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"Economic Growth and Sustainable Development" during 25-26 November, 2021

and presented a paper titled

Impact of Agricultural Transformation on Sustainable Agricultural Growth

and the paper was co-authored with

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sdmimd 6th International Conference on "Economic Growth and Sustainable Development: Emerging Trends *November 25-26, 2021, Mysuru, India*

Impact of Agricultural Transformation on Sustainable Agricultural Growth

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Abstract

For decades together agriculture and the agricultural sector have been the backbone of Indian society, and it continues to contribute towards the economy in today's time too. When we go back to Indian history and examine the agricultural practices, then it could be noted that, it was more about land labor and capital and not much importance was attached to the quality of seeds used for production, innovations etc. So, it could be stated that the traditional and outdated methods of cultivation did not contribute much towards agricultural transformation in the earlier time phase, but since the late 1960s onwards agricultural transformation took pace with more stress on agriculture and land reforms, and innovations taking place on the other side, it contributed to use of high yielding varieties of seeds, cultivation of cash crops, use of fertilizers and pesticides, irrigation etc.

Now as transformation is taking place the question that arises is that of sustainability or sustainable development, as the term implies, meeting the needs of the present generation without compromising the ability of the future generations to meet their needs. Thus, the objective of this paper is:

1. To analyze agricultural transformation, and the shift towards sustainable agricultural growth.
2. To examine the land use patterns and changing trends.
3. To analyze the impact of crop diversification
4. To analyze the impact of use of fertilizers on the fertility of the soil and also on the output of agricultural production and sustainability

ISBN: 978-93-83302-50-5

Keywords: *Agriculture Transformation, Sustainable Agriculture, Cropping Pattern, Land use Pattern and Crop Diversification*

Introduction

The primary source of livelihood for more than 58% of India's population is agriculture. Thus, it contributes significantly to the Indian economy and accounts for about 18% of India's GDP. Indian agriculture is evolved over a period of time, say, for instance, the pre-Harappan technology was used by the Indus Valley Civilization, and they cultivated rice, peas, etc. they also indulged in rainwater harvesting as a result of which they were in a position to sustain during the dry seasons. The practice of mixed farming and irrigation systems emerged in the Indus Valley Civilization. The crops also included varieties of cereals, fruits, and vegetables.

Going by History, The Mauryan Empire categorized soils and made meteorological observations, which came as an aid for agricultural activities. They also facilitated the construction and maintenance of dams and also introduced horse-drawn chariots in place of bullock carts. Down South, people cultivated a variety of crops like rice, sugarcane, millets, black pepper, palm, jackfruits, etc., and systematic ploughing, manuring, weeding, and crop protection were practiced.

During the British period, there occurred changes in agricultural cultivation partly due to the introduction of the land revenue system, which disintegrated the village community, and partly due to the commercialization of agriculture, as it led to the exploitation of the Indian peasantry. According to Daniel and Alice Thorner; 'the zamindari system made the landlords masters of the village communities, the ryotwari system cut through the heart of the village communities by making separate arrangements between each peasant cultivator and the state. This helped in the concentration of economic power in the hands of landlords and moneylenders and handicapped agriculture and the peasantry. The commercialization of agriculture led to the substitution of food crops with commercial crops which in the long run led to a fall in food production.

At the time of Indian independence, she had a severe problem of the food crisis and it went to the extent of importing food grains from other countries. And thus, agriculture was given significant importance in the post-independence period which can be symbolized by various reforms and policies, and significant being land reforms. Thus, the green revolution was basically the outcome of the systematic planning to improve the agricultural sector, which led to the utilization of modern available technology for agricultural production, the introduction of a high-yielding variety of seeds, fertilizers, and pesticides, mechanization of farming, etc.

Agricultural transformation can be understood as a process in which there is increased farm productivity, which in turn makes it commercially viable and also strengthens the interlinkages with other sectors of the economy. As we say agricultural transformation literally means that, the peasant class has better access to financial resources, modern tools of production, ownership of land, etc. But if we take into consideration India alone it can be stated that India still has problems with equal access to financial resources for the farming class, and also the modern tools of production are also not equally distributed and when it comes to land holdings, they are either small or scattered, making it literally unprofitable.

