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Chapter

Crop Diversification an Effective Strategy for Sustainable Agriculture Development

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Abstract

Sustainable agricultural practices involve a variety of approaches. The most important approached for sustainable agriculture development is crop diversification. It allowing the farmers to employ biological cycles to minimize inputs, conserve the resource base, maximize yields and also reduce the risk due to ecological and environmental factors. It serves as an important opportunity to augment income and employment generation for rural communities. Crop diversification promotes the interaction of beneficial soil bacteria, interrupts the disease cycle, and reduces the quantity of weeds. Crop diversification boosts land-use efficiency and crop output by improving the physical and chemical qualities of soil. Crop diversification shows a lot of scope to alleviating the problems such as resurgence of insects-pests and weeds, soil degradation, environmental pollution, soil salinity, decline farm profit and climate change. Crop diversification through crop intensification system enhanced the net returns, B:C ratio, and overall system productivity of a farm. In order to achieve the benefits of crop diversification farmers are shifting from low value low yielding crops to high value high yielding crops. Thus, crop diversification has the sound capacity for achieving the goal of nutritional security, income growth, food security, employment generation and sustainable agriculture development.

Keywords: crop diversification, sustainable agriculture, nutritional security, food security

1. Introduction

An ever-increasing worldwide population, especially in many developing nations, necessitates additional food, fiber, and oil supplies, posing a serious challenge to agricultural scientists to produce more and more from limited, diminishing, and degraded land and water resources. By 2050, it is expected that the global population will have increased by 50%, and global grain demand would have doubled [1]. The stress from climate change, accompanying extreme weather and urbanization also creates the burden. Global agriculture in the present status points to a formidable challenge to agricultural sustainability. The most important danger to food security

and the environment is dwindling per capita natural resources, as well as resource depletion and degradation. Existing intensification technologies are showing symptoms of wear and tear. The loss of biodiversity, groundwater shortages, fossil water extraction, groundwater contamination, and rising atmospheric CO₂ levels are all severe risks to sustainability. A variety of methodologies are used in sustainable production practises. Specific strategies must take into account the site specific and individual nature of sustainable agriculture. Reduced dependency on monocultures can give better resilience and reduce the chance of total system failure, which is critical for attaining long-term sustainable agricultural development. It can be a dynamic and continuous process to adjust in changing circumstances. Diversification is the process of utilization of the various emerging opportunities created by new market, technology, changes in governmental policies, higher profitability and also stability in the production system [2]. It is a useful strategy for reducing the risk in farming [3]. Crop diversification is generally viewed as shift from a traditionally grown less remunerative crops to more remunerative crops. Crop diversification is recognized as one of the most environmentally feasible, cost-effective, and reasonable approaches to reduce uncertainty in agriculture, particularly in the face of climate change. Crop diversification helps in minimizing the alleviating second generations problem such as soil degradation, soil salinity, insect-pest and disease insurgence, environmental pollution, decline in farm profit, nutrient imbalance, climate change etc. Crop diversification promotes farm resilience, or the ability of an agroecosystem to return to its former productive state after being perturbed, by increasing geographical and temporal biodiversity. Although crop diversification is not a new concept to many rural people in developing and emerging economies, there has been little research on the subject to date. However, there is increasing global interest in the area, owing to current worries about biodiversity loss, as well as human and environmental health. Thus, in this book chapter we are trying to give some understanding about the topic Crop diversification an effective strategy for sustainable agriculture development.

2. Concept of crop diversification

Crop diversification, as opposed to specialized farming, can be defined as an attempt to promote crop diversity by crop rotation, multiple cropping, or intercropping, with the goal of improving productivity, sustainability, and supply of ecological systems [4–6]. It could be one step toward more sustainable production systems, value chains for minor crops [7], and socioeconomic benefits [8]. Enhanced agricultural diversity, better diverse crop rotations, mixed cropping [9, 10], cultivation of grain legumes in generally cereal-dominated systems [11], perennial leys or grassland [12], and regionally adapted varieties or variety combinations are all examples of agricultural diversification strategies. In developing countries, crop diversification is defined as the substitution of one or more agricultural products for another. Diversification in agriculture can be defined as the reinvestment of some farm productive resources, such as land, capital, farm equipment, and labour, into new enterprises [13]. A shift from less profitable cropping system to more profitable cropping system is also known as diversification. Diversification of agriculture, in general, refers to transitioning from a single crop's regional or temporal dominance to the production of a variety of crops in order to meet the ever-increasing need for cereals, pulses, oilseeds, fibers, fuel, and feed. Crop diversification is a demand-driven, need-based situation specific and national goal seeking dynamic and iterative concept that incorporates

