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Recent Advancements in Sustainable Agricultural Practices

Harnessing Technology for Water Resources, Irrigation and Environmental Management

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Foreword

Recent Advancements in Sustainable Agricultural Practices: Harnessing Technology for Water Resources, Irrigation and Environmental Management

Water's pivotal role in agricultural sustainability is expanded and explored through in-depth analysis in this book and guiding policymakers to address the escalating detrimental impacts of climate change on water availability and its distribution. Effective water management strategies depicted in the book can be very well applied to safeguard agricultural productivity and food security. The compendium's synthesis of traditional agronomic practices coupled with modern insights offers a nuanced approach to mitigate climate change risks in agriculture.

In this book, technology emerges as a powerful catalyst for transformation, exemplified by the Internet of Things (IoT) in smart irrigation and monitoring systems. Drip irrigation, bolstered by IoT-based automation, becomes a compelling policy consideration, conserving water and enhancing crop yields. Moisture sensor-based irrigation scheduling stands as a potent policy tool to optimize water usage and promote responsible water stewardship. Nanotechnology's potential in agriculture water management holds promise for policymakers keen on fostering eco-friendly practices.

The compendium's visionary concepts of smart green housing and vertical farming resonate with seeking sustainable urban planning. By incorporating these practices, cities can enhance local food production while reducing rural agricultural burdens. Geospatial techniques offer data-driven policy avenues for optimizing irrigation projects and water body monitoring. Policymakers can invest in these techniques to inform targeted water resource management decisions. Canal automation is underscored as a policy choice for optimizing water use efficiency and resource distribution, encouraging equitable water access.

Specifically tailored to India's agricultural perspective, policymakers can draw essential lessons from the compendium to navigate the challenges posed by a rapidly changing world. Policymakers are urged to adopt sustainable watershed management and livelihood practices thereby striking a balance between human development and ecological preservation. This book holds tremendous significance from a policy-making standpoint, offering invaluable insights and transformative strategies for the realm of agriculture and environmental stewardship. With a strong focus on achieving Sustainable Development Goal-17, this book emphasizes global partnerships and collaborations as indispensable drivers for a sustainable future.

Indian Chamber of Food and Agriculture (ICFA) M. J. Khan
New Delhi, India

Preface

Irrigation water management plays a crucial role in ensuring global food security and sustainable agricultural production. However, the increasing demand for food coupled with climate change and water scarcity has put immense pressure on irrigation water resources. In recent years, there has been a growing interest in exploring the water-crop-climate nexus to improve irrigation water management and increase agricultural productivity while ensuring environmental sustainability.

The book entitled "Recent Advances in Sustainable Agricultural Practices" is a comprehensive guide that focuses on the integration of water, crop and climate data to optimize irrigation water use and improve crop yields. It is a compilation of cutting-edge research conducted by leading experts in the field of irrigation water management. One of the key areas of focus in the book is advanced irrigation technologies that provides detailed information on the latest irrigation technologies, such as drip irrigation, sprinkler irrigation, and precision irrigation, and how they can be used to optimize water use efficiency and improve crop yields. It also covers topics such as automation and control systems for irrigation management, water storage and reuse, and soil moisture sensors for precision irrigation.

Another area covered in the book is crop water use efficiency. The book discusses how crop water use efficiency can be improved through the selection of drought-tolerant crops, crop breeding, and genetic engineering. It also covers topics such as crop modeling, crop evapotranspiration and water productivity which are critical for understanding and managing the water requirements of crops.

The book also provides an in-depth analysis of soil-water-plant-atmosphere interactions, which is essential for optimizing irrigation water use. It discusses the physical and chemical properties of soils and how they affect water availability to plants, the role of plant roots in absorbing water and the impact of atmospheric conditions such as temperature, humidity, and wind on crop water requirements. It also addresses the impact of climate change on irrigation water resources. It provides insights into the effects of climate change on water availability, water quality, the frequency and severity of droughts and floods. It also discusses the adaptation strategies that can be implemented to cope with the impact of climate change on irrigation water management.

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About the Editors and Contributors

About the Editors

Yasheshwar an Associate Professor at Acharya Narendra Dev College, University of Delhi with 18 years of teaching experience in the Dept. of Botany, specialized in plant physiology, phytochemistry, and agriculture science. His research area is water deficit stress and secondary metabolite production in horticulture crops. He served as Convenor of the National Assessment and Accreditation Council (NACC) and Coordinator of Internal Quality Assurance Cell (IQAC) and PARAMARSH scheme of UGC from 2019 to 2021 at college level. Currently, he works on drip irrigation's impact on secondary metabolites in horticulture crops and pharmacognosy and pharmaceuticals aspects of secondary metabolites. As an educator, he runs the YashFame Classes on YouTube channel offering insightful lectures on plant physiology and science & society. He was conferred "Ibn Sina Public Health Award" in 2022. He earned the LL.B Degree from Faculty of Law, University of Delhi, New Delhi. As a lawyer, he delivers lectures on legal jurisprudence and environment law thereby fostering interdisciplinary teaching-learning experiences.