ISBN: 978-93-83302-50-5

The transformation in the agricultural sector literally means that there is a mechanization in agriculture. Mechanization in agriculture consists of using modern tools and equipment from cultivation to the harvesting of crops. Mechanization helps in increasing the economic benefits for the farmers as it reduces the input cost and increases the value of output. At the same time, it also helps in the diversification of the crops.

When we examine the transformation of the agricultural sector it should be noted that the pre-green revolution period between 1950/51 to 1967/68 was characterized by a sharp decline in the growth of GDP in agriculture and the decadal growth plummeted from 2.8% to 1.06%. The impact of the green revolution which was initiated in the year 1966, and the adoption of advanced technology and several institutional reforms had a positive impact as the decadal growth neared 3% by the decade 1985/86. There began deceleration of growth from the year 1997 onwards with a clear indication of slumping of the agricultural sector and the slump is basically perceived as an outcome of substantial diversion of resources away from agriculture to other sectors of the economy. And it could be stated that there was a deceleration of the agricultural sector in the post reforms period and an unambiguous turnaround in the last five years that is basically the eleventh five-year plan period.

In the last few decades, the country has witnessed a drastic structural transformation with the contribution of the agricultural sector in GDP declining to around 15% from 51% in the 1950s. But it has also to be noted that, despite the decline in its contribution to GDP, the agricultural sector still houses more than 50% of the workforce in India.

Agricultural Transformation and Sustainable Agricultural Growth

Sustainable agriculture refers to farming practices that meet society's current food and textile needs without jeopardizing current or future generations' ability to meet those needs. It could be founded on a knowledge of ecological services. There are a variety of approaches that can be used to improve agriculture's long-term viability. It is critical to building flexible business processes and farming methods while developing agriculture within sustainable food systems. Agriculture has a massive environmental impact, contributing to climate change, water scarcity, water pollution, land degradation, deforestation, and other processes; It is both causing and being impacted by environmental changes at the same time. Sustainable agriculture refers to farming methods that are favourable to the environment and allow for the production of crops or livestock without causing harm to human or natural systems. It entails avoiding negative consequences for soil, water, biodiversity, nearby or downstream resources, as well as individuals working or living on the farm or in the surrounding environment. Permaculture, agroforestry, mixed farming, multiple cropping, and crop rotation are all examples of sustainable agriculture.

The transformation of the Indian agricultural sector has been driven by several factors, in many instances similar to experience worldwide. These include supply-side factors such as policies to push growth, better and efficient use of resources like land and labor; introduction of new technology and increased use of modern inputs like chemical fertilizers and expansion of irrigation infrastructure; and, investments in general infrastructure like roads, power as well as demand-side factors such as population, income growth, urbanization, and demand from the rest of the world through gradual liberalization of international trade. Here we shall discuss a few factors which are considered to be the important factors for sustainable growth in the agriculture transformation.

ISBN: 978-93-83302-50-5

sdmimd 6th International Conference on "Economic Growth and Sustainable Development: Emerging Trends *November 25-26, 2021, Mysuru, India*

Cropping Pattern in India

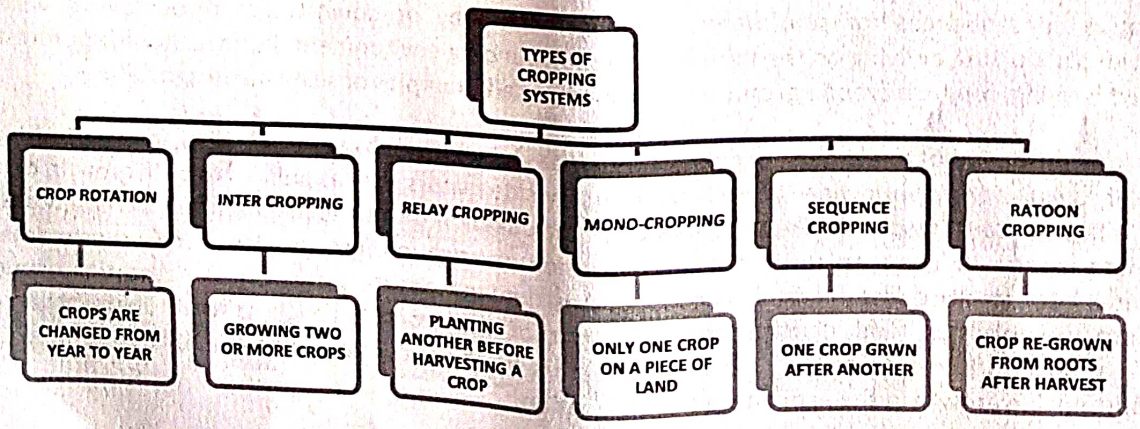
Cropping System: by the term cropping system we refer to crop sequences and management techniques used on a particular agricultural field over a period of years. The objective of the cropping systems is efficient utilization of all resources like land, water, etc., and maintaining stability in production. Cropping systems are inclusive of cropping pattern and it refers to the proportion of area under various crops at a point in time and it basically involves crop rotation, yearly sequence, and spatial arrangement of crops.