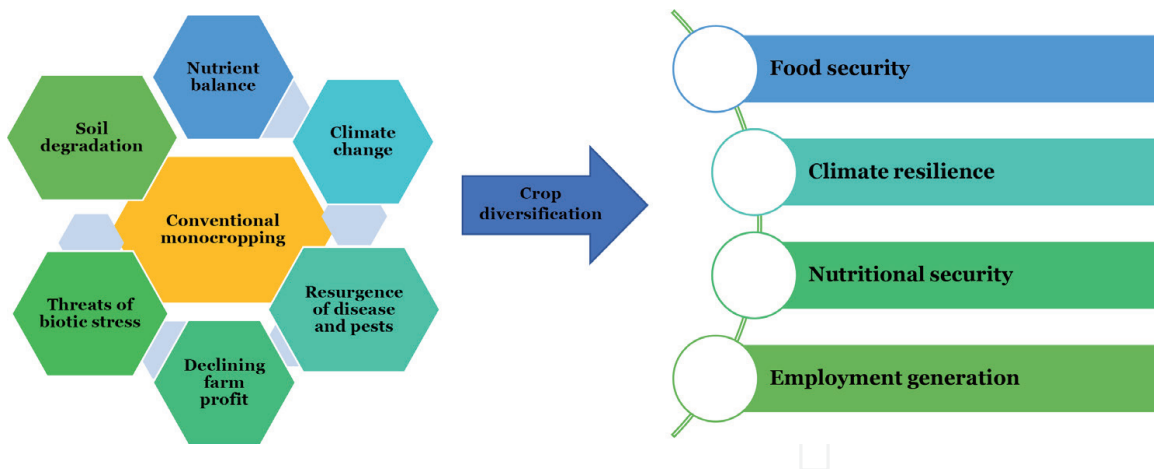


Figure 1.
Basic concept of crop diversification.

spatial, temporal, value addition, and resource-complementary techniques, as well as a move from traditional and less-remunerative crops (**Figure 1**).

3. Trends of agricultural diversification in South Asian Countries

South Asia has a long history of intensive agriculture, particularly irrigated rice cultivation techniques. Sector strategies in the region are mostly based on food self-sufficiency policies [14]. Throughout the last 30 years, the system's research and agricultural support services have increased food production faster than population expansion and diminished the percentage of people living in poverty. There has been significant income increase, diet diversification, and decreases in per capita grain intake throughout the comparable time span. South Asian countries are actively diversifying their economies in favor of high-value commodities such as fruits, vegetables, livestock, and fisheries, with some inter-country variation. Price policy, infrastructure development (particularly markets and highways), urbanization, and technical advancements all have a significant impact on agricultural diversification. Agricultural diversification in favor of high-value crops by substituting inferior coarse grains has helped rainfed areas more [15]. Agricultural diversification is also helping to increase export markets and create new job possibilities. Using appropriate institutions, it is necessary to properly coordinate the production and selling of high-value commodities. Market reforms in the form of building and strengthening desired institutions through necessary legal changes might go a long way toward encouraging agricultural growth, increasing small farm income, and boosting exports. Diversifying rural production is the process by which families create several livelihoods utilizing different variations of resources and assets in order to be less influenced by changes in the marketplace (such as price decreases) and to secure market stability [16]. So, if a region has high demographic pressure but minimal diversification, low-profit traditional commodities cultivation will increase and the farming frontier will spread, causing deforestation and soil erosion [17, 18]. As a result, investing in agricultural diversification can help to prevent environmental degradation by allowing for the production of a wider range of commercially feasible and productive crops [19]. Various options of crop diversification in South Asian countries are presented in the below **Figure 2**.

