

Cropping System Diversification

Stabilizing smallholders' income and enhance agro-ecosystem services

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A significant agricultural challenge of the 21st Century is providing sufficient food, feed, and fuel for the increasing global population without degrading the planet's natural resources and productive capacity. Consequently, balancing crop productivity, profitability, and maintenance or improvement of soil and water quality and biodiversity is critical to meet these goals. Diversification through crop rotation is especially useful strategy in farming system that integrate crop and livestock production. The addition of forage crops, including fodder cowpea, berseem etc., to cereal-based systems, can enhance nitrogen supply through fixation by legumes, and increases nutrient cycling due to greater livestock density and manure production. These changes will allow the intensification of both crop and livestock production, and increase yields substantially. In addition to reducing requirements for purchased fertilizers, soil-related benefits of this practice include improvements in soil carbon storage and microbial biomass, soil physical structure, plant-available nitrogen, and infiltration and retention of water. Manure transfer between on-farm enterprises or neighbouring farms provides an opportunity to integrate crop and livestock operations within a watershed and can alleviate costs associated with manure storage, handling, and disposal.

Keywords: Agro-Ecosystem Services, Cropping System Diversification, Fertilizer, Indo-Gangetic Plains

Introduction

The Indo-Gangetic Plain (IGP) is the most important food producing domain of India, occupy an area of 44 Mha of which rice-wheat rotation alone occupy an area of 9.6 Mha in lowland and 1.8 Mha of maize-wheat rotation in upland. This region is not only filling the grain basket for India but also providing sustainability of livelihoods for smallholder farmers residing in this agroecoregion. Traditional rice-wheat cropping system is primarily the livelihood for the farmers' in this region. On medium lands, farmers used to grow pulses such as grass pea, lentil, or Bengal gram in winter, on residual moisture after harvesting of long duration, photosensitive local rice. Productivity and return of those crops were low. However, due to the

introduction of high-yielding short duration rice in the 1970s and increasing irrigated area, 'Boro' season (Rabi, dry season rice) rice replaces most pulses in this area. Crop intensification and/or diversification has now further increased with the inclusion of short duration rapeseed and potato in between wet season rice or jute and dry season rice, resulting in increasing productivity per unit time, greater nutrient and groundwater removal, and rapid changes in soil fertility as compared with predominant cropping system viz., rice-rice and rice-wheat rotations.

A plateauing in the productivity is now appearing in this region where such exhaustive cropping systems are being followed continuously during the last few decades, because of

fatigue natural resource base (high groundwater removal due to 'Boro' rice cultivation), imbalanced fertilization (higher removal of K while build up of P), soil structure disintegration, and soil organic carbon (SOC) depletion as well as climatic uncertainties (low rainfall, extreme weather events etc.). It is, therefore, imperative to explore the possibility of crop diversification of the rice based system in the light of Integrated Farming System (IFS). Diversification can be done by replacing dry season rice with a grain legume, oilseed, forage and tuber crop, while partial diversification is possible by accommodating a short duration legume during summer months when fields generally remain vacant after harvest of mustard or potato crop for about 70-80 days.

Why diversification in cropping system is of utmost necessity?

Crop diversification generally focuses on shifting from traditionally grown less remunerative crops to more remunerative crops. Moreover, diversified cropping systems provide sustainability in the productivity of different crop production systems *vis-à-vis* restores ecosystem services such as increase in soil organic C (SOC) sequestration, improve nutrient(s) cycling, pest protection, energy efficiency, and consequent impacts on soil and water resources. Such insights could be valuable for guiding agriculture for fulfilling the meet of feed, fibre, bioenergy of growing global population with finite natural resources and uncertain trajectories of environmental change. Mostly, inappropriate cropping practices such as continuous cereal based rotations involving exhaustive crops like potato and/or ‘Boro’ rice and chemical fertilization can overexploit irrigation and create imbalances of primary nutrients (buildup of soil P with depletion of native N and K) as well as multi-nutrient deficiencies (including micro and secondary nutrients), and significant deterioration of soil physical quality. On the contrary, rational cropping practices such as inclusion of legume and fodder/forage crops, manure incorporation, crop residue recycling *etc.* not only enhances farmers’ profitability from the same farm unit but also can significantly increase the SOC storage, improves soil structure, increases nutrient recycling, improves soil microbial biomass, therefore, enhances soil quality which collectively enhances agro-ecosystem services.

In a developing country like India, diversified cropping systems contribute to climate smart agricultural pillars. FAO’s Economic and Policy Analysis of Climate Change (EPIC) in its findings emphasized crop diversification can as a potential climate change adaptation strategy. Through crop diversification, farming households can spread production and income risk over a wider range of crops, thus, reducing livelihood vulnerability to weather or market shocks.