Anil Kumar Mishra is a distinguished Principal Scientist specialized in soil and water conservation engineering at the Water Technology Centre, IARI, New Delhi. With a notable presence in the field, he contributes significantly to the advancement of water technology. He holds a prominent position as a key figure in research and development activities at the esteemed Water Technology Centre. His expertise in soil and water conservation engineering underscores his commitment to addressing crucial challenges in this domain. Dr. Anil K. Mishra's role as a Principal Scientist signifies his leadership in driving innovative solutions and contributing to the scientific community's understanding of water-related issues. His work at the interface of soil and water management showcases his dedication to sustainable practices and the efficient utilization of water resource. He has received prestigious awards for outstanding contributions to agricultural science. His impactful research papers in esteemed journals reflect his dedication to advancing sustainable practices in soil and water conservation.

Mukesh Kumar He earned his graduation degree in Agricultural Engineering and Masters in Soil and Water Engineering from Punjab Agricultural University, Ludhiana. He was awarded Ph.D. in Agricultural Engineering (Soil and Water Conservation Engineering) from Indian Agricultural Research Institute, New Delhi. Dr. Kumar joined as Assistant Professor in 2006 at School of Agriculture, Indira Gandhi National Open University, New Delhi and presently working as Professor. He has associated in several research projects funded by the ICAR, NCPAH and different Ministries. He has published around 50 research papers in peer reviewed national & international journals and participated in 38 national & international conferences. He has also contributed more than 22 book chapters and published one edited book with international publisher along with two extension manuals. He has organized number of national and international conferences as Organizing Secretary /Co-organizing Secretary/member organizing committee. He has developed number of educational programmes in the field of water management, watershed management and food safety and quality management. He has also developed one MOOCs related to solar water pumping system. He is a life member of different professional societies and actively involved in Indian Society of Soil and Water Conservation, New Delhi. He has received Ph.D. Student Incentive Award-2012 award, Gold Medal-2014, Special Research Award-2016 and National Fellow-2019 from Soil Conservation Society of India. Fertilizer Association of India has awarded him with Golden Jubilee Award for Doctoral Research in Fertilizer Usesin 2013 for outstanding research work on dynamics of nutrient movement in soil under fertigation during Ph.D. He has also honored with University Silver Medal-2015 by the Indira Gandhi National Open University, New Delhi, India.

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Sustainable Developmental Goal 17 and Agriculture from an Indian Perspective

1

Priti K., Prashant Kumar, and Kaushlesh Singh Shakya

Abstract

Sustainable Development Goal (SDG) 17 emphasizes strengthening the means of implementing global partnerships through multisectoral and multinational approaches. SDG 17 aims to attain global partnership elements in financial capital, technology advancement, capacity building and skill development, trade and systemic issues at different constituencies (global, regional, national and local levels). The global partnership improves the sustainability of all types of development cooperation for the collective welfare of people, planet, prosperity and peace. Implementing and framing strong national and international policies, programs, schemes and action plans via collaboration of stakeholders, innovators, entrepreneurs and institutes is essential in promoting sustainability and achieving SDGs by 2030. The UN has defined 19 targets and 24 indicators for measuring progress toward SDG 17. The progress of all other 16 SDGs is dependent on and linked with goal 17th. Seventh goal will promote universal social, economic and environmental development through equitable trade, coordinating investment across borders, collaborative actions and improving and supporting coordination and collaboration among nation-states. To achieve 17th goal targets, it requires huge funding in infrastructure to empower different sectors like energy, agriculture, transportation systems and IT to ensure fair and equitable distribution of resources among the world's community. The agriculture sector accounts for 4% of global GDP, and in developing countries like India, it provides employment to over 50% of the nation's workforce and contributes 17–18% to the

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India's GDP. The world states must take concrete actions for the agriculture sector to achieve Goal 17 of the SDGs by 2030. Strengthening and promoting five elements—capital, technology, skill-building, bilateral and multilateral trade policy and systemic issues such as storage facilities, climate change, stubble burning, irrigation facilities, etc.—is crucial to achieving global partnership. Today, progress has been made in several areas, but globally, action to achieve the sustainability in agriculture sector is not progressing at the required momentum or magnitude. This decade must bring concrete efforts in the agriculture sector to achieve global goal 17 by 2030. This work aims to understand the multiple risks associated with Indian agriculture and how global partnership in terms of finance, technology, trade, capacity building and skill can help handle the Indian agriculture risks and attain sustainability in the whole agriculture network.

Keywords

SDG · Global partnership · Agricultural risks · Technology advancement · Entrepreneurs · Collaborative actions · Policy intervention

1.1 Introduction

The concept of sustainability came way back in 1987 with the establishment of the Brundtland Commission by the UN. The Brundtland report named 'Our common Future' defines sustainable development as maintaining the social, economic and environmental (three pillars) equilibrium of resources, allowing prosperity for today and preserving for future generations. Sustainable development is a long-term, inclusive approach to a progressive and striving society. Achieving economic progress, environmental protection and social inclusion with fair use of natural resources is challenging. Sustainable development persuades the universal conservation and use of resource base by promoting a transition in technological innovation to meet the world's fundamental requirements such as employment, food, energy, water and sanitation.