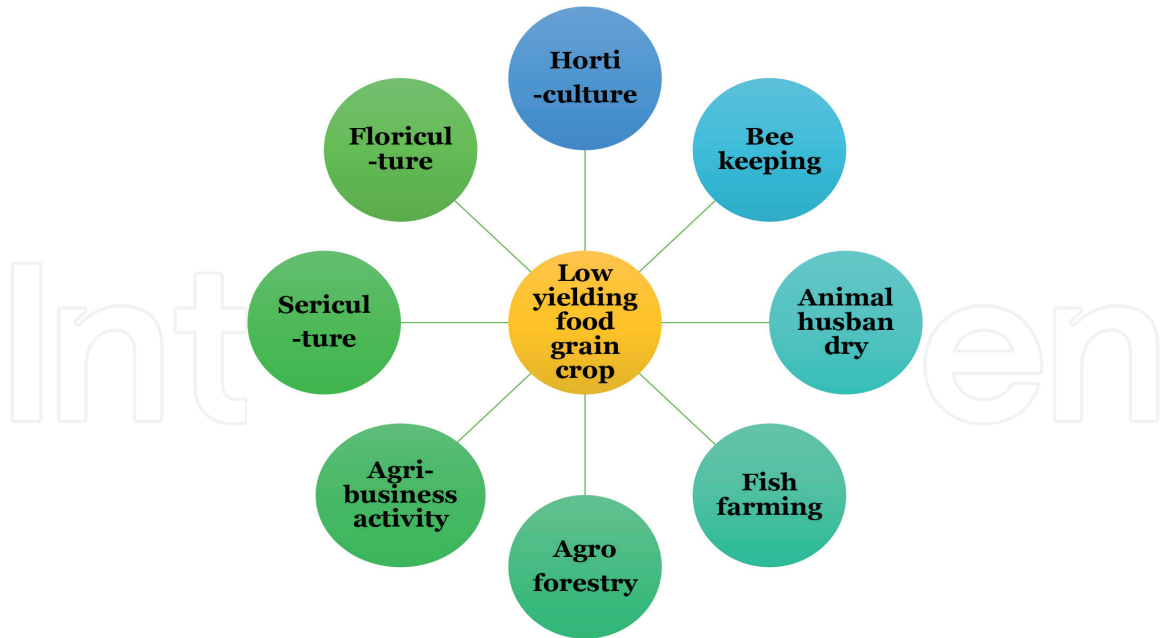


Figure 2.
Various options of crop diversification.

4. Approaches to crop diversification

The next sections examine the many techniques to crop diversification depending on land appropriateness, water availability, and market demand viz. regional, seasonal, and temporal [20]. The different approaches of crop diversifications are presented in **Figure 3**.

4.1 Horizontal diversification

It is done by basically two approaches, through crop substitution and crop intensification. These two approaches have been the two main process of crop diversification. Crop substitution means replacing any crop which is continuously growing as a monoculture crop or gain a tendency of specialization. For example, during green revolution era there was a tendency to growing cereals crops only. Now a days the trend has change a lot in developing countries. Farmers are shifting from monoculture cereals based staple food to high value crops like vegetable, spices etc. There are several advantages of crop substitution which could be higher net returns, improve resource use efficiency (land and labour), break in cycle of pest and disease etc. On

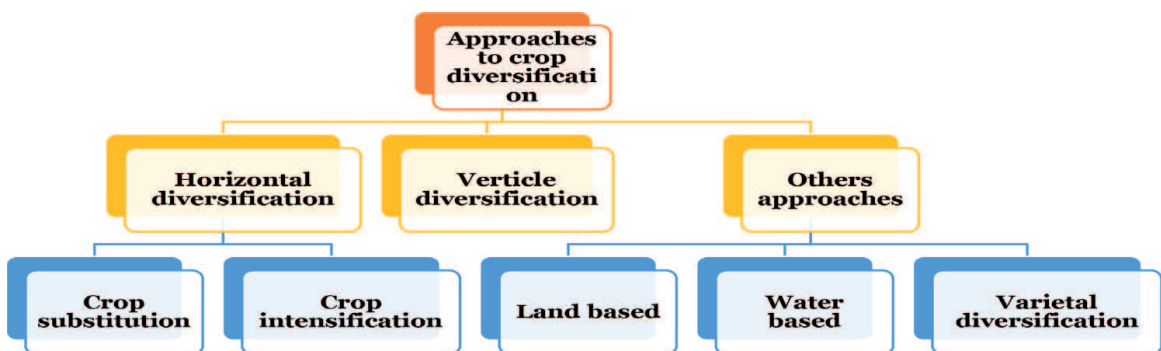


Figure 3.
Different approaches of crop diversifications.