Cropping pattern helps to increase soil fertility, that is to say, prolonged planting of the same crop type results in the depletion of specific nutrients in the soil, and thus crop rotation helps in increasing soil fertility by controlling deficient or excess nutrients as it replenishes nutrients that are not available or absorb nutrients that are in abundance. It could also increase the crop yield as some scientific investigation shows a 10-25% increase in crop yield due to crop rotation. Further, it helps the soil in increasing its nutrients, as cropping pattern allows the land to regenerate and rejuvenate its nutrients without the overt use of fertilizers, which further prevents soil compaction, thus improving the physical condition of the soil as well as soil texture, which results in better scope for healthy seed germination and root proliferation.

One of the most distinguishing characteristics of Indian agriculture is the diversity of cropping systems, which may be linked to rain-fed agriculture and the socioeconomic conditions of the farming population. More than 250 double-cropping systems are thought to be in use across the country, and 30 major cropping systems have been recognized based on the justification for crop spread in each district.

Cropping systems in a given region are mostly determined by a variety of soil and climatic elements that define the overall agro-ecological setting for nutrition and the suitability of a crop or group of crops for production.

Nonetheless, prospective productivity and monetary rewards serve as guiding ideas for farmers when selecting a crop or cropping system. These choices of crops and cropping systems are further narrowed by the effect of a number of other elements, including infrastructure, socioeconomic conditions, and technological improvements, all of which interact at the micro-level.



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Based on some homogeneity and commonness, major crops regions in India may be divided as Rice Region, Wheat Region, and Jowar –Bajra Region, Cotton Region, Millet and Maize Region, Fruit and Spice Region. With the introduction of modern agricultural technology, India's cropping patterns underwent many modifications, particularly during the Green Revolution in the late 1960s and early 1970s. There has been a steady increase in the demand for varied agriculture in terms of crops, owing to economic reasons. Crop pattern changes, on the other hand, are the result of the interaction of several elements that can be divided into five categories:

1. Irrigation, rainfall, and soil fertility are all resource-related factors.
2. Factors relating to technology include not only seed, fertilizer, and water technologies, but also marketing, storage, and processing.
3. Food and fodder self-sufficiency requirements, as well as investment capacity, are household-related issues.
4. Price-related factors include output and input prices, as well as trade and other economic policies that directly or indirectly affect these prices.
5. Farm size and tenancy arrangements, research, extension, and marketing systems, and government regulatory policies are all examples of institutional and infrastructure-related variables.

Table 1 and 2 shows the area (in million hectares) and production (in million tonnes) of major crops

Table.1: Year wise area under major crops from 1950 -51 onwards.

CROPS	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11	2018-19
RICE	30.81	34.13	37.59	40.15	42.69	44.71	42.86	43.79
WHEAT	9.75	12.93	18.24	22.28	24.17	25.73	29.5	29.14
PULSES	19.09	23.56	22.54	22.46	24.66	20.35	26.40	29.03
FOOD GRAINS	97.32	115.58	124.32	126.67	127.84	121.05	126.67	123.94
OILSEEDS	10.73	13.77	16.64	17.60	24.15	22.77	27.22	25.50
SUGARCANE	1.71	2.42	2.62	2.67	3.69	4.32	4.88	5.11
COTTON	5.88	7.61	7.61	7.82	7.44	8.53	11.24	12.66

(Sources: Directorate of Economics and Statistics)

Table.2: Year wise production of major crops from 1950-51 onwards.

