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The Nexus Between Sustainable Agriculture Practices, Food Security And Climate Change In India: A Review.

Douglas Marowa[1]*, Manoj Pokkiyarath[2], Pozhamkandath Karthiayani Viswanathan[3]

Abstract
More than 850 million people experience food insecurity globally, which is a serious concern. Worldwide food insecurity and malnutrition, particularly in India, are a result of the ever-increasing population growth, aided further by increased food demand. This review attempts to discuss the relationship between sustainable agricultural practices, food security and climate change in India. Factoring in the operationalization of a system that transfers different kinds of environment brilliant horticultural mediations (logical innovations, native specialized information, institutional developments and data, and communication advances) that can assist with advancing maintainable occupation and food security. Taking on a non-systematic approach, various peer-reviewed articles, journals, books, and institutional reports were reviewed. Sustainable agricultural practises have not gained ground in India, precisely among the small-medium sized agricultural enterprises. Food security remains susceptible to climate change given its roots in rain-fed agriculture that is largely practised by smallholder farming communities. The purpose of this article is to inform governments, policymakers, service providers and civil society regarding the importance of sustainable agriculture practices and its relationship with food security as a climate change strategy, and to plan strategies to improve the household food security status in India.

Keywords: *Sustainable development, agriculture, food security, climate change, livelihood*

1. Introduction

An increase in the world population means demand for food also increases resulting in worrying trends in food security and malnutrition. Food production, distribution and consumption worldwide has also changed leading to negative effects on food security to the rural communities (FAO, 2022). Food security is a state where the accessibility, openness, usage and strength of food are guaranteed, and it is sufficient to cover the food interest of individuals (United Nations, 2008). Attempts to improve food security using modern strategies have been made before, including the Green Revolution that was introduced in India in 1960 (Hardin, 2008). There were economic prosperity early years of the introduction of the Green Revolution, as it prompted expansions in the horticultural result, supporting India's general economy. Farmers' incomes were rising by more than 70% by 1970, and Punjab was producing 70% of the nation's total food grains. (Sandhu, 2014). However, despite the initial prosperity experienced, the Green Revolution had negative effect on cost for small farmers in using hybrid seed varieties, demands of increased irrigation systems, fertilisers and pesticides. The high costs of cultivation forced rural farmers to take out loans with high interest rates because they were having trouble paying for the expensive technologies. This included over-borrowing and they were entrapped into a cycle of debt, leading to low production or even not producing at all. Over the top and unseemly utilization of composts and pesticides dirtied water and kills useful bugs and natural life. The Green Revolution caused overuse of the soil, depletion nutrients, and soil and land degradation. These issues were exasperated because of nonattendance of preparing to utilize current innovation and huge lack of education prompting inordinate utilization of synthetics (Dutta, 2012). Farmers' loss of biodiversity, an increase in stubble burning cases, and monoculture practices with a few major crops are unsustainable farming practices. Unsustainable farming like intensive farming causes adverse impacts, due to the use of pesticides, intensive farming led to unsustainable farming practices. Herbicide-resistant plants have developed, soil and water pollution brought on by intensive herbicide use (Sudheesh, 2015). These farming practices would also increase the effects of heavy monsoon and they could cause huge damage including landslides as the soil will be weak. According to Vinodini et al., (2021), monsoons may be linked to the frequently occurring floods that cause destruction of land and the

[1]*Amrita School for Sustainable Futures, Amritapuri, Amrita Vishwa Vidyapeetham, India
briddids20003@am.students.amrita.edu ORCID 0000-0002-1563-7288
[2]Amrita School of Business, Bangalore, Amrita Vishwa Vidyapeetham, India
[3]Amrita School of Business, Amritapuri, Amrita Vishwa Vidyapeetham, India

washing away of farmland soils and houses. This study suggests adoption of district specific policies for arresting food insecurity and the improvement of covering rural awareness programmes.

The world's agriculture and food systems are not presently delivering desirable outcomes on food security and nutrition (Edmundo et al., 2020). Unsustainable agriculture practices and inappropriate anthropogenic activities in rural communities are closely linked to food insecurity. Addressing food insecurity in the world is still of major challenge and India is not exceptional. UNEP (2021) reviewed that sustainable agriculture is farming that meets the needs of existing and future generations, while also ensuring profitability, environmental health, social and economic equity. UNEP further indicated that it favours techniques that emulate nature to preserve soil fertility, prevent water pollution, protect biodiversity and ensure food security. FAO (2014) defines sustainable agriculture as an integrated system of plant and animal production practices having a site-specific application that will over the long term satisfy human food and fiber needs. Gahukar (2009) also reviewed that the India's tenth Five Year Plan (2002-07) laid emphasis on food security and employment opportunities in rural areas. However, the question remains whether the agricultural practices are contributing to people's food security.

Hence, it may be important to understand and critically review the interface between sustainable agriculture practices, food security and climate change in Indian context. The need for such an attempt is reasoned by the increasing food insecurity challenges in the context of climate change as well as India's continued engagement with food production by allocating almost half of the gross cropped area for growing food crops. The main question addressed in this review is to examine if and how sustainable agriculture practices contribute to food security in India? Particularly, it reviews the main dimensions of both sustainable agriculture practices and food security, and the nature of food security. The review also addresses how integration of the food system approach could be utilised as a conceptual framework to explain the nexus between sustainable agricultural practices, food security and climate change in the Indian context.

2.0 Methodology

This study adopted a non-systematic review approach by examining peer-reviewed articles, journals, books and reports. To understand the study matter, the paper examined sustainable agriculture and its importance, dimensions of sustainable agriculture, Indian agriculture practices and sustainability, food security and the nature of food security in India, and climate smart agriculture models. It also covered the policies towards food security in India, including farmers' perception of sustainable agriculture, the roles of key stakeholders in sustainable agriculture practices for food security and the integration farming systems through food system approach.