Conventional cropping system	Crop intensification	Advantages	References
Maize-fallow	Maize-rajmash Maize-toria Maize-buckwheat Maize-buckwheat Maize (green cobs)-urdbean-buckwheat	Increased the grain equivalent yield, system production efficiency, relative production efficiency and land use efficiency.	Babu et al. [21]
Transplanted boro-transplanted aman	Wheat-mungbean-T. aman with full tillage Wheat-mungbean- dry seeded aman with strip tillage	Increased land and water productivity, system productivity.	Alam et al. [22]

Table 1.
Example of crop intensification and their advantages.

the other hand, crop intensification is adding of new value crops to existing cropping system to increase the farm's overall productivity. To reap the benefits of agricultural diversification, we must move away from simple crop rotation and toward intensive systems such as multiple cropping, intercropping, relay cropping, and so on. Crop intensification helps in job opportunity, profitability and energy use efficiency [21]. Some examples of crop intensification and their advantages are discussed in **Table 1**.

4.2 Vertical diversification

Vertical crop diversification, on the other hand, represents the degree and level of industrialization of agricultural production. In this approach famers and others add value to products through packaging, processing, regional branding, merchandizing to improve the marketable value of crops. Food crop vertical diversification is also described as the extension of post-harvest activities, such as processing and transformation industries, to allow food crops to be sorted, graded, processed into both food and industrial products, packed, stored, and transported to domestic or export markets [23]. The rise of processing and transformation industries appears to be the most important factor in rural areas in terms of creating revenue and jobs. To boost crop yields and income creation at the local, regional, and national levels, both types of diversification (*i.e.*, multiple cropping or horizontal diversification and agri-business or vertical diversification) will be required. The concept of vertical diversification is presented in the **Figure 4**.

4.3 Others approaches

- Land based approach
- Water-based approach
- Varietal diversification
- Diversification for nutritional security
- Diversification for nutrient management
- Diversification for pes management
- Diversification for mitigation and adaption of climate change