To bring sustainability to the world's system, in September 2000, the leaders from 189 countries signed on Millennium Declaration to achieve 8 quantifiable goals by 2015. The Millennium Development Goals (MDGs) put a unified aim of poverty reduction through enhanced governance and accountability. As a result, MDGs have substantially reduced poverty, with about 471 million fewer people experiencing extreme poverty, and saved about 21–29.7 million lives globally (Rahaman et al. 2021). The world bank report of 2012 shows the progress in MDGs with poverty cut down to half, reduced child mortality to 45% and successfully provided water and energy to at least 2.6 billion individuals (Lowe 2021). However, the achievements have been uneven at the national and international levels. There are still 886 million people who lack excess to sufficient food, 1.4 million people do not have excess electricity, and more than 1.2 billion people are without access to sanitation and potable drinking water (Galabada 2022). The MDGs had flaws, such as these goals focus on outcomes rather than policy strengthening of the institutions required to attain those outcomes and a lack of attention to systemic risk factors and achieving social justice. To this end, the UN defined 17 broad goals in September 2015 to transform the world by 2030. The Sustainable Development Goals (SDGs) are not legally binding; nevertheless, the world has promised itself to achieve a healthy and amiable planet at UN Summit by establishing the national framework. The SDGs are highly interdependent and interconnected, ensuring the fair and equitable development of the world's community. The SDGs embrace that achieving universal health and well-being needs a holistic, multisectoral approach. The 17 SDGs focus on the integrated development approach, i.e. social inclusion, environmental protection and economic growth, whereas 8 MDGs work on the pillar approach system but lack an integrated approach. MDGs 1–6 mainly focus on the social aspect of development, MDG 7 focuses on environment protection, and MDG 8 focuses on economic points such as building trade, fund allocations, debt relief and technology transfer. Therefore, the SDGs are supposed to address what the MDGs left unfinished. The 17 global goals are defined as 169 targets, each measurable by several indicators. The SDGs represent a significant extension of scope from eradicating extreme poverty to fostering international relationships. The world leaders at SDG Summit, 2019, called for a Decade of Action as only 10 years are left to achieve 5 'p' approaches, i.e. public (SDGs 1–6), planet (SDGs 13–15), prosperity (SDGs 7–12), peace (SDG 16) and partnerships (SDG 17). The UN secretary called for action on three levels, global effort, local action and people action, to ensure strong leadership, capital movement, innovations, transition in policies, budgets, institutions, strengthening regulatory framework and collaborations among academicians and stakeholders for pushing the 2030 transformation agenda. Today, progress has been made in several areas, but global efforts are not progressing at required speed. This decade must bring substantial effort to achieve goals by 2030.

Sustainable Development Goal 17 emphasizes strengthening the means of implementing global partnerships through multisectoral and multinational approaches. Goal 17 can play an essential role in empowering the other 16 SDGs in terms of financial capital, technology development and transfer, capacity building and skill development, equitable and inclusive globalization and trade and systemic issues at the different spatial levels from global to local scale. The strengthening of global partnership requires a robust policy framework for addressing sustainability issues such as energy, agriculture sector, infrastructure, transportation systems, IT infrastructure, climate change and air and water pollution. The collaborative actions of multi-stakeholders through public-private partnerships, mobilizing resources for innovation and new technology development, firm commitment and governance structure, building infrastructure, accountability and corporate social responsibility in the system can help nations negotiate relative progress or lack in progress toward sustainable development. The UN has defined 19 targets and 24 indicators for measuring progress toward targets for SDG 17. Targets 17.1–17.5 of SDG 17 deal with finance building like resource mobilization, improving tax collection infrastructure, assistance commitments from developed nations, foreign direct investment, fostering debt financing, debt relief and debt restricting (Blind 2020). Targets 17.6–17.8 work with environmentally sound technology development, transfer, dissemination, diffusion and innovation in communication and information technology, and 17.9 implements the effective and targeted capacity-building program. Targets 17.10–17.17 support globalization and a multilateral trading system, increase the global share of exports, remove trade barriers, enhance policy coherence and coordination and enhance multi-stakeholder partnerships that act as catalysts in knowledge, expertise, technology and financial resource sharing and public-private and civil society partnership. Targets 17.18–17.19 deal with systemic issues like data reliability (Fig. 1.1).