CROPS	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11	2018-19
RICE	20.58	34.58	42.22	53.63	74.29	84.98	95.98	284.95
WHEAT	6.46	11.00	23.83	36.31	55.14	69.68	86.87	116.42
PULSES	8.41	12.70	11.82	10.63	14.26	11.08	18.24	23.40
FOOD GRAINS	50.82	82.02	108.42	129.59	176.39	196.81	244.49	284.95
OILSEEDS	5.16	6.98	9.63	9.37	18.61	18.44	32.48	32.26
SUGARCANE	57.05	110.00	126.37	154.25	241.05	295.96	342.38	400.16
COTTON	3.04	5.60	4.76	7.01	79.84	9.52	33.00	28.71

(Sources: Directorate of Economics and Statistics)

ISBN: 978-93-83302-50-5

Land use Pattern in India

Land is the most vital resource for human survival. The grouping of land uses for various reasons is known as a land-use pattern. Forests, land not suitable for cultivation, cultivable wastelands, fallow land, and net area sown are the most common land use patterns in India. Humans and physical factors influence how land is used. Physical factors mainly depend on the nature of lands, such as topographies, climate, and soil types, and so on, and human factors dependent on human activities and usage, including population density, culture and customs, and technical competence.

Because of the rising demand for land for agriculture and industrialization, the amount of land under forest has remained constant since 1960-61. The Green Revolution resulted in the expansion of agricultural as well as forest removal. Forests cover only 21.67 percent of India's land area, although they should cover 33 percent ideally. Forest acreage has also decreased as a result of industrialization and urbanization. As the population grows, so does the need for housing, resulting in deforestation and a reduction in the country's forest cover. Almost 54% of India's land area is now suitable for cultivation, with 25% of it being wasteland and 3% being grassland. The remaining acreage is being developed for urban use. As a result of all of these reasons, the amount of area covered by forest has remained relatively constant since 1960-61.

- Forest area: Only 40.48 million hectares (14.2 percent) of India's land was covered in forest in 1950-51. In 2017-2018, however, it was increased by 24.39 percent to 80.20 million hectares. The forest's reporting area must be 33.3 percent of the overall land area, according to National Forest Policy 1952. The proportion of forestland in the country is not evenly distributed.
- Land not available for cultivation: This category includes terrain utilized for human habitation, transportation lines, canals, quarries, mountains, deserts, marshes, and so on. It makes about 12.11 percent of India's total land area.
- Fallow areas and other uncultivated lands: Permanent pasture and other grazing areas, land under various trees, crops, groves, and cultivable waste all fall into this group. This category accounts for around 8.6% of the country's total reporting land.
- Fallow land: a land that hasn't been used for cultivation in the last three to five years. It is possible to nurture it. It makes up roughly 8.13 percent of India's total land area.
- Net sown area: India's net sown area accounts for 46.2 percent of the country's total reported land. During the last five decades, the net area seeded has increased dramatically. The reclamation of barren, uncultivable land, pasture land, and other areas has resulted in this growth. According to the 2013-14 land use data, the country's overall geographical area is 328.7 million hectares, with 141.4 million hectares of reported net sown area and 200.9 million hectares of gross cropped area, with a cropping intensity of 142 percent.

The land is an earth's surface with all the physical, chemical, and biological features that influence the use of resources. Land use can be sustainable only if it protects biodiversity and preserves the eco-balance of the entire system. So, land use that restricts or limits the interaction among soil, water, and atmosphere and causes a degradation in the habitat standards vital to the biological diversity of flora and fauna cannot be considered to be sustainable. Thus, sustainable land use is inclusive of technology, policies, and activities aimed at integrating socio-economic principles with environmental concerns to enhance productivity, to enhance the soil capacity and reduce the level of production risk, to protect the potential of natural resources, and to prevent degradation of soil and water quality and to be economically viable.