3. Review and discussions

3.1 Definitional relationships: sustainable agriculture, food security and climate change

Sustainable agriculture is the process of farming crops and livestock for human needs through prompt utilization of resources with improved efficiency without distressing or polluting the surrounding environment. Regarding this motto, India achieved effective green revolution technology because of efficient usage of high-yielding seed varieties (Tahat et al., 2020). Whereas food security is described as when the overall human population during all times, possesses economic and physical accession to adequate nutritious and safe food. The food which meets their dietary needs, and their health preferences has to be securely reached in order to lead a healthy and active lifestyle. The four dimensions of food security are physical availability, economic and physical accession to food, food utilization and stability. These four dimensions have to be realized and fulfilled simultaneously in order to attain the objectives of food security (Ansah et al., 2019). Concurrently, the climatic change denotes to the long-term change in the weather and temperature patterns. Such shifts could be natural or manmade causing the variations in the solar patterns, over production of methane and carbon di oxide etc (Arora, 2019). Undesirable climatic change affects agricultural sustainability and thereby, food security and hence this study focussed on the nexus between the three defined terms that has been represented in the following sections.

Therefore based on the definition relationships given above, food security remains a potential global-wide problem, especially after the middle of the twentieth century (Huang & Wang, 2014). Food security has been affected adversely mainly due to the consistent rise of the human population, which remains to increase at an exponential pace in developing and poor nations. The per capita requirement for food relies huge pressure on the available natural resources. The forests and agriculture are the predominant source for meeting several

population demands. Hence the present study shifted the focus towards sustainable agriculture and its integration with the scenarios of food security and climatic change. It has been determined that the food requirements might double in the upcoming century. Globally 800 to 850 million and nearly 220 million people in India are faced with hunger. Accordingly, the World Bank state that one out of nine are remain undernourished. The main criteria of developing countries for forestry, agriculture and land usage is to provide nutritious food for all (Huang & Wang, 2014).

Since food security is mainly based on food production and climatic condition, understanding the available resources and its dynamics (Leggett, 2020). Within constrained land resources, nearly 38% of the land has already been used under reserved forest. Hence sustainability for agricultural production in relation to food security and climatic factors is on the uptrend (El-Ramady et al., 2013). The overall demand for food increases with the increase in population associated with the major threat to natural resources. The bio physical competency of agricultural land to produce quantified and qualified food requirements of the people requires innovative agriculture technology to secure the people and the land. Hence sustainable development goals have been conceptualized and targeted to be completely realized by the year 2030. The Sustainable Development Goal number two aims to address hunger with the new technology and climate variability management through the promotion of sustainable agriculture farming practices. Several interventions and activities of global agencies attempted to secure people and work towards the development of well-nourished and healthy population. These organisation and government policies put their efforts and capacity in determining the specific areas, nations and the role of agriculture and problems associated with the climatic conditions. To highlight an ideal food security indicator is under recent research for the past decades. The present study has collected information from several existing literature and made an atom to inform the policymakers governments service providers and the civil societies about the significance of sustainable agriculture practices and its correlation with food security and climatic change. The study has been expected to enhance the household food security in India.

3.2 Sustainable agriculture and its importance

UNEP (2021) reviewed that sustainable agriculture is farming that meets the needs of existing and future generations, while also ensuring environmental health, social and economic equity and profitability. UNEP further indicated that it favours techniques that emulate nature to preserve soil fertility, prevent water pollution, protect biodiversity and ensure food security. The United Nations (2008) further reviewed that the processes are to be done in a sustainable manner. FAO (2014) further reviewed that sustainable agriculture integrates system of plant and animal production practices having a site-specific application that will over the long term satisfy human food and fiber needs. FAO (2017) highlighted that sustainable agricultural development manages and conserves the natural resource base, and the involves the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Therefore, sustainable agriculture practices enhance social requirements, economic demands and environmental quality and the natural resource base upon which the agricultural economy depends. It provides a potential solution to enable agricultural systems to feed a growing population within the changing environmental conditions (Rockstrom et al., 2016). It seeks to integrate three main objectives into farmers' work, a healthy environment, economic profitability, and socio-economic equity (UC, 2021). It also provides an adequate and dependable household income through reducing poverty and associated problem of population and reduce environmental degradation and conserve resources (Chioma, 2018). Farmers become less dependent on external inputs, seeking to capitalize more effectively and efficiently on the natural resource base (Prabhakar et al., 2017). Sustainable farming is a major element in the ecosystem's capacity to sustain essential services and services' relationship with social demands. Sustainable agriculture practices would result in achieving of food self-sufficiency, creating grain surpluses, stabilizing food prices, sustaining agricultural growth, absorbing labour force in rural areas, and alleviating rural poverty; all of which are vital for food security.

In any farming environment, the area under productive and sustainable agriculture would capture the three dimensions of sustainable production: environmental, economic and social. Achievement of these dimensions leads to the achievement of the five pillars of sustainable agriculture, which are productivity, security, protection, viability, and acceptability.

