

Promotion of Crop- Livestock Integration for Sustainable Resource Utilization

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Abstract— *The Indian economy has undergone structural changes over time with variation in agricultural growth and contribution to agricultural GDP. Although, self-sufficiency in food production achieved at the macro level it is still facing food deficiency in food production. The Green Revolution introduced in 1960s serves as a landmark example of agriculture's transformative role in India's economy. It was successful by introducing high-yielding variety (HYV) seeds, chemical fertilizers, and modern irrigation techniques, significantly increasing the agricultural output. This has not only alleviated the nation's dependency on food imports but also boosted rural incomes with technological interventions to revitalizing agriculture and food security. The conventional agriculture is known to cause soil and pasture degradation because it involves intensive tillage particularly due to intense practice lead to marginal productivity. As a solution farmers, intensify their activities by integrating components of crop and livestock to work more economically feasible and environmentally sound farming. The crop-livestock farming introduced enhanced livestock production with substantial increase of food from animal origin. The integrated farming revolutionized with integration of livestock, aquaculture, horticulture, agro industry and allied activities helped poor farmers to sustain their livelihood with increase farm inputs. Integrative approach that combines with traditional agricultural practices aimed to achieve long-term environmental and socioeconomic benefits with traditional practices of crop rotation, intercropping, organic fertilizers, and water conservation methods. This provides ecological resilience and cost-effectiveness, benefiting small-scale farmers by enhancing soil health, biodiversity and environmental sustainability. The introduction of modern practices such as precision agriculture, modified crops, application of digital tools, and efficient irrigation systems offers productivity and resource management in food security need promotion of traditional knowledge for sustainable agricultural development. The improved integrated crop-livestock system and mixed farming can guarantee farm resource utilization with minimal impact of intensive farming preserving the environment.*

Keywords— *Agricultural practices, Aquatic resources, Animal husbandry, Integrated and mixed cropping, Sustainable production, Way forward.*

I. INTRODUCTION

Agricultural productivity is an important concern for tackling food security issues in India. India's total food grain production (2024-25) recorded a production of 353.96 LMT with wheat, maize, groundnut, soybean due to favorable monsoon and timely rainfall promoted healthy crop development(PIB, 2024). The farmer-centric policies enhanced agri-infrastructure contributed to the rise in crop production with use of innovative agricultural technologies. Agricultural productivity realizes increase output level crops, livestock, or allied products by utilizing inputs such as land, labour, capital, fertilizer, feed, and livestock. While resolving the environmental and social issues it is possible to achieve the goal of food security, poverty reduction, and rural development. The Food Security Mission launched by India is increasing food access for the growing masses with improved productivity, reduce waste and ensure food to poor for livelihood support and poverty reduction (Singh et al, 2015). India is unlocking the full potential of agriculture to ensure long-term food security addressing challenges through effective extension services. Policy frameworks that addresses the structural constraints, promote inclusive growth, and facilitate value chain expansion that can help India's agricultural sector fulfilling the economic potential. By integrating innovation, sustainability India can paving way for a future agriculture prosperity. Historically, Indian agriculture has been rooted in a rich tradition of

sustainable practices, including crop rotation, organic fertilization, and water-conserving techniques. These methods promoted ecological balance and supported biodiversity. The Green Revolution introduced in 1960s brought an intensive focus on high-yielding varieties, chemical fertilizers, and pesticides, which significantly increased food production.