Crop productivity, nutrient uptake and nutrient use efficiency (NUE)

Increase in agricultural production in the past was because of both expansion of cultural area (altering natural ecosystem to generate agricultural products) and intensification (producing more of the desired product per unit of area of land already used for agriculture) where the cropping system played a key role. Productivity of crops in the monoculture has been increased by introducing other crops in the system. Nevertheless, issues of recent stagnation/decline in yield with constant input under long-term field experiment (LTE) in rice-rice and rice-wheat cropping systems are of particular concern among scientists and farmers. The possible causes of this yield stagnation/decline might be due to depletion of SOC, changes in biochemical and physical composition of soil organic matter, soil fertility imbalance due to gradual decline in the supply of plant nutrients, imbalanced application of fertilisers, scarcity of surface and groundwater and quality water that concern ecological sustainability of the system. However, different cropping systems have different productivity levels (Table 1). Many workers have compared the productivity potential of different rice-based cropping systems of diversified eco-systems. Reports on higher total economic yield of diversified cropping systems including pulses or vegetables are always surpassing the yield and profitability of monocrop rice (Fig 1). For example, sorghum yield improves in legume based cropping system as compared to solo sorghum crops indicating the potential of crop diversification.

Intensive cropping leads to heavy withdrawal of nutrients from the soil

and its success depends largely upon the application of external application of nutrients commensurate with the nutrient uptake. The nutrients uptake values, therefore, would provide a relative estimate of the nutrient requirement under varying soil-climatic situations and form the basis for the development of a sound fertiliser recommendation strategy for realizing higher productivity while enabling soil fertility. The status of nitrogen in cropping system has practical importance because of large quantities of N uptake by intensive cropping systems and a significant amount of N loss from the environment. Further, in the absence of any appreciable residual effect, each crop should receive the optimum dose of fertiliser nitrogen particularly in sequences that do not include a legume. Nitrogen uptake by a system varies depending upon number and nature of the component crops. The improved efficiency of the input system is a reaction to the perceived defects of the high external inputs system and seeks to provide a production system that is both high-yielding and more environmentally benign. The key feature of improved efficiency of input is that external inputs are used with greater efficiency to minimise both on and off-site environmental consequences.

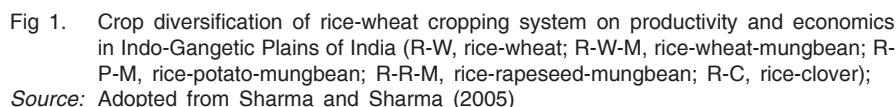
Approaches of diversified cropping system

Apart from yield diversity, the adoption of cropping systems focus on year round profitability of small and marginal farmer which can achieve; i) Integrate livestock through inclusion of fodder/forage crops; ii) Maximize income through inclusion of cash crops vegetables, pointed gourd, brinjal, chilli; iii) Reduce the use of costly inorganic fertilizers (N and P) through inclusion of legumes

Table 1. Long-term crop diversification of maize-wheat cropping system on improving soil Indo-Gangetic Plains of India

Cropping system	Soil organic C (Mg C ha ⁻¹)	C:N ratio	KMnO ₄ -N (kg ha ⁻¹)	Olsen’s P (kg ha ⁻¹)	NH ₄ OAc-K (kg ha ⁻¹)
Maize-wheat	11.7	10.4	202.1	16.0	172.1
Maize-wheat-mungbean	13.5	10.2	227.2	18.0	186.0
Maize-wheat-maize-chickpea	13.1	10.7	216.0	17.2	185.9
Pigeon pea-wheat	13.6	10.4	217.4	16.8	183.2

Source: Adopted from Venkatesh et al., 2017



The future of agriculture depends

on our ability to understand both the efficient use of natural resources and the ecological principles that promote agroecosystem resilience and stability. While the production of food, fiber, and fuel will remain core goals of farming systems, the provision of other ecosystem services will become increasingly important. Measures to enhance agricultural yield will be evaluated with greater attention to potential trade-offs among other ecosystem services.

The Indo Gangetic Plain (IGP), and in particular, the states falling under the lower Gangetic Plain (IGP) regions, the eastern part of the IGP, one of the World's most

important agricultural eco-regions. The zone is primarily a traditional rice-growing area with low productivity. Most of the cropping system based previous work has focused primarily on the specific aspects of R-R or R-W systems with a strong emphasis on yields, nutrient management, economics *etc.* However, studies providing a comprehensive assessment of more diversified, intensive, energy and water use efficient cropping systems in the perspective of Integrated Farming System (IFS) that would integrate crop and livestock under the same unit, promote ecosystem services (improvement in soil structure, soil C storage and soil microbial biomass), supplement synthetic external inputs (mainly chemical fertilizers) used to maintain crop productivity, reduce income risk of the small holders' over a wider range of crops and thus reducing livelihood vulnerability to weather or market shocks have remained relatively rare, but they are needed for understanding options for intensification and diversification in the lower Gangetic flood plains of the state. Cropping system diversification would not only integrate crop and livestock production under the same farm unit (*i.e.* Integrated Farming Systems or IFS) but also increases small holders' income and nutritional security which in turn promote ecosystem services, and eventually displace, synthetic external inputs (mainly chemical fertilizers) generally used to maintain crop productivity. IFS approach will evaluate the cropping systems in the light of ecological, nutritional, feed and economic perspectives along with resource dynamics.



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