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So sustainable land use refers to continuity, durability, and equity in the exploitation of natural resources over longer periods, and it refers to the methods by which land is managed, that is through crop rotation, tillage, etc which aims at preserving or restoring the quality and fertility of the soil. And sustainable land management is significant for sustainable agricultural development. And sustainability can be achieved only through the collective efforts of all those involved in managing resources as it requires a policy that empowers the farmers and other decision-makers to provide benefits for good land use and penalize inappropriate land use. Integration of economic and environmental interests is also required for sustainable land management, and it can be done by giving due consideration to environmental concerns in assessing the impact of economic development. As balanced land management can contribute to economic as well as environmental well-being. And all of these depend on soil and land quality. Soil quality can be defined as the capacity of a specific soil to function within natural or managed ecosystem boundaries to sustain plant and animal production, maintain or enhance water quality and support human health and habitation. On the other hand, land quality is the condition, state, or health of the land relative to human requirements, including agricultural production, forestry, conservation, and environmental management.

From the Indian scenario, it should be noted that the soil has been polluted due to extreme use of chemical fertilizers and pesticides, which in turn could affect the agricultural output in the long run, and hence, along with crop rotation and crop diversification, there should be an attempt to enhance the soil quality and prevent degradation of the soil and its natural nutrients, thus measures should be taken to use more of organic fertilizer for production, keeping in mind the environment as a whole.

Crop Diversification in India and its Impact

Crop diversification in agriculture refers to the shift from regional dominance of one crop to regional production of numerous crops. In another sense, it also refers to the addition of new cropping systems to the agricultural production on one respective farm by taking into consideration the economic returns and the market opportunities. The term cropping system refers to crop sequences and management techniques used on a particular agricultural field for years. Some of the cropping systems that are widely followed are sequential cropping, mono-cropping, intercropping, mixed cropping, etc. Crop diversification is an outcome of several interactive factors like environmental factors, technological factors, price factors, institutional and infrastructural factors, etc., and the adoption of different crops is influenced by these factors.

The diversification of farms tends to be economically and ecologically resilient. By diversifying their farms, the farmers are less susceptible to the price fluctuations associated with changes in demand and supply. There are two approaches to crop diversification in agriculture. They are horizontal diversification in which *diversification is done by adding the new high value of crops to the pre-existing cropping system*, in simple words it refers to cultivating multiple crops instead of one single crop in a given piece of land. The second approach is the vertical diversification approach, which refers to the incorporation of industrialization along with multiple cropping here they are also in western horticulture livestock rearing etc. further the farmers add value to the products through processing, regional branding, packaging, merchandising, etc.

The reasons for agricultural diversification could be due to several factors like climate change, increase income to support the standard of living, and export purposes. It could also be done because it helps in the reduction of risk factors concerning the investment by the farmer, as crop diversification ensures that the farmer doesn't lose the entire investment as harvesting of multiple crops in a given field could help in substituting the loss incurred due to the failure of other crops or any other factors. It also helps in the

ISBN: 978-93-83302-50-5

conservation of natural resources like the introduction of legume bin rice-wheat cropping systems that can fix atmospheric Nitrogen and help sustain soil fertility.

The diversification of crops also faces certain challenges as the majority of the cropped area is highly dependent on rainfall and on the other side overuse of resources like land and water harms the environment and sustainability of agriculture. Further inadequate supply of seeds and plants, fragmentation of landholdings, poor harvest technologies, decreased investment in the agricultural sector, lack of training all come as barriers for effective diversification of crops and bloom of the agricultural sector. It could also be noticed that changes in crop patterns have also contributed to serious environmental crises, like depletion of the groundwater level, loss of fertility of the soil, waterlogging, and salinity. There was a departure from the traditional subsistence nature of agriculture as the green revolution progressed and non-remunerative or low-yield crops were replaced with non-food crops that fetched higher market prices. Another trend that could be observed is that the farmers resorted to horticulture, sericulture, apiculture, etc. And this resulted in the decline of the area under food crops. All these aspects could reduce productivity and could also affect the sustainability of agricultural practices.