Table 1. The Dimensions of sustainable agriculture: Source, Authors; (2023)

Dimension of Sustainable Agriculture		
Social Sustainability	Economic Sustainability	Environmental Sustainability
Indigenous Knowledge	Efficient land use and productivity	Natural resources restoration
Gender and inclusiveness	Profitability and viability	Soil, water, land, forest and air quantity/quality management
Household food security	Self-sufficient and reliant	Climate change adaptation & mitigation strategies
Participation, human skills development & empowerment	Financial Risk management	Biodiversity conservation and management
Socially acceptable technology	Employment opportunities	Natural disaster and risk management

These dimensions would be addressing sustainable development goal number two, whose aim is to end hunger, achieve food security and improved nutrition and promote sustainable agriculture, and concurrently fulfil other sustainable development goal targets and indicators especially SDGs 1, 3, 5, 6, 12, 13, 14 & 15. Viswanathan et al., (2020) concurred as they indicated that in fighting hunger a number of SDGs and various subcomponents are achieved. As revealed above, sustainable agriculture has three predominant dimensions which are economics, environmental and social dimensions (Bathaei & Streimikiene, 2023). The agriculture needs to obtain sustainability by developing a balance.

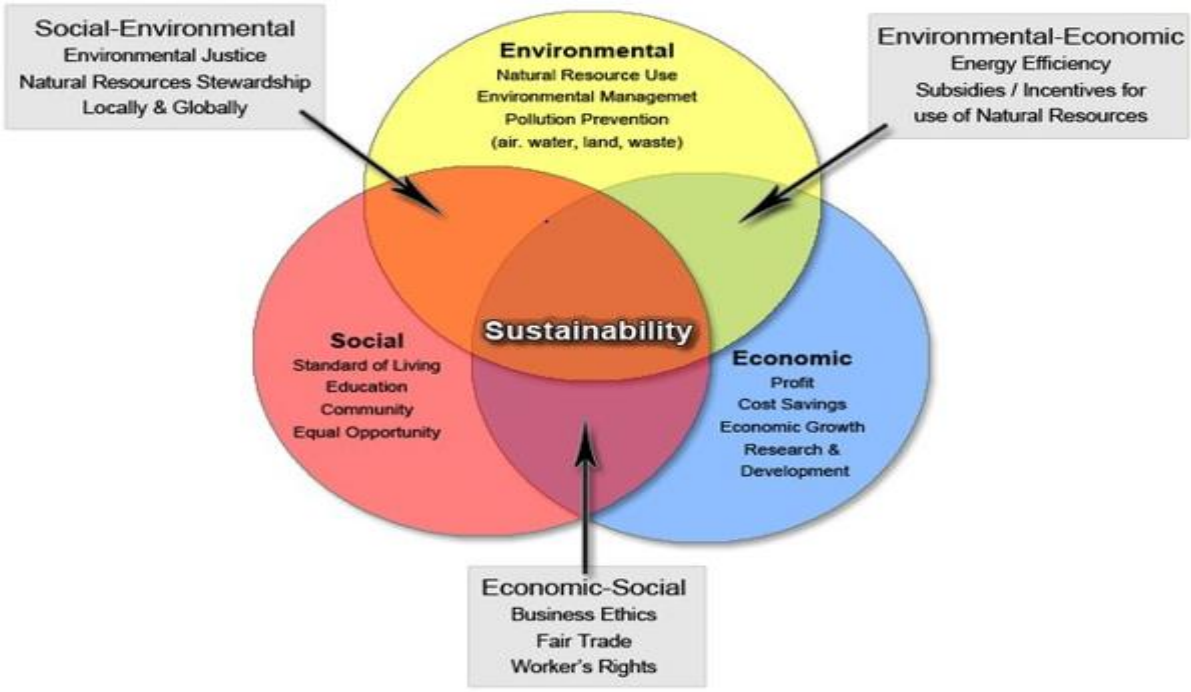


Figure 1. Dimensions of Sustainable Development in agriculture: (Abubakar & Attanda, 2013)

The three significant dimensions are present in the following figure. The sustainable agriculture mainly focuses on decreasing the negative externalities on the health and environment and focus on soil quality, slope and topography. The income due to agricultural productivity has been considered as the economic indicator of sustainable agriculture apart from farmer's participation, technical knowledge and other ecological parameters (Duong et al., 2019). However, it is paramount to monitor the potential negative impacts of a farming system as Gharsallah et al., (2021) indicated that the expansion of agricultural land and the intensification of farm production methods are approaching environmental, social, and economic limits, which necessitates the need to measure sustainability of agriculture. Based on Singh et al., (2009), the Authors selected the following indices as suitable to measure sustainability of Indian farming system. These were found to be used in measuring agriculture sustainability worldwide, especially in developing countries.

Table 2. Agriculture dimensions and indices: Source, Authors; adopted from Singh et al (2009)

Agriculture dimensions and indices		
Dimensions	**Category of the index**	**Indices**
Economic	Eco-system based Indices	Sustainability Performance Index
	Development indices	Index of sustainable and economic welfare
Social	Social and quality of life based indices.	Well-Being Assessment (Well-Being Index)
	Composite sustainability performance indices for industries	Composite sustainable development index
	Development indices	Index of sustainable and economic welfare
Environment	Environmental Indices for Policies, Nations and Regions	Environmental Performance Index
	Eco-system based indices	Agri-environmental Footprint Index

3.3 Indian agricultural practices and sustainability

Sustainable agriculture practices are far from mainstream agriculture in India, however it is observed that there are scattered practices being adopted by farmers across states/ regions that include double cropping, mixed cropping, crop rotation, agroforestry, use of local varieties and resources with host pathogen interactions (Sara & Ovi, 2015). The Authors developed a list of these sustainable farming practices highlighting their scope and significant benefit to Indian farming communities.