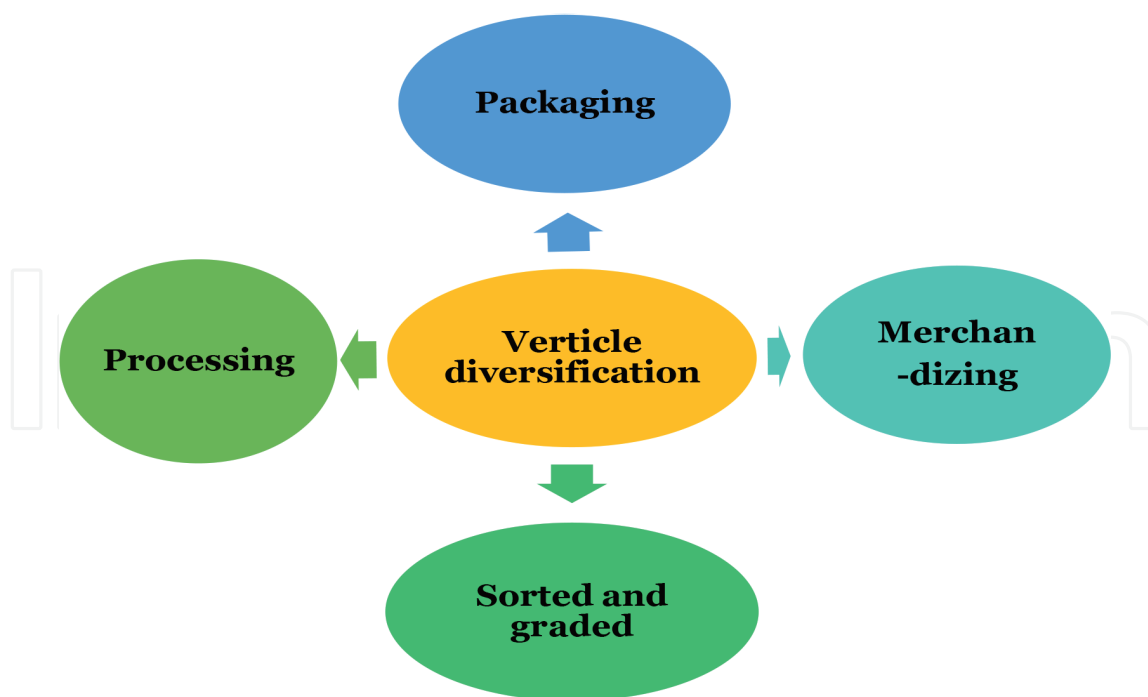


Figure 4.
Options of vertical diversification.

5. Measure of crop diversification and its characterization

Different measurements of crop diversification and their characterization are depicted in the **Table 2** [24].

Measure of crop diversification	Characterization
1. Temporal crop diversification	
Crop rotation	Growing of two or more different crops by one after another in consecutive ways
Catch crop	Growing of crops to in between the space of two main crop or when no main crops are being grown
Double or multiple cropping	Growing two or more crops in one growing season
Relay cropping	In relay cropping second crop is grown in standing crop before the first crop is harvested
2. Spatial crop diversification	
Alley cropping	It is an agroforestry system in which food crops are grown in alleys formed by trees
Intercropping	Growing two or more crops simultaneously on the same land with definite pattern
Mixed cropping	Growing two or more crops simultaneously in the same field
Variety mixture	Growing two or more varieties of a same species
Trap	Growing commercial and non-commercial crop simultaneously in the same land

Table 2.
Measure of crop diversification and its characterization.

Country	Simpson index of diversification in triennium ending			Sources of diversification (%) (1991–1992 to 1999–2001)	
	1981–1982	1991–1992	1999–2000	Cropping intensity	Crop substitution
Bangladesh	0.39	0.36	0.35	64.67	35.33
Bhutan	0.37	0.48	0.44	97.82	2.18
India	0.61	0.65	0.66	36.63	63.37
Maldives	0.77	0.77	0.77	83.22	16.78
Nepal	0.39	0.40	0.41	84.79	15.21
Pakistan	0.54	0.56	0.57	76.56	23.44
Sri Lanka	0.76	0.77	0.75	78.90	21.10
South Asia	0.59	0.63	0.64	42.98	57.02

Table 3.
Extent of diversification and sources of diversification in South Asian countries.

6. Crop diversification pattern in South Asian Countries

Extent of crop diversification pattern, Simpson index and sources of crop diversification is presented in **Table 3** [15].

7. Major driving forces for crop diversification

High-value commodity production is driven by demand, which is primarily determined by rising income and urbanization. The major drivers of crop diversifications are discussed in **Figure 5**.

1. Rapid urbanization of developing countries is one of the biggest reasons of crop diversification. Urbanization puts pressure on land resources, a small number of farmers requires to produce for a larger number of consumers.
2. Change in consumers demand due to shifting from a diet-based staple to nutrient rich animal products, fruits and vegetables.
3. Improving nutritional benefits by diversifying the monoculture of traditional cereals crop.
4. Climate change
5. Value addition
6. Export potential
7. The key driver in altering production portfolios in favor of high-value commodities is road and market. They connect the producer and the consumer directly, reducing transportation and transaction costs. Mostly in case of perishable items, they lessen the danger of post-harvest loss [15].

