prices compared to staple crops and thus improving farmers' income.

Conserving the natural resources and protecting the environment degradation: Crop diversification helps in conservation of natural resources and protects the environment degradation by reversing the declining trends in soil productivity and ground water table. Farmers can sustainably use natural resources, improve productivity, and protect the environment for future generations through crop diversification. Introduction of legume in cropping system has the ability to fix

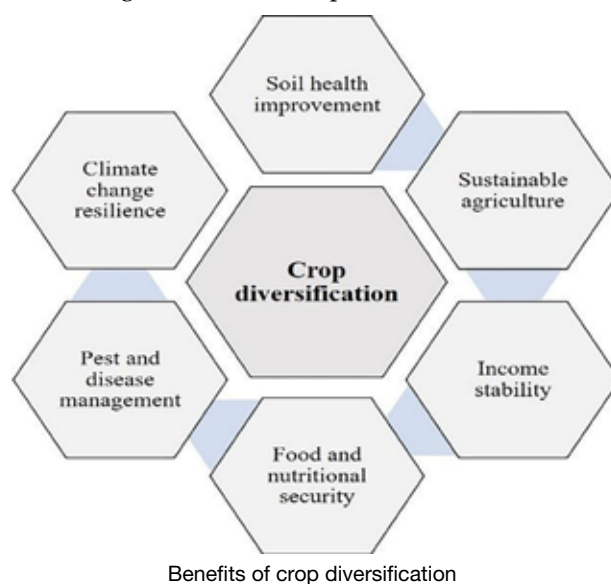
atmospheric nitrogen to sustain soil fertility and helps in conservation of natural resources. It maintains a balanced nutrient cycle thereby protecting the land from overuse. Diverse crops and cropping systems are less vulnerable to climate-related stresses and reduce the use of synthetic inputs decreasing harmful chemical runoff into nearby water bodies and lowering soil and water pollution.

Ecological balance: Crop diversification helps to increase natural biodiversity in agro-ecosystems. Different crops in cropping system improve biodiversity of soil microbes and pollinators which are critical for ecosystem health. Natural predators and parasites in agroecosystem are expected to be conserved by including crops requiring minimal use of pesticides. Improved biodiversity increases ecosystem resilience, helping in buffer against climate extremes and pest outbreaks.

Risk reduction: Weather is responsible for about 70% of the variability in crop productivity. Crop diversification is very much responsive to climatic and biotic stresses. Some crops might thrive when others fail, ensuring some yield and monetary returns from crops which are least affected. In a fragile ecosystem poor farmers improve their food security and farm income by introducing novel varieties and diversify cropping systems. Crop diversification through mixed cropping may be useful under sudden adverse weather conditions and incidence of insect and pest disease. Different crops often attract different pests and diseases thereby reducing the infestations. It can also encourage beneficial insects and natural predators that control pests.

Allows a balance in residue production: Rice straw management before wheat sowing is sometimes problematic due to huge residue production by cereal crops than pulse and fodder crops. Crop diversification can avoid such problem.

Efficient weed management: Monoculture of rice invited grassy weeds and broad leaf weeds. Several researchers found that growing of *Sesbania* (dhaincha) as cover cum-green manure crop before rice reduces weed



population due to allelopathy and/or smothering effect. Inclusion of sunhemp (*Crotolaria*) in crop diversification under uplands and *Sesbania* under lowlands is useful in weed management. Wheat monoculture promoted *Phalaris minor*. Monoculture of wheat has favoured huge weed seed bank and now it is difficult to manage this weed. Crop diversification with legumes like french bean, field pea, chickpea, etc helps in managing this weed.

Efficient utilization of soil water: Different crops have different rooting pattern and water requirement. Crop diversification using deep rooted crops such as alfalfa, redgram, corn, cotton etc extract soil moisture from deeper layers of soil. However, crops like green gram, black gram, mustard, lentil and chickpea require less water than irrigated rice and wheat, and thus can be used in crop diversification programme.

Strategies for implementing crop diversification

Crop diversification is a holistic approach to improve crop productivity, agricultural sustainability, and resilience to climate change, profitability, reducing risks from pests, diseases, and market fluctuations by including a variety of crops instead of focusing on a single crop. Here are effective strategies for implementing crop diversification:

- Shifting from low yielding and low value crops to high yielding and high value crops which provide higher net return as compared to the prevailing crops.
- Shifting from higher water requirement to lower water requiring crops. Crop diversification in water scarce areas or in IGP can be popularized by using micro-irrigation. Responsive crops such as tea and close spaced crops should be identified for sprinkler irrigation. For drip irrigation, sugarcane, potato, tomato, sweet potato, chilli, banana, papaya and fruit crops can be used.
- Inclusion of legumes and oilseed crops in cereal-cereal cropping systems.
- New areas of crop diversification should be explored. Bund crops, alley crops, relay crops, catch crops, bee crops, trap crops, mixed crops, and inter crops have potential roles in crop diversification.
- Inclusion of crop with high demand in national and international market.
- Shifting towards low energy efficient crops to higher energy efficient crops.
- **Cover cropping:** Growing crops like cowpea and green gram to cover soil between main crops, helps to prevent erosion, suppress weeds, and improve organic matter status of the soil.
- Integrated farming system embracing suitable crops should be promoted.
- Strengthening marketing facility for crops grown under crop diversification.