Table 3. Sustainable agriculture practices and their benefits: Sources, Authors; (2023)

Sustainable Agriculture	Scope	Benefits
Organic farming	Cultivation of plants and raring of animals in natural ways, avoiding synthetic substances	Keep the soil alive and in good health by use of organic wastes (crop, animal and farm wastes, aquatic wastes).
Conservation Agriculture	Practices that reduce soil disturbance through, minimum tillage, maintenance of crop residue, and crop rotation	Reduction in soil erosion; increase ground water; improving soil moisture and nutrient content; lowering input use
Agroforestry and food forests	Growing of trees and shrubs amongst crops or grazing land.	Trees create a favourable microclimate that maintains favourable temperature and soil humidity, while protecting crops from wind or heavy rain, soil stability
Crop rotation and polycultures	Mimic natural principles to achieve the best yields through crop diversification.	Most effective agricultural control strategies used in preventing the loss of soil fertility. High biodiversity makes the system more resilient to weather fluctuations, promotes balanced diet
Permaculture	A design system that applies principles that are found in nature, allowing humanity to live in harmony with the natural world	Mulching, growing grain without tillage, each plant serving multiple purposes, and creating swales on contour to hold water high on the landscape
Natural pest management	Avoid use of synthetic pesticides Instead create conditions that do not favour pests	Strengthen natural resilience of crops and practices that interrupt pest cycles.
Urban agriculture	Innovative and sustainable growing techniques being used in cities	Localize food system, as food is grown much closer to home, including in cities
Growth of heirloom and older varieties	Growing heirloom and older varieties of crops to preserve the biodiversity of seeds.	Continuous growing heirloom and other older varieties of plants. Save seeds (traditional). If not, many of the remaining varieties of food plants could be lost.
Hydroponics and aquaponics	Growing of plants without soil, nourishing the plants through specialized nutrients that are added to water.	In *hydroponic* systems, crops are grown with the roots directly in a mineral solution *Aquaponics* combines the raising of aquatic animals with the growing of hydroponic crops. Water is recycled in the two practices
Biodynamic farming	Manage farms as one living organism where cultivated species intertwine and support each other's health.	Generating the necessary health and soil fertility for food production onsite
Natural animal raising	The raring and raising of animals on the pasture or in their preferred environment	It benefits the environment, people's nutritional needs and good for the animals. Manure returns nutrients back into the soil. Plant diversification, opportunity for a variety of rarer plants
Mulching, groundcovers, and manual weed control	Practice involves natural suppressing of weed growth, use mulch and crop covers	Conserve soil moisture, reduce, eliminate the need to apply herbicides to kill weeds, improves nutrient retention and reduces the need for tillage as soils are less compacted
Precision farming	Approach where inputs are utilised in precise amounts to get increased average yields	Reduces cost on resources, input and on labour. High return and yields. In irrigation, the water and solutions are applied at the plant zone. Reduce wastage of resources

Most sustainable agriculture practices have less than five million (4%) farmers practicing them. Crop rotation is the most popular sustainable agriculture practices in India, covering around 30 million hectares of land. Agroforestry, mainly popular among large cultivators, and rainwater harvesting have relatively high coverage of 25 million hectares and 20-27 million hectares, respectively. Organic farming currently covers only 2.8 million hectares or two per cent of India's net sown area of 140 million hectares. Natural farming is the fastest growing sustainable agricultural practice in India and has been adopted by around 800,000 farmers.

Water scarcity, a decrease in cultivable land, high input costs, a lack of marketing networks and opportunities for farm produce value addition, and fluctuating market prices are just a few of the issues facing Indian agriculture (Gupta et al., 2021). According to Sara & Ovi (2015), there are sustainable agriculture methods and farming practices that have been utilized at international level. Farm (2018) added that even at micro level these sustainable agriculture practices would promote the environment, social and economic factors of rural communities, which are the pillars for sustainable development. Therefore, there is a need to find and monitor the contribution of these sustainable agriculture practices to food security. This relationship will be through measuring food contribution to households and at national level. This can only be done through measuring food security sustainability among the rural communities specifically targeting to measure improvements on the food security dimensions in the rural communities. Therefore, the four dimensions can be measured separately. Mutea et al., (2019) revealed that for the development of the food security index (FSI), most researchers focused on the mostly used indicators to measure household food security. They included: (a) household dietary diversity score (HDDS), (b) food consumption score (FCS), (c) coping strategies index (CSI), (d) months of adequate household food provisioning (MAHFP), and (e) household food insecurity access scale (HFIAS). To the above indices, Rafael & Ana (2008) added household income and expenditure surveys (HIES) and others.

Table 4. Food security dimensions and the indices: Source, Authors; (2022)

Dimensions	Indices
Availability	Months of adequate household food provisioning (MAHFP)
	Household income and expenditure surveys (HIES)
Utilisation	Household dietary diversity score (HDDS)
	Food consumption score (FCS)
Accessibility	Household food insecurity access scale (HFIAS)
Stability	Coping strategies index (CSI)

In the prevailing sustainable agriculture network, the combined utilization of an extensive range of nutrients, soil and pest management methods like crop residue, dung and other bio solids, mixed cropping and biological nitrogen fixation were under promotion. Such measures improves the quality of the soil and other criteria such as nutrient pools, climate resilience, biological diversity and ecosystem restoration by decreasing the soil degradation and increasing the socioeconomic status of the farmers (Trigo et al., 2021). But the low availability of organic fertilizers and subsidized rate of inorganic fertilizers has been considered as a major challenge in the organic management of the agricultural ecosystems (Shalaby et al., 2011). Hence the raise in the organic inputs associated with the balanced usage of inorganic fertilizers are promoted in sustainable agriculture for improving the nutrient pools and soil quality. The fundamental strategy for sustainable development in agriculture relies on more production using less least environmental resources. For achieving basic goals of sustainable development, various alternative agricultural practices like organic farming and conservation agriculture for soil management, bio fertilizers, water saving, precision agriculture were emerged and suggested.