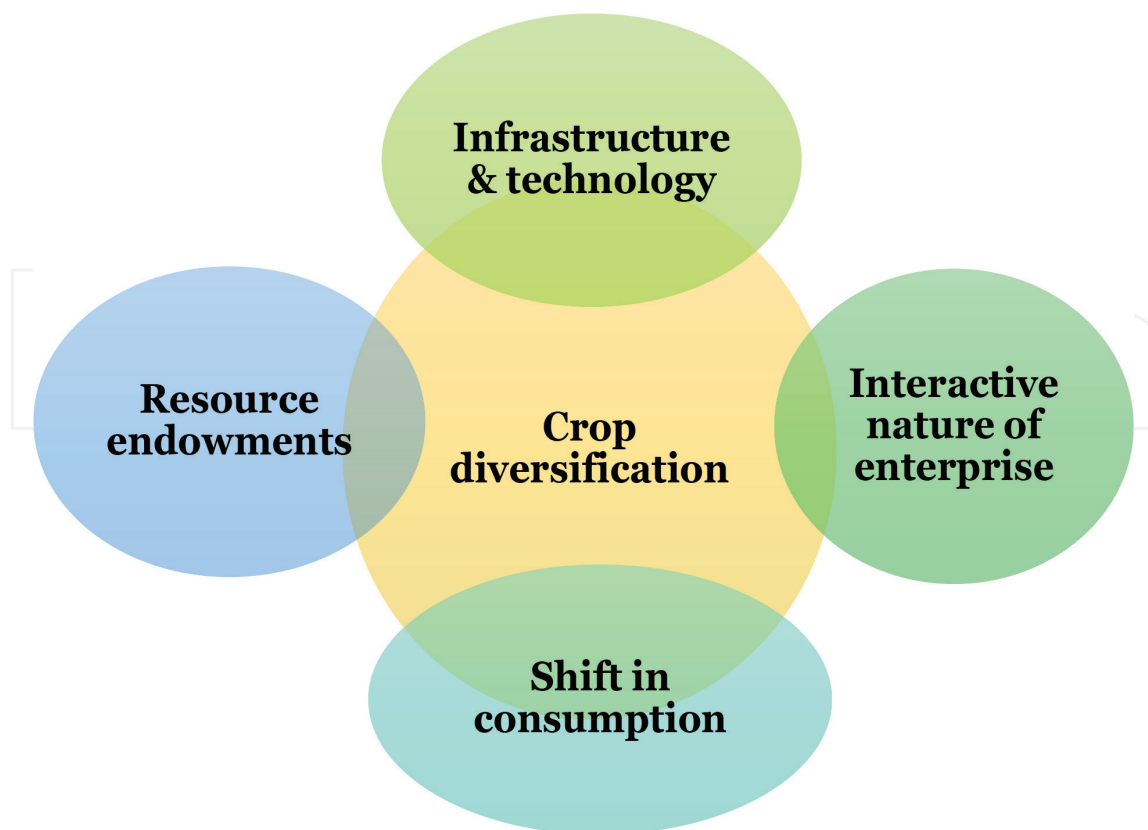


Figure 5.
Factors determining crop diversification.

8. Technology innovation may be a powerful driver for fostering agricultural diversification and accelerating agricultural growth. The fundamental driver of the 'Green Revolution' of the 1970s was biological technology [15].

9. Changing in governmental policy

10. Resilience and stability in production system.

11. Higher profitability

8. Need for crop diversification

1. Nutritional food security and quality of life can be improved through diversification in food basket.

2. Food security

3. Poverty alleviation

4. Employment generation

5. Trade needs

6. Protecting the environmental degradation by reversing the decline trend in soil productivity and ground water table.
7. Income growth
8. Ecological balance
9. Sustainability of natural resources

9. Strategies for crop diversification

1. Shifting from low yielding low value crops to high yielding high value crops.
2. Shifting toward higher water requirement crop to lower requirement crops.
3. Shifting toward low energy efficient crop to higher energy crop
4. Inclusion of legumes and oilseed crops
5. Inclusion of crop which has national and international market demand.

10. Advantages of crop diversification

10.1 Increasing the profitability of small farm holdings

The domination of marginal and small farmers is one of the primary issues confronting India's agricultural sector. These household makes up the majority of the rural population. Due to their low operating base, increasing the production of existing crops (staple food crops) may not be enough to boost their earnings. Therefore, diversifying the traditional cropping system is a best option to enhance income of small and marginal farmers.