During this period the policymakers focused on research, extension, input supply, credit, marketing, price support, and spread of technology. This adoption of a new agricultural strategy relied on high-yielding varieties of crops, focus on multiple cropping, package approach, modern farm practices, and spread of proper irrigation facilities. The HYV seeds could yield more than double the existing level which enabled the nation to become self-sufficient in food grains. As a result, in 1966 India imported 18000 tonnes of HYV seeds which were distributed in the highly irrigated areas of Punjab, Haryana, and Western UP. Total food grains harvest increased from 74 million tonnes in 1966-67 to 105 mt in 1971- 72. Output growth increased food grain supplies leading to a decline in food grain prices. India is giving emphasis on industrial agriculture being a high growing remunerative sector with the use of technology like precision farming and automation, a focus on agro-based industries such as food processing, textiles, and dairy, and its significant contribution to the country's exports and economy. The challenges to promote crop livestock synergies and interactions aimed to integrate crops and livestock effectively with careful land use and raise productivity of specific mixed crop- livestock systems to facilitate expansion of food production ultimately to safeguard the environment with efficient use of natural resources. The farming sector is also aware of ecological sustainability combining with economic viability with integration of livestock that improves agricultural productivity while reducing negative environmental impacts. The maintenance of an integrated crop livestock system is dependent on the availability of adequate nutrients to sustain animals and plants and to maintain soil fertility. The growing fodder legumes and using them as a supplement to crop residue is the most practical and cost-effective method for improving the nutritional value of crop residues. The traditional knowledge and experience by local farmers able to apply an integrated system relatively to adopt with traditional wisdom with modern sustainable practices in precision agriculture to restore ecological health while maintaining productivity. Adopting climate-resilient methods can help farmers adapt to erratic weather patterns, safeguarding livelihoods and promoting community well-being. A holistic approach, merging traditional and modern methods catalyze sustainable agricultural model that balances productivity with environmental stewardship. Several challenges are facing Indian agriculture, viz: climate change, erratic weather patterns, droughts, and floods affect crop yields and farmer livelihoods, water scarcity, inefficient irrigation systems and over-extraction of groundwater exacerbate water scarcity. The overuse of chemical fertilizers and poor farming practices reduce soil fertility and crop yields. Research inputs and farm based innovations provided solutions to the sustainable agricultural practices, promote organic farming, crop rotation, and agroforestry to enhance soil health and biodiversity. The focus on diversification from cereals to high-value crops like fruits, vegetables, and medicinal herbs to increase incomes and reduce environmental degradation. The soil health cards promotes sustainable soil management enhancing the natural farming practices addressing challenges in food security and economic growth. Sustainable agriculture encompasses a diverse array of agricultural approaches aimed at enhancing the long-term resilience, productivity, and ecological sustainability. The agricultural models developed creating synergy by using the waste from one system as a resource for the other, such as manure for crops and crop residues for animal feed. This integration enhances soil fertility, reduces reliance on chemical inputs, and offers diversified income streams, and increases farm resilience to market and climate fluctuation underpins biodiversity conservation, nutrient cycling enhancement, and the fortification of agro-ecosystems against environmental change (Wezel et al., 2009. Giller et al., 2011). The primary objectives of sustainable agriculture are conserving natural resources, reduce reliance on synthetic inputs, mitigating negative environmental impacts, and ensure the financial viability of farmers by achieving long-term benefits like improved soil health and resilience. Crop-livestock integration intensify farming integrating components of crop and livestock to diversify farm produce and exploitation of unutilized resources (Patel et al, 2015). The integrated system reduces erosion, increases crop yields, soil biological activity and nutrient recycling This ecological balance is possible because of healthy soil supports like water regulation, nutrient cycling, and carbon sequestration, making agriculture more sustainable ease in agricultural yields, ecosystem services. The sustainable agricultural methods enhance crop yields by fostering beneficial ecosystem services, such as pollination, biological pest control, and nutrient cycling, which support natural processes and reduce the need for external chemical inputs. Practices like biodiversity conservation, cover cropping, and reducing tillage improve soil health and create a more resilient, productive farming system. (Bommarco et al., 2013). Organic Farming methods maintain soil microbial populations engaged in nutrient cycling, while agroforestry systems can provide habitat for pollinators and other beneficial creatures (Pretty et al., 2006; Jose, 2009).

Integrated farming system has revolutionized conventional farming of livestock, aquaculture, horticulture, agro fish integration, livestock-fish integration or combinations of crop, livestock, fish and other enterprises. Thus integrated system offers benefits such as improved soil health and nutrient recycling, increased food production and income diversification, and enhanced resilience to climate change by minimizing reliance on external inputs (Olele et al. 1999). The system help poor small farmers, who on and a few heads of livestock to diversify farm production, increase cash income, improve quality and food production by exploitation of unutilized resources. Crops provide animals with fodder from grass, leguminous forages and crop residues and takes advantage of the animals on the farm to improve the environment in which crop production takes place. The animals provide draught power in crop production where the practice of animal traction is popular and their dung used as manure to improve soil fertility on crop fields. In crop-livestock integrated farming reduces erosion, increases crop yields, soil biological activity and nutrient recycling, intensifies land use understood to exist where both livestock and crop production take place within the same locality that put forward to improve sustainable productivity (Chan, 2006). The system help production, increase cash income, improve quality and integrated farming systems the most visible feature is the synergy between crops and livestock. Crop rotation and intercropping are adequately addressed for soil fertility and animal husbandry enhance soil health by increasing organic matter, improving nitrogen cycling, and promoting soil biodiversity enhancing the agricultural yields with augmented fertilizer availability and water use efficiency. In sub-Saharan Africa study indicates that maize yields increased by an average of 53% when cultivated in agroforestry systems compared to typical monoculture systems improving farmers' livelihoods through sustainable agriculture practices with better market access (Sileshi et al., 2008).

II. METHODOLOGY

Extensive reviews were made to understand the farming system practiced in India and globally, covering prehistoric to the present day agriculture. The culture and the cropping systems adopted to suit different climatic conditions studied. Strategy suggested for adoption of farming pattern in the irrigation pattern for agriculture and allied integrated activities. The sustainability and productivity issues studied to address various challenges in farming system. The schemes and programs beneficial to farming community suggested with emphasis on introduction of new crops, technological innovations, farm management and crop diversity in agro-climatic zones for enhancing the production and sustainability. Information gathered on data classification and grouping ecological aspects, natural resource management, organic fertilizers and biodiversity issues highlighted. Qualitative descriptive methods suggested to understand the comprehensive and holistic approach in sustainable farming practices. Literature Selection relevant to research topic, data reliability and subject related journals, books, research reports were referred. The descriptive and diagnostic methodology explored to examines essential concepts and contexts in depth. The study emphasizes reliable secondary sources, encompassing a wide range of published and unpublished materials, such as academic literature, expert reports, books, journals, specialized media, websites, public records, and scholarly articles. Data is systematically organized and presented to fulfill significant insights, conclusions.