3.4 The nature of food security and policies towards food security in India

As per the recent survey, nearly 795 million population were observed to be undernourished around the year 2017 (Arulbalachandran et al., 2017). There is a considerable and huge number of population needs healthy, active and wealthy life and hence the concept of food security that is based on accessibility, food availability, stability and its prompt utilization has been under research. The term food security is described to offset the variation in the production and prices. Hence obtaining food security and sustainability is considered as the vital challenge in terms of sociological, scientific, economic and political challenge in today's era. This remains to be major issue in those countries with high rate of fertility and so increased population growth of India needs intensive care on its research (Qaim, 2020). A considerable elevation up to 145% in the global wide food production has been observed because of introducing green revolution. But the problems associated with food security has been more under research in poor countries. The growth of population is considerably high in India, and it stands for 74th position in the FSI (Food security Index). But the food production growth is more

than the growth of population for the past three decades (Shirsath et al., 2020). India was found to be in the place of 103 under Global Index 201 and it has been estimated that a requirement of 122 metric tonnes of rice, 41 metric tonnes of course grains, 102 metric tonnes of wheat, 143 metric tonnes of milk and 28 metric tonnes of pulses for feeding 1.3 billion Indian people is needed by the year 2025.

This study (Jatav et al., 2022) analysed the condition of food security associated with its different components like accessibility, food availability, and stability by using multi-dimensional index across the Rajasthan districts with reference to indicators. Quantum Geographic Information System (QGIS) mapping and the quintile approach have been utilized for mapping the districts of Rajasthan into low, high and medium categories. Accordingly multiple regression analysis has been implemented in this study for the determination of important determinants of food security and the components. These results confirmed that there is extensive range of in-equalities across Rajasthan. This study observed that Ganganagar district was considered as the highest food secured district with 0.407 index due to its high food stability. In contrast, low food availability 0.084 with accessibility of 0.183 that contributes to lower food security was found in Durgapur district. Furthermore, the districts correlated with the dry regions are more susceptible to less food security. This occurs mainly due to less surface irrigation facilities. This article strongly suggested to adopt diversification from farm to non-farm, adequate storage capacity for controlling price fluctuations during the entire year, adoption of climate resilient technologies, promotion of water management, investment in infrastructure, conservation methods, water management promotional activities and replenishment of the groundwater in the rural areas for the augmentation of crop intensity. This study also suggested to adopt district specific policies for arresting the food insecurity and the improvement of covering rural awareness program. During mid-1970, the Government of India introduced three significant food intervention programmes to develop food security. This includes Public Distribution System (PDS) for food grains and Food for Work. Over several years, various novel programs were launched and few of them are being reconstructed with improving experience of program administration. Recently there are various poverty alleviation programmes for explicating the food components. As mentioned in the literatures the Indian government is working continuously to ensure food security and the undersection describes the polices adopted. The perspective of food availability analysed and a strong 5 year plan has been framed by India to support agricultural production (Janker et al., 2019). The Indian government initiated rehabilitation programs to the landless workers of agriculture field. Followed by this 5 year plans all focus to improve the industrialisation process and the determination of long term investment and Rapid economic growth (Leung & Tester, 2019). Meanwhile sustainability and food security was found to be important target in seventh five year plan (Patel et al., 2020). Furthermore, the 11th five-year plan provided significant importance to food security such as increased Gross Domestic Product, providing clean drinking water etc. accordingly the national food security act ensures food security through the planning commission of India and the following schemes were implemented:

- Building buffer stocks of food production
- Improving public distribution system
- Materialisation household food security programme
- Antyodya Anna Yojna
- Food supplementation of the vulnerable groups – integrated child development service, mid-day meals scheme
- Nutrition education especially through food and nutrition board and integrated child development service
- Annapurna
- Mahatma Gandhi National Rural Employment Guarantee Programme
- National old pension scheme
- The national maternity benefit scheme
- The national family benefit scheme
- Efforts of the health sector to tackle adverse health consequences of under nutrition; adverse effects of infection and unwanted fertility on the nutritional status; micronutrient deficiencies and their health consequences.
- The “Right to Food” campaigning and
- The National Food Security Act, 2013

Buffer stocking policy is an insurance policy that provides protection against inadequate production. It becomes a significant component for managing food security after famine in Bengal. When discussing about the PDS, it was operated in a joint forum by central and state government to eradicate the high prevalence of poverty especially in Tribal areas. The responsibilities for the determination of storage, procurement and storage of

food grains via central government and the state government through Food Corporation of India (FCI) was considered. The Antyodaya Anna Yojana strives to decrease hunger and offer minimum food security, as nearly about 5% of the overall Indian population could not take two square meals a day. After the formation of Antyodaya Anna Yojana in December 2000, nearly 25million poor people were observed to be highly beneficial under this system.

Improving public distribution system (ICDS) has been launched on October 2, 1975 and sponsored by Government of India. Under this system, the government provided welfare schemes for reducing malnutrition and improved the health of pregnant, lactating mothers, girls below 6 years. The main objective of the scheme could be obtained by Aganwaadi centres. Consequently, the Mid-day Meals has been implied in the year 1925 and this scheme has been expanded gradually to Tamil Nadu and Kerala. This scheme has been developed to enhance the nutrition level of children mainly in the drought affected areas and helps to improve the educational status of the poor people. More than 106 million students were highly benefited from this program. Meanwhile the national Food security Act 2014, which is also represented as right to food act focussed on the governmental policies and planning.