10.2 Employment generation

Employment generation is a significant role of agriculture. But adopting the conventional cropping system like rice-wheat generally leads to lack of employment during off seasons. According to a number of studies, there is a serious problem of seasonal unemployment in different regions of our country, which leads to seasonal migration of labours/farmers to surrounding cities/towns in quest of contractual work [25]. Crop diversification helps rural households to have more opportunities of full-time employment.

10.3 Natural resource conservation and enhancement

Diversification is required to recover and enhance the value of the deteriorated natural resource base. Farmers in eastern India, particularly in West Bengal adopted

wheat into a primarily rice system to take advantage of leftover moisture and so minimizes the need for wheat irrigation. In Punjab, on the other hand, an injudicious crop-mix, such as wheat-rice, has exacerbated the problem of water logging and salinity.

10.4 Improving export potential

To increase export potential, it is very much essential to adopt diversification in cropping systems. Such factors have weighed heavily on the minds of farmers in eastern India, particularly in West Bengal, where wheat has been introduced into a primarily rice system to take advantage of leftover moisture and so minimizes the need for wheat irrigation.

10.5 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 improve their food security and income generation while also protecting the environment [26].

10.6 Pest and disease control

Crop diversification, which favors species combinations over monocultures, is one of the most cost-effective ways to combat pests and disease, and it has sparked a lot of attention in recent years [27].

10.7 Improvement of soil fertility

One of the most important constraints for sustainable crop production is low soil fertility. In smallholder systems, poor farming practises, mostly continuous cropping with limited external inputs, have gradually depleted soil fertility. Interaction of crop species with beneficial soil biota helps in maintaining biogeochemical cycling of both organic and inorganic nutrients in the soil and maintaining soil quality [28].

11. Review of literature

Kasem and Thapa during 2011 conducted a study in Thailand, collecting primary data from 245 farm households using a structured questionnaire to examine the impact of crop diversification on income and input consumption. They discovered that the vast majority of farmers stated that crop diversification contributed to a significant rise in their revenue [29]. The results of their research findings are depicted in **Table 4**.

Birthal et al. studied into the impact of crop diversification on India's farm poverty. Data from a nationally representative survey was used. The dataset, according to them, contains information on the crops grown, as well as the costs and returns

Opinion	Frequency (n = 81)	%
Increased income	68	84
Enhanced food sufficiency	54	66.7
Flow of income throughout the year	43	53.1
Offers opportunity to produce crops according to market demand	12	14.8
Smoothens the effect of price fluctuation	10	12.3

Table 4.
Diversified farmers viewpoint about benefits of crop diversification.

Crops	Marginal ≤1 ha	Small (1–2 ha)	Medium (2–4 ha)	Large >4 ha	All
Total cereal	9044 (456)	7099 (256)	7518 (403)	6164 (599)	8301 (304)
Fruits	37,347 (9283)	51,859 (19,187)	36,726 (13,289)	30,433 (13,585)	39,523 (9566)
Vegetable	22,423 (3100)	19,226 (1748)	20,641 (2402)	19,114 (4657)	21,459 (1852)
High value crops	25,618 (2486)	22,329 (2292)	21,411 (2834)	21,518 (4014)	24,263 (2091)

Figures in parentheses are standard errors. Total cereals include rice, wheat, maize, and coarse cereals like pearl millet, sorghum, and barley. High-value crops include vegetables, fruits, condiments and spices, flowers, aromatic and medicinal plants, and plantation crops like tea and coffee. One US\$ = 47.62 in the survey year i.e., 2002–2003 [30].

Table 5.
Comparison of net returns (Rs ha⁻¹) from higher value crops with other crops by crop diversification.

associated with each crop. This allows us to investigate the pattern and breadth of high value crop diversification across land sizes, as well as their profitability in comparison to other crops. In comparison to other crops, **Table 5** shows the estimated net returns per hectare from high value crop cultivation. When compared to cereals, high value crop (HCVs) provided much higher returns to all types of farmers, including marginal farmers [30].

Despite differences between countries, rural households in the majority of countries tend to rotate a small number of crops. Two, three, or a maximum of four agricultural products are the most common combinations used by households. Few households grow more than six distinct crops, most likely due to the small size of their allotment and the inherent challenge of producing many goods viz. water requirements, necessity of sun exposition and type of soil, among others. An empirical evidenced from eight different countries were analyzed and presented in **Table 6** [31].