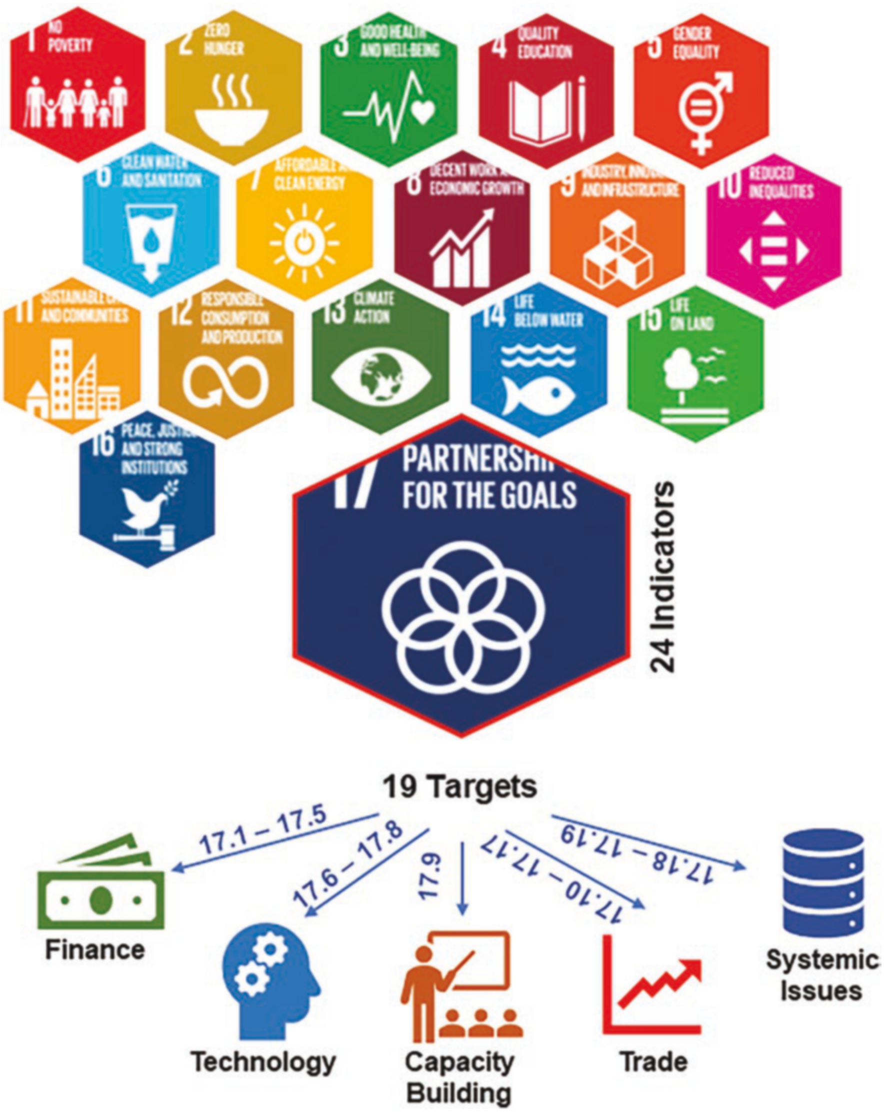

Fig. 1.1 Global partnership (SDG 17) and its five elements

Agriculture is one of the crucial sectors in terms of employment generation and improving the gross domestic product (GDP) of any nation worldwide. The agriculture sector accounts for 4% of global GDP, and in developing countries like India, it provides employment to over 50% the population and contributes 17–18% to the India's GDP. The green revolution in India came around the 1960s with the aim of self-sufficiency production of food grains to change India's status from a food-deficit nation to the world's leading producer. Indian agriculture converted from subsistence farming to an industrial agriculture system primarily with the instigation of high-yielding variety (HYV) seeds of staple crops especially wheat and rice, along with package of other improved agriculture practices such as government incentives on irrigation projects, availability of synthetic chemical fertilizers and pesticides, mechanical thresher and a policy support framework, and the success of this agriculture revolution was more prevalent in northern states of India (Parayil 1992). Farmers were encouraged to embrace new technologies through input subsidies and production price incentives. However, not reforming these policies post the green revolution distorted farm-level benefits and resulted in some latent problems such as natural resource deterioration. The massive increase in productivity was due to increased land-use intensification, which resulted in shift in the cultivation mechanism, such as an increased dependency on irrigation and synthetic fertilizers, alteration in sowing schedules and greater homogeneity (monoculture) in the types grown. These changes had serious environmental consequences, including increased salinity and waterlogging, groundwater depletion and aquifer pollution and insect and disease outbreaks (Nelson et al. 2019). The lowering in the water table was caused by intensive irrigation water consumption combined with poor drainage.

The implications of modern agriculture are now observed in low production and economic loss due to natural resources' deterioration. In turn, this will increase the food price and encourage food availability disparity (Fig. 1.1). Thus, to achieve sustainable agriculture growth, it is crucial to meet 17 ambitious SDGs by 2030. It will help farmers and governments take concrete action through a global partnership with SDG 17. Strengthening and empowering farmers in finance, technology, capacity building, worldwide collaboration and trade and systemic issues like storage facilities, climate change, stubble burning, irrigation facilities, etc. is vital to attain sustainable growth. In addition, the global partnership between government, private and farmers is essential for sustainable agriculture. These inclusive partnerships are needed at international, national, regional and local levels built on values, principles, shared vision and goals.

The integrated approach plays a crucial role in attaining sustainability in the agriculture system. Therefore, combining SDG 17's five elements, i.e. financial regime, technology advancement, capacity building, trade and handling systemic risk associated with agriculture, is essential to make our agriculture system long-lasting with an environmental health, economic profitability and social equity approach. This work aims to understand the multiple risks associated with Indian agriculture and how global partnership in finance, technology, trade, capacity building and skill can be useful in handling the Indian agriculture risks and attaining sustainability in the whole agriculture network.