Use of Fertilizers and Its Impact on the Fertility of Soil

Fertilizers are chemical substances that are used in agricultural production to increase productivity. Fertilizers can be artificial or natural. The fertilizers consist of nitrogen, phosphorus, and potassium which are referred to as primary or macronutrients, as they are required by the plants in large amounts and have an impact on the plant growth in the soil system. It also includes Sulphur, magnesium, and calcium and they are referred to as secondary nutrients as they have less impact on growth factors in the soil system. The use of fertilizers helps in boosting the growth of plants, for instance, fertilizers that are rich in nitrogen help to boost plant growth. The Phosphorus elements in the fertilizers accelerate the maturation process. Whereas the potassium helps to reinforce the stalks and straws of plants and thus enhances resistance capacity. Thus, it can be said that fertilizers aid better harvest as it helps in the prevention of chlorosis; a yellowing of plant tissue due to the reduction of the chlorophyll formation, necrosis; the death or dying of plant tissue which could be due to drought, herbicides, etc., delayed flowering, premature falling of leaves and buds, stunted plant growth, etc.

Though chemical fertilizers help in increasing crop production, the overuse has hardened the soil, have also decreased fertility in the long run, and have also contributed to different kinds of pollution, thus contributing to hazardous impact on human and the environment, and thus they pose challenges to the balanced and sustainable growth. These chemical fertilizers contain high amounts of salt in them and they are not just harmful to agriculture but also the soil in the long run and overt use of it depletes nutrients and minerals which are naturally found in the fertile soil. On the other side, phosphorus contents don't dissolve in water and it eventually would lead to the hardening of the soil. And alkaline fertilizers like sodium nitrate reduce the fertility of the soil and could make it barren. Hence for sustainable growth, there is a need for a balanced supply of essential nutrients and minerals and overt use of chemical fertilizers reduces this balance and results in soil degradation and loss of equilibrium of stable soil.

No doubt that chemical fertilizers help in the faster growth of plants but at the same time it should also be noticed that the plants do not get sufficient time or natural time to mature and develop that is to say they could probably have weak root growth, weak stems etc and the chemical fertilizers could also lead to root burn as these fertilizers do not allow sufficient water intake for the plants. And as chemical fertilizers have higher amounts of nitrogen salt and when they are absorbed by the soil too quickly, it

ISBN: 978-93-83302-50-5

could dehydrate and dry up the plants. It further contaminates groundwater. Further, it would also kill the soil-friendly microorganisms.

Now in recent time's bio-fertilizers are sought after replacing chemical fertilizers due to the realization that chemical fertilizers are harmful to not just human life but also the environment at large. Bio-fertilizers are wherein one makes use of different microorganisms, like bacteria or fungi, algae to enhance fertility. And this is considered to be an alternative to chemical fertilizers as it promotes environmentally friendly practices.

Organic-based fertilizers are one of the best solutions for sustainable agricultural practices. It could be noted that the nutrients provided by the organic-based fertilizers follow the natural cycle of nitrogen release in the soil and work in harmony with both climatic conditions and crop growth patterns. They are rich in organic matter which enhances the biological activity of the soil and thus improves and sustains biodiversity. It should be noted that soil is the medium that sustains organisms such as fungi, earthworms, etc. and thus it helps retain the natural nutrients of the soil and thus helps agricultural productivity as well as the wellbeing of the biosphere at large. They also help in transferring atmospheric carbon dioxide into the soil and also impede its emission back into the atmosphere. They play a significant role in soil carbon sequestration in a natural and environment-friendly way. Thus, they also help in mitigating the effects of climate change.

Organic-based fertilizers help to boost the efficiency of water use thus rendering crops more robust and resistant to droughts. They also help improve soil health by maintaining the soil's organic content, which in turn adds to more retention of water and resists erosion and leaching. They are a rich source of organic carbon, which enhances fertilizer efficiency through a slow release of nutrients like nitrogen and phosphorus. Organic liquid fertilizers that are derived from plants and animal manure and make it a sustainable product. The waste from animals such as cows, fish, chicken, etc. are used to make organic fertilizer and these fertilizers provide sufficient nutrients to the plants as well as soil. Thus, it not just provides high economic returns but also helps in the better use of natural raw materials, thus maintaining the environmental balance.

There was a departure from the traditional subsistence nature of agriculture as the green revolution progressed and non-remunerative or low-yield crops were replaced with non-food crops that fetched higher market prices. Another trend that could be observed is that the farmers resorted to horticulture, sericulture, apiculture, etc. And this resulted in a decline of the area under food crops.