Table 5. Scope and impact of food schemes as remedial measures: (Lathi & Narkhede, 2010)

Government's Scheme	Target beneficiaries & Scope	Year of Launching	Aspect of the Scheme
Essential Commodities Act,1955	General population and is spreads to all of India	Launched in 1955	Food Availability
Integrated Child Development Scheme	Children and expectant mothers from 33 Community Development Blocks out of 6118 blocks nationwide, including 4790 in rural regions, 805 in tribal areas, and 523 in urban areas	Launched in 1975	Food Utilisation
Mid-day Meal Scheme	Class I–V pupils attend government primary schools that are managed by local bodies.	Launched in 1995	Food Utilisation
Village Grain Banks Scheme	For those who are willing BPL/AAY households (from food shortage areas), the Ministry of Tribal Affairs launched the programme, and the Department of Food & Public Distribution is implementing it in 11 States.	Launched in 1996-97 & Implemented in 2004	Food Availability
National Food for Work Programme (NFFWP)	Underdeveloped districts (150), rural people who need jobs and want to perform physical and unskilled labour.	Launched in 2000	Food Accessibility
Antyodaya Anna Yojana	5% of the nation's population who doesn't eat two meals each day.	Launched in 2000	Food Accessibility and Vulnerability
Sampoorna Grameen Rozgar Yojana (SGRY)	Women, Scheduled Castes and Tribes, and parents of young children who have been removed from dangerous vocations in all States and Union Territories.	Launched in 2001	Food Accessibility
National Rural Employment Guarantee Act (NREGA)	Rural households of unskilled or semi-skilled labourers who are below the poverty line.	Launched in 2005	Food Accessibility and Vulnerability
National Food Security Mission	Increase production through area expansion and productivity; create employment opportunities; and enhance the farm-level economy (i.e. farm profits) to restore confidence of farmers	Launched in 2007	Food Availability
Rashtriya Krishi Vikas Yojana	Agriculture growth. Encourages states to increase spending on agriculture and related industries	Launched in 2007	Food Accessibility and Vulnerability
Targeted Public Distribution System	With a focus on serving the poor (more than 330 million families), the population below the poverty line	Launched in 1997	Food Accessibility and Vulnerability

To ensure food security, the Indian government declared the new act known as the National Food security act in which it can provide food for nutritional security by providing good quality food at affordable prices. This scheme offered six thousand beneficiaries. The progress in the growth and production in the overall income of a person is the key component for improving nutrition and food security. Recently when the food security is increasing continuously, there is an urgent need to concentrate on the malnutrition of the child. Table 5 above shows that the government was responding to the crisis by investing in agriculture and infrastructure and expanding safety nets. However, it was observed that the aspects of each of the schemes only targeted one of the food security dimensions while ignoring the other dimensions and the stability dimension was never considered in any of the schemes. These interventions will help to save lives and families, although given the severity of the crisis, much more needs to be done.

3.5 Distribution Wise Analysis (DWA)

The nature of food security in India, according to FAO (2022), the worldwide food security situation is very worrisome as the prevalence of undernourishment and the prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES) are showing increase trends in food insecurity. This is illustrated in figure 4 below. Based on literature reviewed from FAO 2022 reports, the trend including the moving average, India claims to be self-sufficient in food production, but facts say otherwise. If the government decides to feed its entire hungry people, India's tag of a net exporting country will be easily lost. According to the Ministry of Agriculture and Family Welfare, in 2016, the country barely had enough to feed its own people, let alone be self-sufficient or a net exporter.