1.2 Multiple Risks Associated with Indian Agriculture

Modern agriculture has become a complex and challenging business. One of the challenges is meeting food demand of rising population in terms of quantity and quality. However, the arable land is limited, and also clearly, forest land for cultivation will cause multiple risks like changing land use pattern, which again is responsible for various systemic risks. India currently holds 16% of the world's population but just 2.45% of the global surface area and 4% of the world's water resources. Thus, the higher demand and limited resources have put considerable pressure on framers to produce maximum. The resource constraint has resulted in multiple risks to Indian agriculture in terms of social, environmental and economic risks. The intensive agriculture activities have led to great stress on soil productivity, surface water resources and groundwater aquifers, biodiversity, climate and air quality (Fig. 1.2). Especially in years of the green revolution in India, farmers and the government focused on maximum production using high-yielding varieties of seeds and excessive use of chemical fertilizers. One of the drawbacks of the green revolution was it was only limited to the states of Haryana, Punjab and western Uttar Pradesh and emphasized mainly the production of wheat and rice. This lack of longsightedness during decision-making in the Indian agriculture system has resulted in severe negative impacts on groundwater aquifers in Haryana: the problem of accumulation of excessive chemical fertilizer in the region of Punjab causing various health problems and making the water unfit for consumption and destruction of local food culture of these states like jowar, bajra, maize, til, cotton pulses like arhar, urad, guar, etc. In Haryana, the cultivation area of paddy crop (water-intensive) has

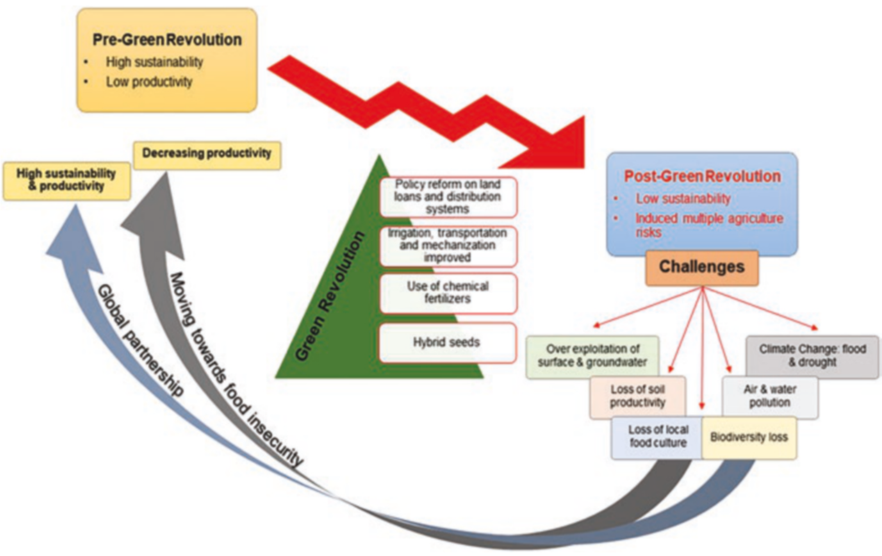

Fig. 1.2 Shift from subsistence agriculture to industrial agriculture in the Indian agriculture system

increased dramatically from 8.5 lakh hectares in 1996 to 13.87 lakh hectares in 2018, before declining to1.2 million hectares in 2020–2021 (Singh 2000). Numerous studies have illustrated that the rotation of wheat and rice crops in the Indo-Gangetic region is not a long-term sustainable approach (Ramesh et al. 1997; Chand et al. 1998; Bathla 1999; Banjara et al. 2021). The groundwater level in some districts of Haryana state—Kurukshetra, Kaithal, Bhiwani, Mahendragarh and isolated portions of Fatehabad and Sirsa—are facing severe groundwater depletion which is approaching 40 m depth and the rate of decline is 1 m every year since 2013 and has reached to about 20.67 m in May 2020 according to a study by Khedawal et al. (2021).

As per aquifer mapping, India's groundwater extraction has increased from 58% (2004) to 63% in 2017, much higher than the national stage in 13 states/UTs with Haryana, Punjab, Rajasthan and Delhi having had a 100% stage of extraction according to a report of the Comptroller and Auditor General of India on Groundwater Management and Regulation (CAG 2021). This dropping of groundwater aquifers is linked to significant declines in yield, cropped area and production for wheat, rice, sugarcane and maize (Joshi et al. 1991). Despite the detrimental effects of groundwater depletion on agricultural productivity, there is little evidence that farmers switch from more water-intensive grains to less water-intensive crops (Bhattarai et al. 2021). The reasons behind the cultivation of water-intensive crops are procurement of these staple crops by the government by providing remunerative prices in the form of minimum support price (MSP), and flat tariffs of electricity are another reason for the gigantic extraction of groundwater (Singh 2001). Though flat tariffs (fixed monthly rates) have lower administrative expenses and make water distribution more fairly accessible between high-income and low-income farmers, such power utility system lacks in providing farmers no incentive for water conservation. Metered tariffs (consumption-based), on the other hand, can encourage water conservation, but they are difficult to administer and discriminate against low-income farmers (Sidhu et al. 2020). The study estimated that groundwater irrigation emits 45.3–62.3 MMT of carbon yearly, accounting for 8–11% of India's total carbon emissions (Rajan et al. 2020). Also, deep tube wells contribute to a large carbon footprint, and the increasing number of wells poses serious environmental concerns. The carbon emissions have increased to about 161% in the last five decades through a shift in agriculture functionality in India (14.81 TgCE/year in 1960 to 38.71 TgCE/year in 2010). Rice had the highest emission of 23.75 Tg CE/ha, while red gram had the lowest (2.98 Tg CE/ha) (Sah et al. 2018). Another study estimated the carbon and water footprint for rice and wheat for the Punjab region as the CF per unit area of rice is 8.80 ± 5.71 and for wheat is 4.18 ± 1.13 t CO_2eq/ha and the average water footprint is 1097 and 871 m^3/t, respectively (Kashyap et al. 2021). The intensively cultivated region of Indo-Gangetic plains has resulted in crop production increasing up to 2.5-fold, but along with benefit, it has increased threefold in GHG emissions (Benbi 2018; Jaiswal et al. 2020; Devakumar et al. 2018). The carbon and water footprints for rice are much higher than for less water-intensive crops.