III. SUSTAINABLE FARMING SYSTEMS: COMPONENTS AND PRACTICES

3.1 Agro-climatic Zones of India and Farming Suitability:

India's agricultural scenario depends largely on agroclimatic conditions, which include factors like climate, soil type, rainfall, temperature, and topography. Different crops require different temperatures and rainfall patterns to sustain different farming systems. An integrated farming systems is a judicious mix and positive interaction between two or more components such as horticulture crops, livestock, aquaculture, poultry/ducks, apiculture, and mushroom cultivation. It uses with the principles of minimizing competition and maximize complementarity with advanced agronomic management tools. This environmentally friendly farm income, family nutrition supports ecosystem services. It also based on the objectives to minimize the waste from various subsystems of the farm by expanding the symbiotic or synergistic systems between livestock, aquaculture, agriculture, and agroindustry. The waste of one process becomes the input for other operations in India. In All India Coordinated Research Project (AICRP-ICAR) on IFS network has been established on various IFS models in 15 agro-climatic regions covering 23 states and 2 UTs. The rice grows well in hot and humid regions, while wheat needs cooler climates. Rainfall and irrigation are crucial for crop success with less rainfall depend heavily on irrigation. The plains are more suitable for extensive farming, while hilly regions support terrace and plantation agriculture. The Government of India's Planning Commission giving emphasis on the utilization of long-term resource efficiency and sustainability in agriculture based on the soil's topography

(Planning Commission of India, 1989, Table 1 & Figure 1}. The Indian Council of agricultural Research (ICAR) has redefined the resources and differentiated them on crops based patterns considering soil health, topography, rainfall, and temperature. The identified zones are used for scientific research and agricultural development in India. (Rohit Pradhan, 2014, Shubhdeep Mandal and Muthu Gogoi, 2022).

TABLE 1
DIFFERENT AGRO-CLIMATIC REGIONS/ZONES

Zone No.	Agro-climatic regions/zones	States represented	New Region
1	Western Himalayan region	Uttarakhand, Himachal Pradesh, Jammu and Kashmir	A
2	Eastern Himalayan region	Assam, Arunachal Pradesh, Manipur,	B
		Meghalaya, Nagaland, Mizoram, Sikkim,	
		Tripura and West Bengal	
3	Lower Gangetic plain region	West Bengal	C
4	Middle Gangetic plain region	Bihar, Uttar Pradesh	
5	Upper Gangetic plain region	Uttar Pradesh	
6	Trans Gangetic plain region	Delhi, Haryana, Punjab, Chandigarh, Rajasthan	
7	Eastern plateau and hills region	Orissa, west Bengal, Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra	D
8	Central plateau and hills region	Madhya Pradesh, Uttar Pradesh, Rajasthan,	
9	Western plateau and hills region	Madhya Pradesh, Maharashtra	E
10	Southern plateau and hills region	Karnataka, Tamil Nadu. Andhra Pradesh, Telangana	
11	East coast plains and hills region	Pondicherry, Tamil Nadu, Orissa, Andhra Pradesh	F
12	West coast plains and hills region	Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu	G
13	Gujarat plains and hills region	Gujarat, Rajasthan, Dadra & Nagar Haveli, Daman & Diu	H
14	Western dry region	Rajasthan	I
15	Island region	Andaman & Nicobar, Lakshadweep	Not used

Source: Planning Commission of India(Khanna, 1989)

3.2 Conceptual Framework: Integrated vs. Mixed Farming:

Integrated farming involves a holistic approach to farming, where different components of the farm are interconnected and interdependent. The major difference between integrated farming and mixed farming lies in their approach and scope. Integrated farming involves a comprehensive approach that combines different agricultural enterprises, such as crops, livestock, and fisheries, into a single farming aims to optimize resource use, minimize waste, and promote ecological balance. Mixed farming involves growing multiple crops and/or raising multiple types of livestock on the same farm. In this system different components of the farm may not be necessarily interconnected or interdependent. The primary of both the farming system are to focus on creating a sustainable farming that minimizes waste and optimize resource utilization. It offers numerous benefits, including integrating crops, livestock, and fisheries and farmers maximize resource efficient use of resources like land, water, and nutrients. It supports crop rotation, organic compost, and agroforestry enhance soil fertility and structure, reducing soil