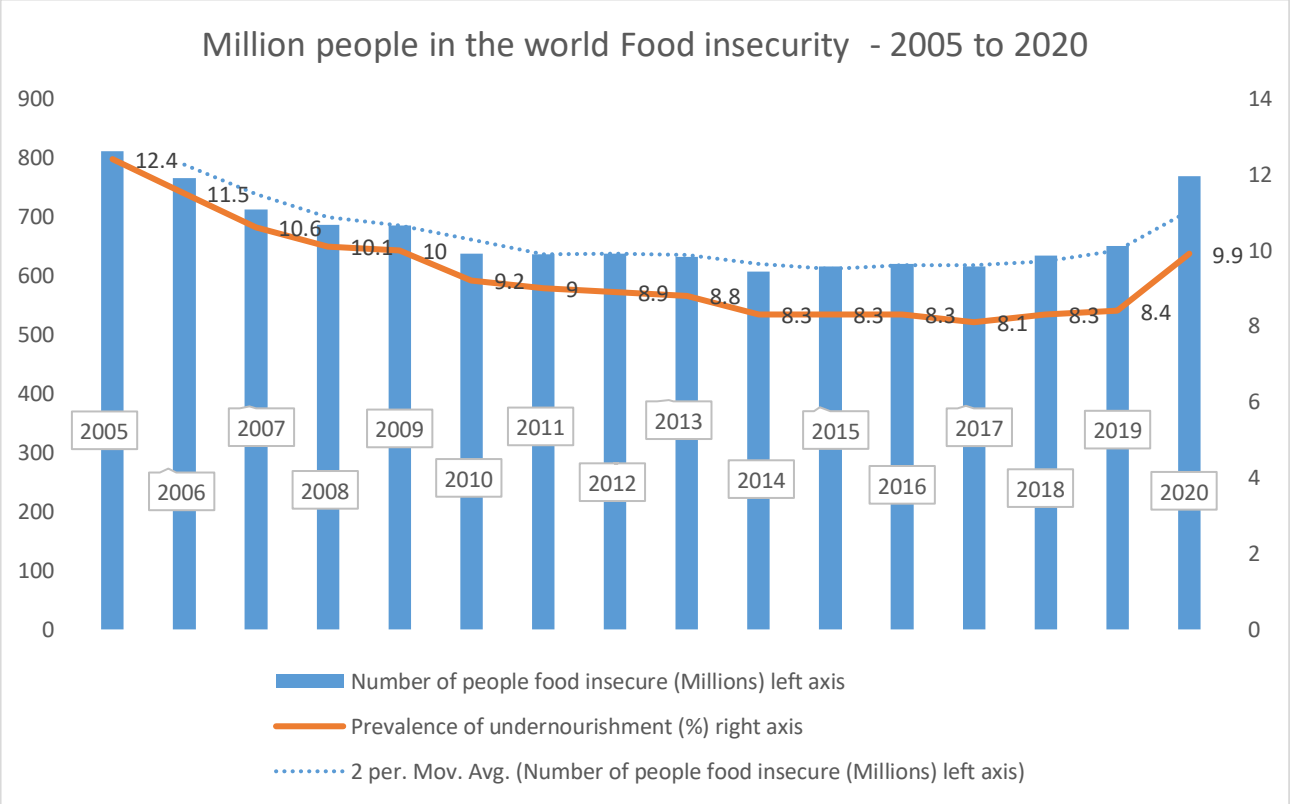


Figure 2. Analysis of prevalence on undernourishment: Source, Authors; (2023)

The country is home to 270 million hungry people, the highest in the world. India stands 97th in Oxfam's Food Availability Index, and 103rd in the 2018 Global Hunger Index (FAO, 2020). A country can be called self-sufficient only when it produces enough to meet its domestic needs. The Food Agriculture Organization (FAO) has created three levels of self-sufficiency, below 80 percent, indicating food deficit; between 80 and 120 percent, indicating self-sufficiency; and, above 120 percent, meaning surplus. As of today, India shows self-sufficiency, and joins the second group which includes China, Tanzania and Bolivia, however despite the projection that even in 2022 food grain production will increase but the people will still remain food insecure.