Conclusion

Agriculture in India is still one of the largest sources of livelihood and 70% of India's rural households depend primarily on agriculture for their livelihood and at the same time, 82% of farmers are small and marginal farmers. In the year 2017-18, total food grain production was estimated at 275MT. India is the largest producer with 25% of global production and also the largest consumer with 27% of world consumption and importer with 14% of pulses in the world. The annual milk production was 165MT in 2017-18, making India the largest producer of milk. India is also the second-largest producer of rice, wheat, sugarcane, cotton, and groundnuts and also the second-largest fruit and vegetable producer, accounting for 10.9% and 8.6% of the world's fruit and vegetable production.

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Despite all these, India still has many concerns, it should be noted that as the Indian economy began diversifying, the contribution of the agricultural sector began to decline and it has been steadily declining since 1951. Though she achieved food sufficiency in production, she also accounts for a quarter of the world's hunger population and over 190 million undernourished people.

The agricultural production in India is resource-intensive, cereal-centric, and regionally biased. And These resource-intensive ways of Indian agriculture have also contributed to severe sustainability-related issues and the use of chemical fertilizers has polluted all landforms including human life, desertification, and land degradation due to overexploitation and pollution of land also poses a threat to sustainable agricultural growth. On the other hand, the increased feminization of agriculture due to rural-urban migration by men at the same time treating women's work at the farm as an extension of household work and further stress on the production of cash crops also impacts the agricultural sector.

It could be said that the agricultural sector and sustainable development could be intensified by increasing the income of farming households, crop diversification, empowering women, strengthening agricultural diversity and productivity, and subsidiaries for nutrient-rich crops. Further diversification of agricultural livelihoods can also be possible through the promotion of Agri allied sectors such as animal husbandry, forestry, fisheries. All these could enhance livelihood opportunities, strengthen resilience and also contribute to an increase in labor force participation in the sector.

With agricultural transformation, it could be observed that there has been a reduction in input costs, and provision of extra income due to a more diversified pattern of agricultural practices. Organic and natural farming, agroforestry, crop diversification, biodynamic agriculture, and permaculture approach reduce dependency on one livelihood option and improve the income sources. It is observed that organic farming yields can be low, high, or equal for some crops with regional variations. Resource conserving practices like vermicomposting, agroforestry, and contour farming also contribute to increased productivity. Further sustainable agricultural practices also have positive health impacts, as the farmers are less exposed to harmful chemicals, and also reduced chemical fertilizers in the production process also aids in retaining the fertility of the soil. Further, the practice of leaf litter in agroforestry acts as a protective soil cover and reduces soil erosion.

In a country like India which is reluctant to adopt new ways of production, provisions should be made to provide incentives at least in the initial phase of transition from chemical to organic fertilizer, as in the initial phase there could be the risk of lower yields and this could harshly impact small farmers and tenants who depend on the harvest from one season to next. Thus, a lack of incentives in the early phase could make farmers reluctant to adopt sustainable agricultural technology and practices. Apart from this, the lack of a market for sustainable agricultural products also acts as a barrier to its promotion. That is to say, most of the sustainable agricultural practices promote on-farm locally made inputs such as compost, vermicompost, bio-inoculants, bio-pesticides, green manure, etc. The preparation of most of these inputs s time and labour-intensive. Even Though the inputs required for organic and biodynamic farming are readily available from input shops, the market is not developed as of the chemical inputs. Further, the products are expensive due to limited demand and the niche nature of the market. Thus, the lack of readily available organic input is a key constraint for farmers. Further, lack of consistent market linkages to support fair prices for sustainable agricultural products also acts as a barrier, and with a limited market, access would lead to farmers selling their produce through the usual channels where they may not fetch higher prices for chemical-free products.

ISBN: 978-93-83302-50-5

It should be noted that, though natural organic inputs are healthier for plants and soil, their limited availability means that their ability to replace chemical fertilizers is also limited, thus the farmers must be trained in the utilization of organic fertilizer in farming activities. It's also sad that India's agriculture sector has a large carbon footprint, which is about 18% of GHGs emitted. Thus, adopting farming solutions like agroforestry, vermicomposting, and precision agriculture could help in reducing emissions.

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ISBN: 978-93-83302-50-5