erosion and nutrient losses. By combining multiple agricultural activities, farmers can generate income from various sources, such as crops, livestock, fish, and other value-added products, reducing their dependence on a single commodity market and sustainable because the waste of one enterprise becomes the input of another, leaving no waste to pollute the environment or to degrade the resource base. Thus crop livestock integration becomes effective and highly productive for achieving waste recycling range of resource-saving practices that aim to achieve acceptable profits and high and sustained production levels (Thornton and Herrero, 2001). The integrated system reduces soil erosion, increases crop yields, biological activity and nutrient recycling with effective land use thereby reduce poverty and malnutrition by strengthen environmental sustainability (Antonio and Silvia, 2010). The leftover crop residues provide fodder for livestock (Van Raay and Leeuw, 1971, Alhassan et al, 1983) while, grain provides supplementary feed for productive animals. The natural ecological conditions as characterized by ample sun, good soils and the absence of temperate extreme making favorable to both crop and livestock production provide suitable climatic condition to sustain farming in the highlands that supports the crop , fodder and animal production are high compared with the other system(Jahake, 1992).

3.2.1 Mixed Farming:

Mixed farming systems are livestock based systems in which more than 10% of the dry matter fed to animals comes from crop by-products such as stubble, or where more than 10% of the total value of production comes from non-livestock farming activities(Steinfeld et al, 2006) The manure is used as fertilizer; animals are used for draught and transport. Crop residues are used as livestock feed and animals can be sold and the revenues generated re- invested in agriculture during crop failure due to bad weather conditions and disease and pests. Mixed farming involves growing multiple crops and/or raising multiple types of livestock on the same farm with primary focus on diversifying agricultural production to reduce dependence on a single crop or livestock (Patel et al . 2015). The numerous benefits are offered by increased productivity efficiently utilizing resources leading to higher crop yields and livestock production. It enhances soil health and reducing reliance on chemical fertilizers and provides farmers with multiple revenue streams, reducing dependence on a single crop or livestock. This farming practice promotes ecological balance, conserves water, and reduces environmental degradation. Some successful examples of mixed farming in India include crop-livestock integration. The integrated crops includes wheat, rice, and pulses with dairy farming and poultry. Fishery and paddy cultivation under mixed farming with cultivation of wheat and maize together and raising cattle and poultry on the same farm maximize resource utilization. In many African countries, farmers practice mixed cropping to promote soil fertility to reduce pests and diseases. In Kenya, farmers grow maize, beans, and potatoes together. Mixed cropping is a common practice in Southeast Asia and India where farmers plant multiple crops at the same time to reduce the risk of total crop failure and make better use of soil nutrients. In the Philippines and Indonesia. It includes rice, maize, and soybeans, while in India, farmers in states like Maharashtra, Madhya Pradesh, and Uttar Pradesh grow wheat, gram, and mustard together. The cereal crops wheat and rye are grown with cattle, sheep, pigs, fish and poultry by adopting farming practices. This method is also known as intercropping when crops are grown in a specific, alternating pattern in rows of one crop followed by the row of another (Mustapha et al, 2021). Cultivation of mixed and rotational cropping can help mitigate climate change by sequestering carbon, reducing greenhouse gas emissions supporting the soil health. The adopted cultivation of crops alongside with rearing of animals for meat, eggs or milk in commercial farming making major investments using advanced technologies. Animal husbandry paid attention by addressing health care issues, cattle breeding, and the veterinary services. Intensive focus on feeding of dairy animals given for better milk yield and high income (Neeraj Kumar, 2024). Comparative productivity and economies of dairy enterprises (mixed farming with three crossbred cows on one hectare of canal irrigated land versus mixed farming with three Murrah buffalo) indicated that mixed farming with crossbred cows under canal-irrigated conditions were more efficiently utilization of land, capital, inputs and the labour resources of the farmer (Kumar et al, 1994). In Gujarat around 75 percent of rural households kept cattle in the face of under-employment, particularly, the cattle kept mainly for milk, contributed 32 per cent and 20 per cent by tribal and non-tribal ethnic groups respectively (Patil and Udo, 1997). The farm animals could also provide gainful resources such as crop residue that can be utilized in integrated system. The waste products of one component serve as a resource for the other. For example, manure is used to enhance crop production; crop residues and by-products feed to the animals, supplementing often inadequate feed supplies, thus contributing to improved animal nutrition and productivity (Ven Keulen and Schiere, 2004. Manyong et al, 2006). The overall benefits of crop-livestock integration keep maintenance of the soil productivity capacity, product diversification and higher yields and quality at less cost. The livestock can be fed on crop residues and other products that would otherwise pose a major waste disposal problem overcome by feeding straw, damaged fruits, grains and household wastes (Fakoya, 2002). Adverse climatic dynamics in recent years have intensified the need for resilient and multifunctional agricultural systems that integrate productivity, ecological sustainability, and socio-economic viability. (Anna Wenda-Piesik and Agnieszka Synowiec, 2021).