Measures of crop diversification

Temporal crop diversification

Crop rotation: It is the practice of growing a series of

different crops in a sequence on the same piece of land with the aim to improve soil health, and combat pest and weed pressure. Rotating cereals with legumes and oilseeds is a common practice to maintain soil fertility and break pest cycles (Table 1).

Catch crop: Growing of fast-growing crops in between successive plantings of a main crops or when no main crops are being grown. It is a specific type of cover crop grown to reduce nitrogen leaching, that promotes environmental benefits through improvement in soil structure and enhancement of soil biological activities. Catch crops protect soil against water erosion through its residue which increases soil roughness and helps in maintaining soil organic matter.

Double or multiple cropping: Growing two or more crops in the same field during a single growing season. It helps farmers to increase their income, improve food security, lower pests and diseases as compared to monocropping and reduce the risk of crop failure due to biotic and abiotic factors.

Relay cropping: Relay cropping is a sustainable agricultural technique in which second crop is grown in standing crop before the established first crop is harvested. This involves overlapping the growth cycles of two crops to maximize resource use and efficiency. If legumes are involved in this system, it can improve soil fertility and structure.

Table 1. Long-term effect of crop rotation (after 7 years) on available macronutrient status

Cropping system	SOC (Mg C/ha)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Maize-wheat	11.65	202.10	16.04	172.98
Maize-wheat-mungbean	13.50	227.19	18.04	186.04
Maize-wheat-maize-chickpea	13.09	216.03	17.19	185.93
Pigeonpea-wheat	13.57	217.43	16.80	183.18

Spatial crop diversification

Alley cropping: It is an agroforestry system in which food crops are grown in alleys formed by trees.

Agroforestry: This refer to integrating trees and shrubs with crops or livestock. Trees provide shade, improve soil structure, and help in carbon sequestration.

Intercropping: Intercropping is the practice of growing two or more crops together in the same field at the same time with a definite row pattern. Planting different crops in proximity helps the crops to benefit from

Table 2. Sugarcane based intercropping systems in India

Region	System	Row ratio
Uttar Pradesh, Haryana, Punjab, Madhya Pradesh, Maharashtra	Sugarcane + maize	1:1
	Sugarcane + rajmash	1:1, 1:2
	Sugarcane + lentil	1:1, 1:2
	Sugarcane + mustard	1:1
Andhra Pradesh, Tamil Nadu, Karnataka	Sugarcane + blackgram	1:2
	Sugarcane + cowpea	1:1, 1:2
	Sugarcane + soybean	1:2
	Sugarcane + onion	1:2



Soybean + pigeonpea (2:1)



Chickpea + mustard (6:2)

complementary growth patterns of each other. The main aim is to increase the crop yield by using the resources that a single crop would not use. For example, soybean + pigeonpea, chickpea + mustard, maize + beans, pigeonpea + sorghum can be intercropped to enhance resource use efficiency. Some of the major intercropping systems with sugarcane is given in Table 2.

Mixed cropping: In contrary to the intercropping, mixed cropping is the growing of two or more crops at the same time without any distinct row arrangements. This is a common practice by farmers in which they mixed the seed of mustard with rabi crops like wheat, chickpea and broadcast in the field.

Trap crop: Trap crops are grown in the vicinity of main crop simultaneously in the same land to divert the insects-pests which would otherwise attack the main crop. Trap crops can be used to prevent pests from reaching the main crop and concentrate pests in a specific area of the field where they can be controlled at a low cost. Mustard are grown in the border area of rabi pulses to reduce the pest incidence.

Approaches for crop diversification

There are mainly two approaches of crop diversification which includes:

Horizontal crop diversification

Crop substitution: It refers to the substitution of the crops and cropping systems which are less suitable with more suitable crops and cropping system based upon the agro-climatic condition of a specific location. For example: substitution of high risk prone crops with short duration pulse and drought and less rainfall resistant oilseed crops. Sometimes crops like wheat can be replaced by chickpea and rice with short duration pigeonpea. Thus, wheat-chickpea and pigeonpea-rice are considered as an alternative of rice-wheat system in IGP.