Diversification of crop through intercropping system has significant advantage in land use efficiency, monetary returns and crop productivity as compared to monocropping. Intercropping results in more efficient use of solar energy and harnessing benefits of positive interactions of crop association. Benefits of some potential intercropping system are discussed in below **Table 7** with regards to system productivity, net returns and B:C ratio.

Number of crops produced and share of households (% of total national sample) producing each number									
Country and year	1	2	3	4	5	6	7	≥8	Total
Malawi, 2004	11	21	23	20	13	6	3	3	100
Nepal, 2003	3	25	8	18	8	10	3	25	100
Vietnam, 1998	7	7	8	8	9	7	8	46	100
Pakistan, 2001	22	61	15	2	0	0	0	0	100
Nicaragua, 2001	6	19	20	17	11	9	7	11	100
Indonesia, 2000	28	29	25	11	4	2	1	0	100
Albania, 2005	11	31	15	14	8	9	3	9	100
Panama, 2003	36	38	19	6	1	0	0	0	100

Table 6.
Share of household practicing different numbers of crops (an empirical evidence from eight developing countries) [31].

Intercropping system	Location	System productivity (t ha ⁻¹)	Net returns (×10 ³ ₹ ha ⁻¹)	B:C ratio	References
Chickpea + Indian mustard	Kanpur, India	2.4	17.1	2.4	[32]
Sugarcane + Maize	Pantnagar, India	200.6	124.9	1.90	[33]
Wheat + Mustard	Kangra, India	4.7	26.7	2.55	[34]
Maize + Potato	Pusa, New Delhi	14.0	35.7	2.14	[35]
Ratoon cane + Berseem	Lucknow	90.8	56.2	2.64	[36]

Table 7.
Economics of intercropping system for crop diversification.

12. Constrains of crop diversification

These are primarily socioeconomic and institutional barriers, such as the lack of holding consolidation and group farming, geographic disadvantages (remote areas far from shops and supermarkets), farmer 'lack of education, the outright failure of the agricultural extension system, and a lack of transportation and marketing facilities.

1. Lack of salt and excess moisture tolerant crops and cultivars.
2. Lack of skill and knowledge in choosing alternate crops in cropping system
3. Small and fragmented land holding creates difficulty to ensure that they participate more fully in crop diversification.
4. Agricultural output is used as a raw material in agro-based industries. When monoculture becomes unsustainable, a more sustainable and profitable crop must be substituted. Because of massive infrastructure expenditure, switching over becomes difficult by that time; for example, the rice industry in Punjab and Haryana, the sugarcane industry in Uttar Pradesh, and the soybean industry in Madhya Pradesh states in India.
5. The major causes of high cost of production are rising wage rates and declining factor productivity. The researchers are being challenged to reduce the cost of production and produce new adaptive cultivars that can capture high market prices.
6. Over use and sub optimal use of natural resources like water and land resources, may negative impact on environment and sustainability.
7. Weak research-extention and farmers linkage.
8. Lack of knowledge among the farmer

13. Lack of concept of Crop diversification

Though there are hundreds of scientific papers in the field of agronomy on agricultural diversity such as crop rotation or intercropping, only a small percentage of these studies are about diversification as a concept [21].

14. Conclusion

Diversification is one of the most effective ways to boost farm revenue, resulting in increased food, nutrition, and environmental security, as well as poverty reduction in developing countries. It creates a tremendous impact on agro-socio-economic gains.

- It increased the flow of income throughout the year.
- Offers opportunity to produce crops according to market demand
- Smoothens the effect of price fluctuation
- Increase the grain equivalent yield, system production efficiency, relative production efficiency and land use efficiency of maize-fallow system.

15. Future prospects for the adoption of crop diversification

- Overall potential of crop diversification is yet to be studied.
- Impact of crop diversification on rural economics and poverty alleviation needs to be investigated in details.
- Effect of crop diversification on soil health properties needs to be studied in details.
- Social benefits of crop diversification are less well known.

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