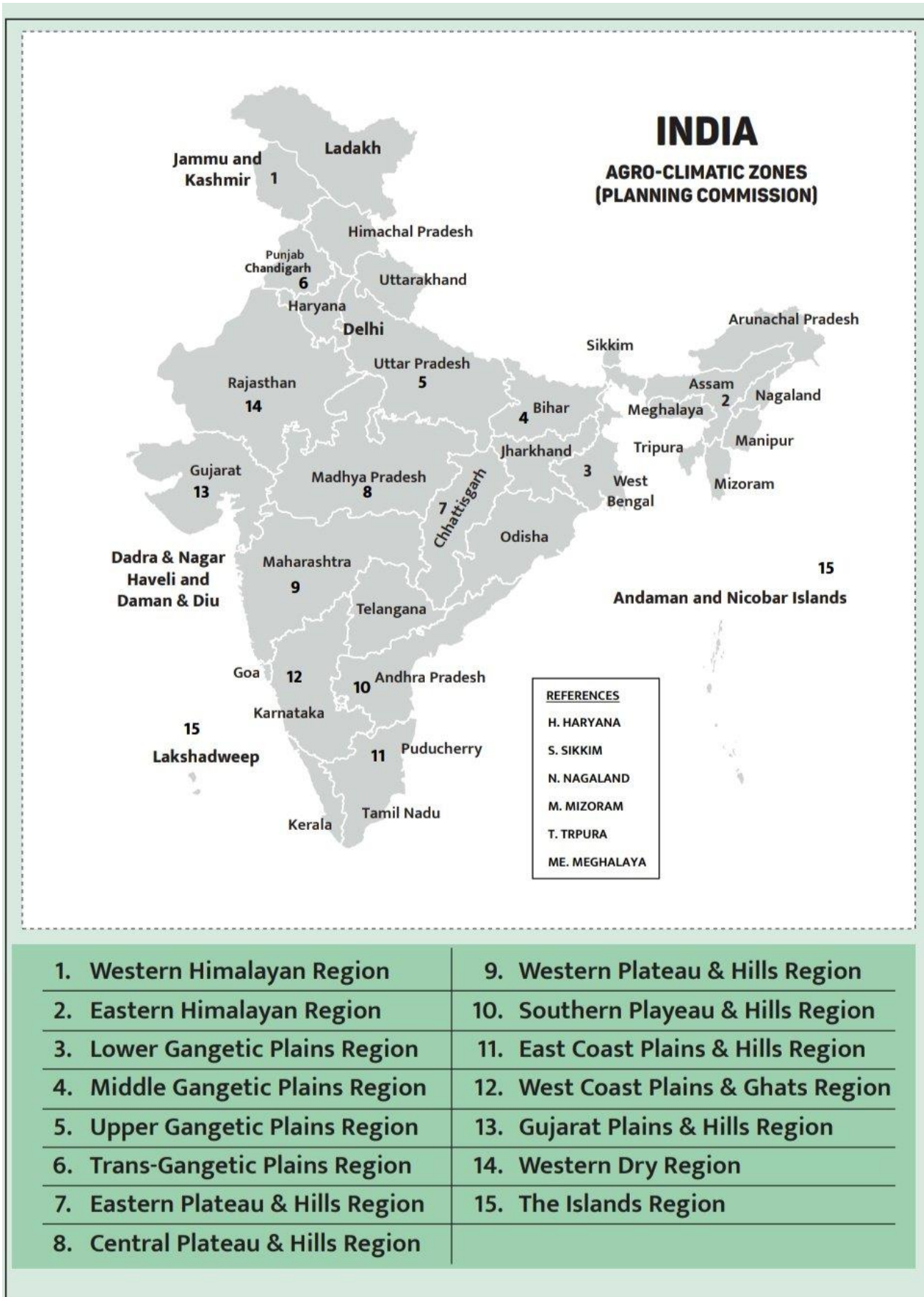


FIGURE 1: Agro-climatic zones in Indian States (Khanna 1989)

3.3 Integration of Aquatic Resources and Aquaculture

India is blessed with vast aquatic resources, promote sustainable development in the fisheries and aquaculture sector. The sector provides food, employment and prosperity of the people. The vast resources provides huge scope for expansion of aquaculture for the production of finfish and shellfish. The fisheries resources are given below in Table 2.

TABLE 2
THE FISHERIES RESOURCES

Marine resources and statistics.
India's Coastline ---8118 km.
Exclusive Economic zone---2.02 million km ²
The Continental shelf---0.42 million km ²
The Fish landing Centers ---1376
Fishing villages---3322
Fishermen Families, as per NMFC, 2005)---764868
Fisher Folk Population(No.)as per NFMC,2005---3574704
Inland Resources:
Rivers and Canals---195210 km.
Reservoirs---31.5 lakh Ha
Tanks and Ponds 24.14 lakh Ha.
Flood Plains/derelict water bodies---8-12 Lakh Ha
Brackishwater ---12.40 lakh Ha.
Saline /alkaline affected area---12.00 lakh Ha.

Source: Report of the Working Group on fisheries, Planning Commission, 2011, Government of India.