Crop intensification: Crop intensification encapsulates strategies and practices of increasing agricultural productivity per unit area of land, water, and other

resources by adding more crops to the present crop or cropping system. Its aim to maximize output from limited resources, limits land conversion and deforestation and boosts income of farmers through higher yields and efficient input use. The inclusion of summer mungbean in rice-wheat or maize-wheat system in northern and central India has been shown to increase the total productivity, profitability and sustainability. A long-term study at ICAR-IIPR, Kanpur showed that intensification of maize-wheat rotation with inclusion of mungbean in summer fallow increases the system productivity by 79%.

Vertical crop diversification

Vertical diversification is an approach which represents the degree and level of industrialization of agricultural production through processing, regional branding, packaging, merchandising or other efforts to improve the marketable value of the crops. This approach is particularly beneficial in areas with limited arable land. Rise of processing and transformation industries appears to be the most important factor in rural areas in terms of creating employment and revenue generation.

Constraints in crop diversification

Crop diversification is the practice of growing different crops on the same piece of land with the aim to enhance food security, improve soil health, reduce risks, and increase farmer's incomes. However, several constraints can limit its adoption and success. The major constraints in crop diversification are discussed below.

Technical constraints

- Lack of technical knowledge regarding suitable crop combinations for a specific region, advanced agronomic practices, and also pest management.
- About two third area of the country is rainfed and completely dependent on rainfall therefore some crops may not be able to survive. Crop diversification often requires precise water management, but inadequate irrigation facilities can hinder this.
- Not all soils are suitable for a variety of crops,

under and over-use of land and water resources, causing a negative impact on the environment and sustainability of agriculture and limiting diversification options.

- In India, availability of machinery, storage, and post-harvest processing facilities are limited for diversified crops. Inadequate storage facilities and poor transportation, power and communications facilities can lead to post-harvest losses for perishable diversified crops. In spite of that, lack of local processing units for certain crops can hinder marketability and profitability.
- Fragmented land holding less favoring modernization and mechanization of agriculture.

Environmental constraints

Uncertain weather conditions, such as droughts or floods, may limit the feasibility and also affect the viability of certain crops. Some crops require specific temperature ranges to survive, and extreme temperature either cold or hot can limit the choices. Crop diversification can sometimes lead to more complex pest and disease management issues and host diseases and pests affecting most crop plants.

Economic constraints

These are the market-related challenges that limit farmers' ability to adopt different crops in cropping systems. Fluctuation in prices and lack of stable markets for diversified crops discourage farmers to adopt new crops. Diversifying crops require purchasing seeds, fertilizers, and pesticides, which can be expensive. High costs of seeds, fertilizers, and pesticides can be a financial burden on farmers. Limited access to agricultural credit makes it challenging for farmers to invest in diversified farming systems. All these constraints and challenges can discourage farmers from transitioning away from monocultures or less diverse agricultural practices.

Institutional constraints

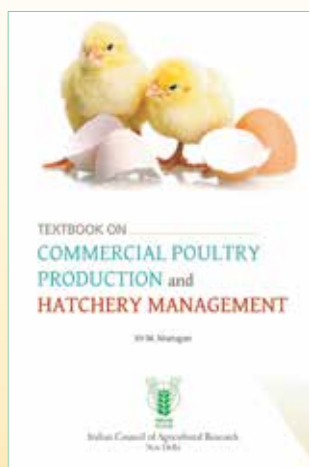
Institutional constraints are the challenges arising from policies, structures, extension services and land tenure systems that limit the ability of farmers to adopt crop diversification. Poor extension services fail to provide farmers with guidance on crop diversification.

SUMMARY

Under climate change scenario, there is huge risk of crop loss and adverse effect on environment from monoculture. Crop diversification refers to the practice of growing diverse crops and is one of the most effective ways to improve agricultural production, profitability, and sustainability resulting in increased food, nutrition and environmental security, as well as poverty reduction especially in developing countries. It holds significant potential to transform agriculture into a more resilient, sustainable, and economically viable sector. Crop diversification can address global challenges like climate change, food and nutritional insecurity, and environmental degradation while improving livelihoods for farmers. Growing multiple crops minimizes the risk of total crop failure due to insects-pests, diseases, or abiotic stresses and increased the flow of farm income throughout the year. It contributes to a more balanced and nutritious diets by producing a variety of crops. Crop diversification, can reduce dependency on imports and mitigate the impact of global supply chain disruptions. Identification of alternate crops to monoculture is location specific and needs to be scrutinized. Crop diversification, must be followed in such a way that it produces sufficient food to meet the need of present generation without deteriorating the present environmental balance and life supporting system of the future generation.

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