Waterlogging and salt stress in soil affect crops and soil fertility in Haryana's semi-arid region (Srivastava et al. 2017). Soil salinity was previously associated with high groundwater level, which pumped salts into the plant roots via capillary forces. However, increased groundwater extraction for crop irrigation has resulted in falling water levels and the risk of sodification and salinization has increased (Shyam et al. 2022). Famers of north-western parts of India are facing twin problems of salinity and waterlogging due to excessive groundwater extraction for irrigation, and it is projected roughly 84 lakh ha of land is under salinity and alkalinity stress and 55 lakh ha being waterlogged in India's arid and semi-arid regions where more than 75% of the population lives (Datta et al. 2002; Ritzema et al. 2008; Singh 2015). Saltwater intrusion near coastal areas is also associated with heavy withdrawal of groundwater. The chemical analysis of groundwater samples around Saurashtra coast, India, shows a very high concentration of total dissolved solids (TDS) >1000 mg/L and chlorides 103–3899 mg/L, and conducted resistivity imaging survey shows shallow resistivity zones (0–3 m) due to saltwater intrusion (Pujari et al. 2009). A chemical characterization study conducted in Cuddalore district, Tamil Nadu, found a high concentration of ions like chlorides (3509 mg/L), sodium (3123 mg/L) and bicarbonates (998 mg/L) which were multiple times higher than standards of WHO, BIS and ISI (Srinivasamoorthy et al. 2013; Venkatramanan et al. 2015). Another issue associated with the over-pumping of groundwater for irrigation is heavy metal contamination in groundwater. The arsenic level in shallow aquifers of West Bengal has increased in recent years, causing concern among groundwater users (Singh et al. 2002). Intensive agriculture, urbanization and industrialization have increased heavy metal content that impacts all organisms through biomagnification. A review study (1991–2018) on heavy metals in Indian soil suggests that zinc and lead concentration surpassed Indian standard limits, and average values for As and Cu cross the limits for all considered soil types except roadside and Cd levels also, which exceed for all soil types. The results show that Cd is the primary pollutant found in all soil types in India.

Due to the shortage of freshwater and groundwater overexploitation, the farmers are now inviting another risk by irrigating farms with municipal wastewater, resulting in heavy metal contamination in vegetables and soil. A case study of Titagarh, West Bengal, found the residues of heavy metals like Pb, Zn, Cd, Cr and Ni in vegetables grown using municipal wastewater and the concentrations were above the permissible levels (Gupta et al. 2008). Another study conducted in Vadodara, Gujarat, India, for metal contamination of soil and vegetables irrigated in wastewater effluent showed that vegetable species of spinach, radish, tomato, chili and cabbage have high levels of harmful metal accumulation and translocation (Tiwari et al. 2011).

The use of chemical fertilizers and pesticides are used to increase crop production and reduce pest infestation. The overuse of synthetic chemical fertilizers has a deleterious effect on soil productivity, surface water resources like lake eutrophication killing aquatic life and groundwater resources and air pollution in the form of (NO, NO_2, N_2O) biomagnification in the food chain and land degradation. The use of the relatively high proportion of chemical fertilizers is lost on surface or groundwater through leaching, surface flow, drainage and volatility in air. Nitrate is one of the most critical characteristics of water pollution. When nitrate concentrations in drinking water exceed, 50 mg NO_3^-/L causes blue baby syndrome and other diseases like goitre, congenital disabilities and heart disease. Also, chemical fertilizers generate harmful GHG emissions and deplete the O_3 layer. Agriculture is the major source of human-induced N_2O emissions, which accounts for 60% of total GHG emissions. When nitrogenous fertilizer is manufactured, greenhouse gases such as CO_2, CH_4 and N_2O are produced. Nitrous oxide is a vital GHG after CO_2 and CH_4, with 310 GWP (global warming potential) of CO_2 equivalent (Kumar et al. 2019a, b). Ammonia is volatilized from the fertilized field and deposited in the troposphere, where it is oxidized to produce nitric and sulfuric acids, resulting in acid rain. Acid rain can harm vegetative cover, structures and aquatic species in lakes and reservoirs. Methane is emitted by rice fields, and its concentration doubles when ammonium-based fertilizers are used. Thus, the chemical fertilizers used in agriculture contribute to climate change and air pollution. Overuse of chemical fertilizers can cause soil acidification and crust, diminishing organic matter, humus, and beneficial organisms, inhibiting plant growth, changing soil pH and increasing pests. Soil acidity reduces crop phosphate absorption, raises harmful ion concentrations in the soil and slows crop growth. Thus, these risks will impact food productivity in India. A recent report by International Food Policy Research Institute (IFPRI) projects that climate change could drop India's food production by up to 16%. Climate change will increase the risk of hunger by 23% (73.9 million Indians) by 2030.