Fisheries provides food, employment and prosperity to the people. The vast area of water resources available in the country provides huge scope for expansion of aquaculture contributes to the national income, exports, food as well as employment generation both in inland and coastal areas. India stand 2nd in fish production with its 8 percent growth share in the global fish productivity and recorded high production of 17.45 MT production in 2023-24(Agro Spectrum, 2023). The Ministry of Fisheries, Animal Husbandry and Dairying is giving major focus on development of fisheries in India for adoption of modern fishing practices, expansion of aquaculture activities, and promotion of fish seed production and technology transfer. The scheme also emphasizes the conservation and sustainable activities to increase fish production, increasing the income of fisher folk. (Ghosh et al., 2019. Patro et al., 2021, Sarkar et al., 2020).

3.4 Advancements in Animal Husbandry Practices:

A combining livestock and crop production system increase income, improve quality and quantity of food with exploitation of unutilized resources. Integration of livestock and crop nutrients allow recycling more effectively to improve livestock productivity, reduce poverty, and increase farmers' income and conserve and develop indigenous cattle breeds, improve their productivity, and promote their use in agriculture. Artificial insemination improved cattle productivity and transferring embryos from high-quality donor cows to recipient cows help increase the genetic quality of cattle. ETT with increase productivity by transferring embryos from high-yielding donor cows, reduced risk of disease transmission between donor and recipient cows. In India artificial insemination (AI) in buffalo and cows widely adopted by injecting semen from high-quality bulls into cows or buffalo to improve their reproductive performance. Operation Flood mission launched in the 1970s, used AI to improve cattle productivity and increase milk production in India. National Dairy Development Board (NDDB) has implemented AI programs across India, improving cattle breed The application of embryo transfer technology (ETT) helped improvement of cattle and buffaloes with good quality breeds and success rate to demonstrate the commercial production of farm animals for higher milk productivity (Misra et.al, 2005). The population increase of crossbreds with artificial insemination program increases the profitability of the farmers and the dairy industry (Rajesh Wakchure et al. 2015). The technologies such as artificial insemination, frozen semen production, progeny-testing validated to fillip the gap of animal genetic conservation and preservation of germplasm. The Indian cattle Zebu, a cross bred of Indian Gir breed and the Holstein breed, known for its high milk production for their distinctive hump, large ears, and heat tolerance yielded better results. The breed is resistant to diseases and parasites, making them well-suited for tropical climates. India's milk production touched a target of 230.58 MT in 2023-24, makes India the World's largest milk producer country, accounting for more than 25 percentage of the world's milk production The Gir cow is the highest milk producing cow breed in India, yielding 50–80 liters of milk per day recognized

for high yield production and adaptability to different climates, with resistance to diseases and parasites. The Central Institute for Research on Buffaloes (CIRB) under ICAR in Hisar has improved the Murrah buffalo breed and for disseminating its semen to farmers and buffalo for fertilization of cows. This breed found most suitable breed in dairy production. The genetic studies and non-genetic factors studies influences the performance traits in lactation, milk yield dry period, birth weight, calf mortality, calving interval per conception and conception rate making effective breeding program with better performance traits. (Sarkar et.al, 2005).

3.4.1 Coordinated Research projects and Rural Bio resources Complexes:

Intensification of agriculture is currently occurring in most of the farming systems favors crop– livestock integration. An All India Coordinated Research Project (AICRP) is multi-institutional, multi-disciplinary research initiative that connects with various research centers and experts across the country to address specific agricultural or national priorities. These long-term projects, primarily supported by the Indian Council of Agricultural Research (ICAR), focus on developing and disseminating region-specific technologies to improve crop yields, animal husbandry, and other vital sectors for the benefit of farmers and the country. AICRP a network of centers, including the State Agricultural Universities (SAUs) and ICAR institutes collectively conduct collaborative research on farm based activities. Projects bring together specialists from different disciplines to achieve targeted outputs addressed to specific agricultural commodities viz; maize, pulses, small millets, or post-harvest technologies to test and develop region-specific technologies and disseminate to farmers to enhance production utilizing resource optimization different agro-climatic zones. Improved tailored made high-impact technologies in various regions and specific needs and supports adoption of indigenous emerging technologies for sustainable crop–livestock integration.

Rural Bio-Resource Complex Project was conceptualized during 2004 supported by DBT at UAS Bangalore with interdisciplinary approach scientists with a view to realize sustainable development in agricultural system. The project was implemented in Tubagere Hobli of Bangalore rural district covering 8340 farming and non- farming families spread over in 75 villages with a goal to enhance income and standard of living of farmers, access to quality inputs and custom hire services of agricultural machineries, provide functional linkage with various institutions working in rural area, market empowerment and the establishment of producers/ commodity based associations. The RBRC project implemented series of capacity building programs implemented for various stakeholders especially farmers through education and training. The results are highly encouraging fulfilling farm production efficiently through empowering farmers by upgrading their knowledge and skill. Empowerment on various facets of agricultural activities right from choice of crops to consumer preference is essential to farmers to enable them to reap the benefit from farm activities with technology adoption, carrying out timely farm operations and other activities like information on markets, transportation of farm to strengthen especially small and marginal farmers with better remunerative prices to their produce (Vinay Kumar et al, 2015).

3.5 The Role of Organic and Natural Farming:

Organic farming plays a significant role in supplementing integrated farming systems by providing a framework of sustainable and eco-friendly practices that enhance the overall production system. Adoption of organic methods reduce reliance on chemical inputs, improve soil health through nutrient recycling, and minimize environmental pollution, by encouraging farmers to adopt natural farming and practice chemical-free agricultural practice integrate with local livestock and diverse cropping systems. It emphasizes sustainability, biodiversity, and the health of ecosystems using compost and organic fertilizers, enhance soil structure, fertility, and microbial activity. These practices improve the soil's ability to retain moisture and nutrients, leading to increased agricultural productivity. (Yoganandham, 2024). Organic farming minimizes soil erosion and degradation. By avoiding chemical inputs that degrade soil structure and organic practices maintain the integrity of the soil ecosystem. By encouraging biodiversity, organic farms create habitats for various species, including beneficial insects, birds, and soil organisms and is the essential element for pollination, pest control, and the overall resilience of the agricultural system. The absence of synthetic chemicals means that organic farms contribute less to water pollution, preserving the health of rivers, lakes, and wetland, thus fostering soil health and promoting ecosystem balance. While embracing organic farming practices, there is need to study harmonious relationship between agriculture and nature, ensuring the well-being of both the environment and human health. The Ministry of Agriculture & Farmers' Welfare initiated to encourage farmers to adopt natural farming, a chemical-free agricultural practice that integrates local livestock and diverse cropping systems. The goal is to promote sustainable farming practices that provide safe, nutritious food for all, reduce input costs and dependence on externally purchased inputs. The NMNF scientifically revive agricultural practices, promoting sustainability, climate resilience, and healthy food both for farmers and consumers. The scheme is implemented in 15,000 clusters in Gram Panchayats reaching hundred million farmers by introducing natural farming over 7.5 lakh hectares and model demonstration farms established at

Krishi Vigyan Kendras (KVKs), Agricultural Universities (AUs), and farmers' fields. (Kumar et al, 2024). The mission disseminated further to develop synergies, and establish market linkages through local markets ultimately to promote entrepreneurship in natural farming practices. Krishi Vigyan Kendra (Farm Science Centre) is an innovative institution of ICAR established at district level. The first KVK was established during 1974 and has grown as a largest network in the country with 631 KVKs during 2012. KVKs are funded by ICAR and administered by ICAR institutes / SAUs /Deemed Universities / Non-government Organizations or State Department of Agriculture. KVKs play a supportive role in the larger agricultural extension system.

IV. INSTITUTIONAL, RESEARCH, AND POLICY SUPPORT

4.1 National Research Initiatives (AICRP, RBRC)

India's agriculture and allied sectors contributed approximately 16% of the national GDP with 46 % workforce employed in agriculture. The sector underpins rural livelihoods and drives the development of allied industries such as dairy, poultry, and fisheries. The prosperity in agriculture is directly linked to enhanced rural infrastructure, better income levels, and improved quality of life in villages. India launched New Agricultural Policy in 2000 aimed to achieve an output growth rate of 4 percent per annum in the agriculture sector on the basis of efficient use of resources in a sustainable manner and to strengthen rural infrastructure along with increasing employment opportunities in rural areas which will, in turn, improve the standard of living and check migration from the rural areas. NAP also supports economic liberalization by fulfilling the needs of the domestic and foreign markets with the process of diversification in non-food grains output like milk, fishery, poultry, vegetables, fruits. The sector significantly supports India's foreign trade, contributing \$50 billion to exports in 2022-23, or approximately 13% of the country's total export by cultivation of high-value crops like fruits, vegetables, and spices, which enhance food security, improve nutrition levels, and provide opportunities for income diversification. It also provides raw materials for various industries, such as textiles, food processing, and pharmaceuticals promoting sustainable agriculture practices and improving farmer's livelihoods ensuring fair prices and promoting sustainable agriculture practices (Astha Banka et al. 2021).