Besides environmental risks, other risks associated with Indian agriculture are social and economic challenges, i.e. significant disparities in resource availability among rich and marginal farmers, e.g. farmers from Panjab have adequate irrigation facilities, subsidies on electricity, government procurement of rice and wheat at MSP, the introduction of genetically modified crops, risk of food waste due to poor logistics infrastructure, risk of yield loss due to rising climate change effects of floods and drought and inadequate finance system. The farmers face such socio-economic challenges and fail to survive. Each year in India, about 16,000 farmers commit suicide, especially in the state of Maharashtra, Karnataka, Andhra Pradesh, Chhattisgarh and Madhya Pradesh (Merriott 2016). The shift in cultivation to cash crops (high production and maintenance cost) from food crops is also one of the reasons for suicides in India, as cultivating cash crops and farmers are more prone to the risk of indebting one crop fails (Ray 2022). Another risk associated with the food system is the failure of coordination during the food crisis, leading to price volatility. For example, rising prices of dry fodder in Haryana and Punjab result from regulators' lack of coordination of the market. India's rigid finance or credit system is another problem for small and illiterate farmers, as sanctioning loans requires time and paperwork. Moreover, they are often not able to get financing aid as farmers fail to provide collateral. In rural populations, the prolonged lack of access to credit is a systemic risk since it hinders both production and resilience to growth in the region.

The leading causes of food losses have been identified as a lack of scientific harvesting procedures and many intermediates in the supply chain (Balaji et al. 2016). The post-harvest losses occur due to a lack of proper technology infrastructure, poor storage facilities and policy ramifications. Pest infestation poses a great threat to crop production and yield loss. The recent attack on chili by a new pest, black thrips (*Thrips parvispinus*), destroyed farms in six states—Telangana, Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Chhattisgarh of India (Pujari et al. 2009).

Thus, the changing climatic conditions and over-exploitation of natural resources have affected the agriculture system severely. The various risks in the Indian agriculture system will affect food security as the population is growing at tremendous rates. It is high time to think locally and act globally to handle the risks proactively. SDG 17 can help India gain a sustainable agriculture approach by inducing global partnerships.

The Indian government and policymakers need to mark on building strong bilateral and multilateral international partnerships for technology development and transfer, finance flow for various irrigation projects like canals and hydropower plants, interlinking of rivers, electrification, road development and capacity building providing technical training regarding new technology, the introduction of AI, machine learning and IoT and encourage farmers to adopt sustainable agriculture strategies; promote research, trade import and export by applying free duties on essential commodities; and handle various systemic risks to data quality and quantity needs to be accurate for policy formulation.

1.3 How Global Partnerships Can Aid Indian Agriculture System

The performance of SDG 17 is critical for achieving the other 16 SDGs, which all rely on stable implementation and long-term global partnerships. The global alliances comprising governments, international organizations, non-government organizations and industry aim to encourage investment in agriculture and food sectors, assist small farmers and establish state welfare connections through the collaborative efforts of all stakeholders (MDG Gap Task Force 2015). In an agriculture network, multiple risks are observed which are interconnected. We can only solve these vulnerabilities with a unified and multidisciplinary approach. India is growing as a possible game changer in global development efforts because of its large 17% worldwide population and a significant development partner for many nations, particularly in the South Asian region. India. Over the years, India's development partnerships have organically followed sustainability goals. In conjunction with the World Food Programme, India joined Kabul's School Feeding Program in 2003, transforming one million tonnes of wheat into high-protein cookies for school distribution. New Delhi began construction of the Salma Dam Power Project on the Hari Rud River in the district of Herat in 2004. It claimed 42 MW of electricity generating as well as a 40,000-ha irrigation capacity (Prabhu 2021).

India is currently focusing on regional connectivity with neighbouring countries to build bilateral relations. Apart from bilateral initiatives, one can find India's development collaborations in several multilateral platforms like IBSA (India, Brazil, South Africa) Fund (2006); India-UN Development Partnership Fund, 2017;

International Solar Alliance (ISA), 2015; Coalition for Disaster Resilient Infrastructure (CDRI), 2019; and New Development Bank, 2015. Despite the fact that multilateralism has been declining in recent years, long-term collaborations are very important in the run-up to Agenda 2030. The global partnership in finance, technology, trade, capacity building and skill can help handle the Indian agriculture risks and attain sustainability in the whole agriculture network. India needs to follow an approach to thinking locally and acting globally. In non-urban areas, agricultural production has always been the most prevalent economic branch. International agricultural cooperation and partnerships are now focusing on global food security, modern sustainable plant and livestock cultivation approaches and their links to other rural economies. The major challenges in contemporary days are achieving global food security and rural residents' well-being, particularly in developing countries like India, as well as in farms affected by natural hazards like drought, frequent floods and other extreme weather events as well as an unstable political situation (Lichtenberg 2002). These rising climate change challenges to food security and agriculture require early investment and assist rural stakeholders in supporting small land farmers and poor consumers. India needs local and global policy-linked research, strong institutions and infrastructure to share the knowledge on institutions, practices and technology to adapt and mitigate agriculture risks (Vermeulen et al. 2012; Auer 2010). There are a handful of good agricultural global partnerships agencies such as the Food and Agriculture Organization (FAO), UN and Consultative Group for International Agricultural Research (CGIAR). More such agricultural organizations are needed to work in the direction of sustainability (Demirović and Petrović 2020). In India, about 70% of the inhabitants live in rural areas. Agriculture, self-employment, services, construction and other activities in rural areas contribute significantly to India's GDP (Petrović 2021). India needs global partnership in agriculture research to provide integrated farming solutions through the collaborative effort of international researchers, practitioners and stakeholders across disciplines. Sharing ideas and knowledge and working on gaps present in the system through collective efforts can help achieve sustainable growth. Agriculture is a risky business, and there are more chances of loss; therefore, diversification of economic activities and revenue shifts from primary agricultural activities toward service-providing industries is needed. There is a lot of potential and skills present in the rural community, and the need is to provide vocational training to women and help promote their skills. In countries like the USA, Australia, France and the European Union, different organizations are working on the integration of local knowledge for rural policy development that would be beneficial in developing rural networks and support developmental projects like rural tourism, ecotourism, traditional community knowledge and skill development (Rewhorn 2019). Such initiatives are essential for Indian farmers to mitigate the economic crisis like threats of indebtedness. In addition, India has great scope for rural tourism, and there is a need to develop global partnerships and work on such projects.

Agriculture can work as a multifunctionality business that integrates agricultural production, environmental protection and societal services (Refsgaard and Johnson 2010). One of the initiatives that can help boost the Indian farming community is rural tourism. Rural tourism is one of the most important non-agricultural aspects of this approach. Rural tourism and its success cannot be seen without community participation. Rural tourism is reliant on natural and human activities in villages where it is flourishing, such as infrastructure, capacity and the availability of lodging, food and beverages, as well as organized events in the direct proximity and multifunctional agriculture practices (Fang 2020; Mili 2012). The establishment of successful rural tourism requires market researchers to gain comprehensive understanding of current trends in rural tourism and through government and local resident efforts to implement successful global development models that take into account all of the unique characteristics and reinforce natural, cultural and other treasures (Ryu et al. 2020). The international organizations associated with tourism like the European Federation of Rural Tourism (EuroGites) and International Association of Experts in Rural Tourism (IAERT) can collaborate and coordinate with the Indian travel market to develop a rural aspect of tourism (Petrović 2018). Also, policymakers should work on finding a solution for farms instead of structurally changing them. Modern agricultural policy should encourage farms to diversify their forms of income by engaging in other economic sectors, such as rural tourism. The policy plans should concentrate on expanding services, fostering ecotourism and rural tourism, promoting a healthy local diet, upgrading public utility infrastructure, coordinating efforts among various stakeholders and motivating farm members to launch new (non-agricultural) ventures, including good business investment infrastructure and work on human resource development (Das et al. 2015). It also entails a variety of approaches for assisting in the development of additional values for local products, such as support for business networks, promotions of collective goods and services, brand marketing of local goods, quality improvement and the establishment of handcraft adaptation facilities (Puri et al. 2019). The financial support of the central government can help small farmers in building partnership and increasing awareness, disseminating information and offering advisory help in expanding their economic activity beyond agriculture services such as tourism and hospitability, selling local products directly to tourists. This will empower small farmers of India. Thus, from small communities to global networks, the 17th SDG establishes partnerships for sustainable objectives involving governmental authorities, the commercial sector and civil society to achieve local and global welfare. Partnerships for the goals are based on shared beliefs, values and goals that put people and the environment at the forefront of international attention. A single industry or organization cannot communicate sustainable development goals; it is only achievable through collective efforts of various stakeholders.

The support of international government is becoming increasingly important for developing countries, as these nations have resource constrain. Also, the stakeholder's partnership is crucial in accelerating progress toward the SDG goals. Also, each country should show responsive behaviour in conduct progress evaluations, including businesses, civic society and representatives from various interest groups. The countries will communicate their practices correctly and deal with public policy issues internationally. In addition, the UN's bilateral and multilateral political dialogue on sustainable development will annually discern problems and propose beneficial initiatives.

1.4 Conclusions

Feeding the 1.38 billion population of India and exporting food grains have put immense pressure on farmers to produce a maximum land potential. The use of modern mechanization technology and chemical fertilizers and overexploiting water resources, especially groundwater have led to many risks in agriculture. The multiple risks associated with agriculture are climate change, pest infestation, saltwater intrusion, biomagnification of chemicals in the food chain, heavy metals in vegetables, loss of soil productivity, loss of local food culture, waterlogging, salinity and depletion of groundwater. These risks affect the social and economic status of farmers. The rising climate change events like abrupt rainfall causing floods and drought are making the condition more worse. These situations force farmers to get away from the farming business and shrink the farming community. Also, food prices are increasing, which puts pressure on the consumer. To maintain the supply and demand chain, it is necessary to take collaborative and coordinated actions for the resilience of farming. Global policy frameworks are necessary on the 2030 Agenda for the sustainability and joint action at the international levels and across several policy domains. When multilateralism is being questioned more than ever, it is critical to find constructive methods to strengthen cooperation across various levels to achieve the 2030 Agenda. Global partnerships can help in achieving sustainable agriculture for a country like India in terms of financial investment in research projects; assistance in building infrastructures like irrigation projects such as canals, rural electrification, road and transport development and technology like water conservation (micro-irrigation, desalination plants, sprinkler method); harvesting and post-harvest technology to reduce food waste and capacity building like training programs to empower woman farmers and focus on farmer entrepreneurship, eco-tourism and rural tourism. Global partnership promotes work for people from various disciplines with a unified approach to achieve a sustainable solution.

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