4.2 Capacity Building and Extension Services

Capacity building is strengthening capabilities to perform their work more efficiently by the individuals to improve the efficiency by equipping the individuals to improve efficiency independently. Strengthening of institutions for promoting integrated farming system is essential for country like India with tailored based approach that addresses the challenges and opportunities in farming and extension services. Various approaches in capacity building of farmers are farmer's field schools, participatory technology development, on farm demonstrations, use of ICT, working through groups, distance education etc. available with institutional arrangements like KVKs, SAUs, and ICAR institutions (Durgesh Kumar Dubey. 2015). The Food and Agriculture Organization (FAO) is giving emphasis on strengthening agricultural institutions in developing countries to promote integrated farming with technical support, facilitate research, and coordinate with relevant stakeholders. The International Fund for Agricultural Development. (IFAD) supports training and extension activities for smallholder farmers in developing countries through workshops, training programs, and demonstration effectively to benefit farmers in integrated farming. The Farmer-to-Farmer Knowledge Exchange Programs disseminates in adoption of integrated farming systems by farmers in developing countries with sustainable agriculture development. The United Nations Development Programme (UNDP) supports policy frameworks with incentives to create an enabling environment for farmers to adopt integrated approaches. Emphasis on digital technologies platforms is given by World Bank to disseminate agricultural information giving access to information empowering the farmers in remote areas with knowledge empowerment. By implementing these strategies in a developing country fostering adoption of integrated farming practices, leading to increased agricultural productivity, improved sustainability and enhanced livelihoods.

4.3 National Missions and Policy Frameworks:

The Agriculture Development Strategy to 2025 and Vision 2030, strategic document projected the multifaceted approach to ensure the food security, produce comparative and competitive agricultural commodities, develop clean, safe and sustainable agriculture and shift agriculture gradually with modernization of technology. The government is addressing the need of farmers for food, income, and livelihood by emphasis on utilization of natural resource for better health and environment, employment generation with an aim achieve UN Sustainable Development Agenda 2030 (Niti Aayog, India, 2023). Fulfilling the vision, PM KISAN Yojana launched to support small and marginal farmers with allocation of budget introducing subsidies for food, fertilizers, and petroleum. The domestic agricultural marketing policies framed to create a fair and efficient marketing system to bring reforms, create market access to farmers for their produce (Acharya, 2001). NABARD (National Bank for Agriculture

and Rural Development), ICAR, APMC (Agricultural Market Produce Market Committee), and Food Corporation of India giving emphasis on Institutional Financing, Cooperative farming and bringing awareness for doubling farmer income with awakened lowering subsidies on seed and fertilizers. The crop insurance program brings multiple stakeholders into a single window through PMFBY. The Kisan Call Centre, Agri Market App, and Kisan Suvidha App with digitalization, also introduced subsidies to meet the cost of agriculture for drone purchase and farm machineries. National Food Security Mission (NFSM) enhancing agricultural and food grains to improve the availability of essential food grains in the country. The emphasis is given soil and water management and soil health for sustainable and inclusive growth in food grain production. NFSM program has yielded positive and significant impact on increasing the production and productivity of rice, wheat and pulses, thereby helping in nutritional security of the masses. The performance was evaluated and the impact of NFSM on agricultural productivity, food security, and farmer welfare issues were examined (Kumar and Singh. 2017, Kumar and Jha, 2020).

V. DISCUSSION AND WAY FORWARD

India is giving focus on sustainable integrated farming systems with improved extension services for farmers, scientists and stakeholders to improve the productivity efficiency for adoption in rural communities. While doing so it enhances agricultural productivity by addressing the pressing environmental concerns, including soil degradation, water scarcity, and biodiversity losses. It revives the traditional farming techniques, such as crop rotation, agroforestry, and organic farming, complements with modern practices like precision agriculture in agricultural system to sustain ecologically harmonious agricultural future. From this review it is concluded that the integrated farming system (IFS) is a promising enterprise for the marginal and small farmers by sustainable utilization of resources particularly who has less farm holdings. The study suggested to provide progressive economic growth, employment opportunities, family nutritional requirements, optimal utilization of available resources of the farming enterprises. Further many researchers found many types of integrated farming system models existing in the country but it has not properly documented to reach the mass farmers. Hence measures needed to document such kinds of farming system models to needy farmers. Although the integrated farming system has certain constraints the scientific community and research station has to initiate steps to alleviate such problems of the farmers to improve their standard of living and income.

VI. CONCLUSION

Sustainable agriculture require strategies to mitigate the impact of climate change on agriculture, including crop management, irrigation systems, and soil conservation. The highly improved integrated livestock system ensure the interest of poor small farmers thereby increase the productivity of traditional farming systems by adopting an effective biomass while conserving the natural resources. India has taken major initiatives to excel the economic growth, job creation, and agricultural development with the initiatives launched by the government and by promoting organic farming with emphasis on horticulture of fruits, vegetables, and flowers. The animal husbandry, dairy and fisheries sector given scaling up integrated farming system in India and other developing countries. The potential for expanding integrated agricultural systems in India is by strengthening education and training that can bring awareness with enhancement of farmer's capacity. The research on sustainable agricultural practices can fosters innovation and sustainability with the schemes like crop insurance, crop protection and crop losses due to natural calamities. These are well addressed issues in agriculture and allied sectors with promotion of advanced farming technologies and introduction of organic farming. The policy initiatives taken by government fostering supportive frameworks and enhancing institutions by ensuring equitable access to capital inputs and markets and promotion of new commodities with sustainable resource utilization.

VII. CONFLICT OF INTEREST

Author declares that there is no conflict of interest.

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