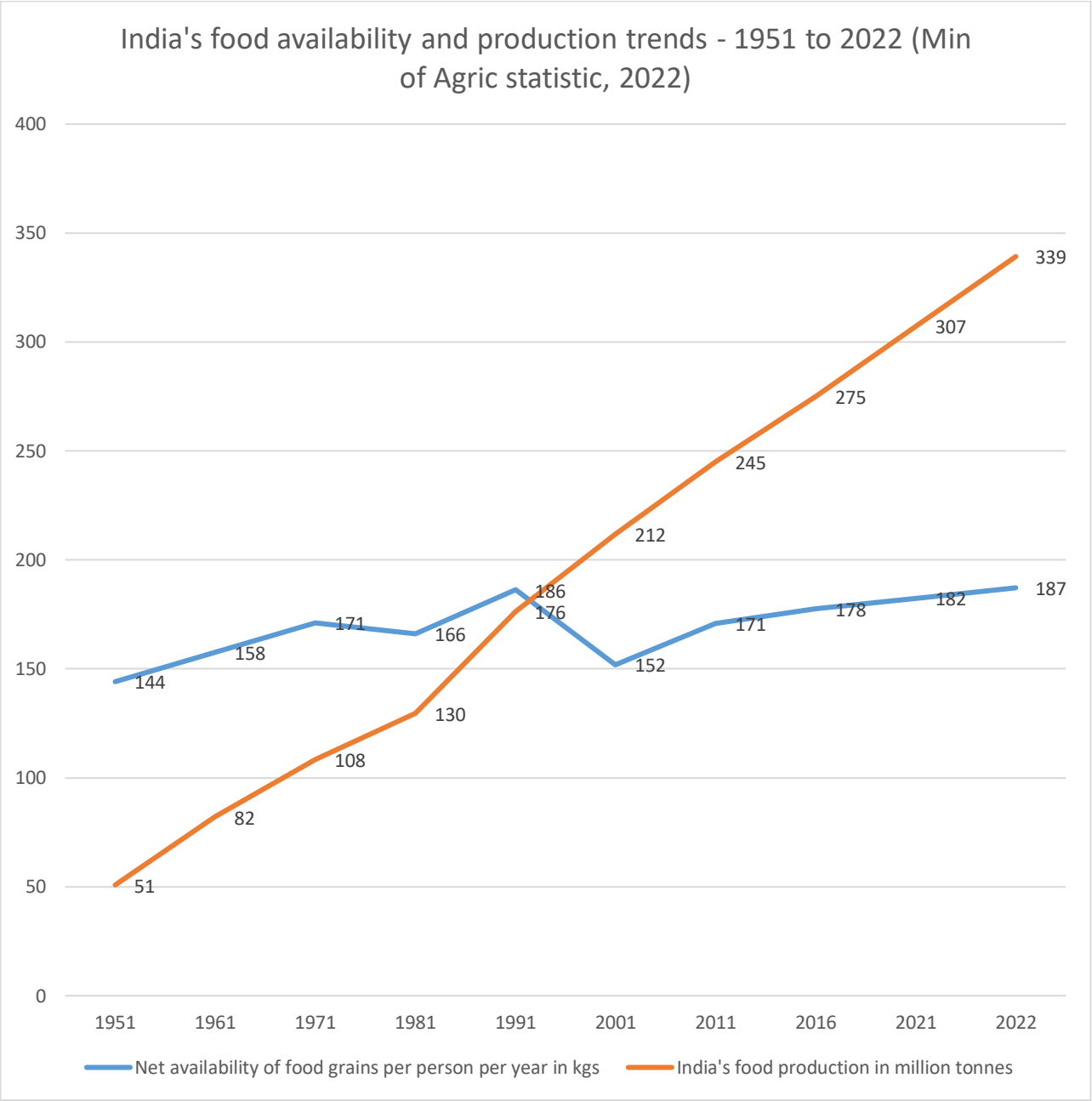
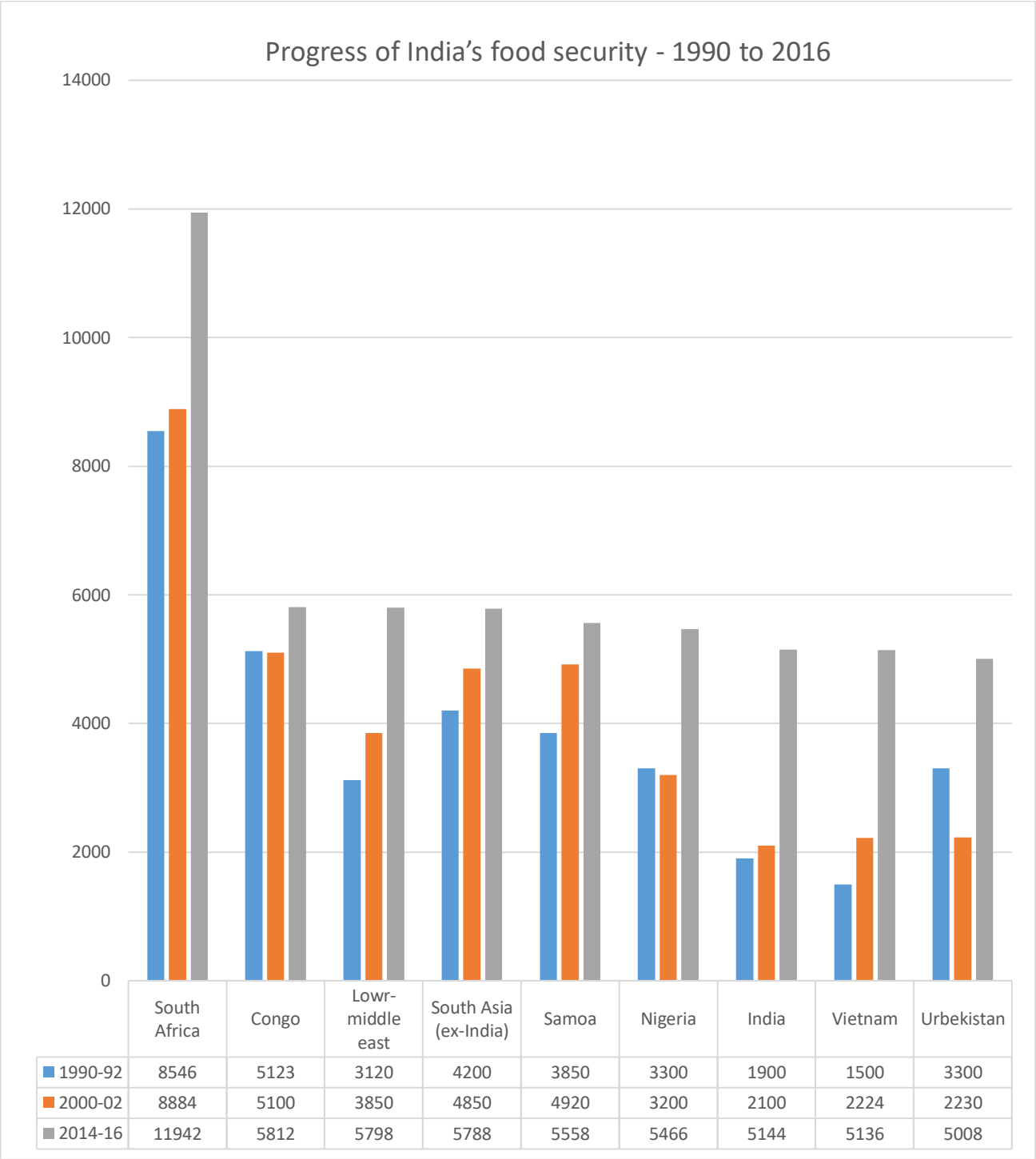


Figure 3. Food availability stagnant in India: Source, Authors' projection based on Min Agric Statistics.

Regardless of tremendous growth, India is still home to a quarter of all the undernourished population in the world (FAO, 2014). It is of highest priority for India to ensure secure access to food for all its citizens, now and for the future. In this regard, agriculture policies should encourage and influence farmers to explore various sustainable agriculture practices and options that India can pursue to ensure adequate food production to meet the food demand of all its citizens by 2030. Reddy (2016) examined the progress of India's food security from 1990 to 2016, using components such as availability, accessibility, stability and utilization, which are the same dimensions used as FAO food security indicators.



	South Africa	Congo	Lowr-middle east	South Asia (ex-India)	Samoa	Nigeria	India	Vietnam	Urbekistan
1990-92	8546	5123	3120	4200	3850	3300	1900	1500	3300
2000-02	8884	5100	3850	4850	4920	3200	2100	2224	2230
2014-16	11942	5812	5798	5788	5558	5466	5144	5136	5008

Figure 4. Progress of India's food security from 1990 to 2016: (Reddy, 2016)

The progress compared to eight countries with similar per capita GDP, India's record in protein availability and prevalence of undernourishment was dismal. Performance on access and utilization was miserable. India needs to improve its production of protein-rich foods and increase investments in irrigation to stabilize food supply. It needs to strengthen food entitlement for its vulnerable population through sustainable crop management that includes crop rotation, drought tolerance crops, short duration crops, legume intercropping and flood tolerance varieties. Sustainable livelihood management that includes crop livestock integration, agroforestry, rice-fish farming, crop diversification and migration can support this.

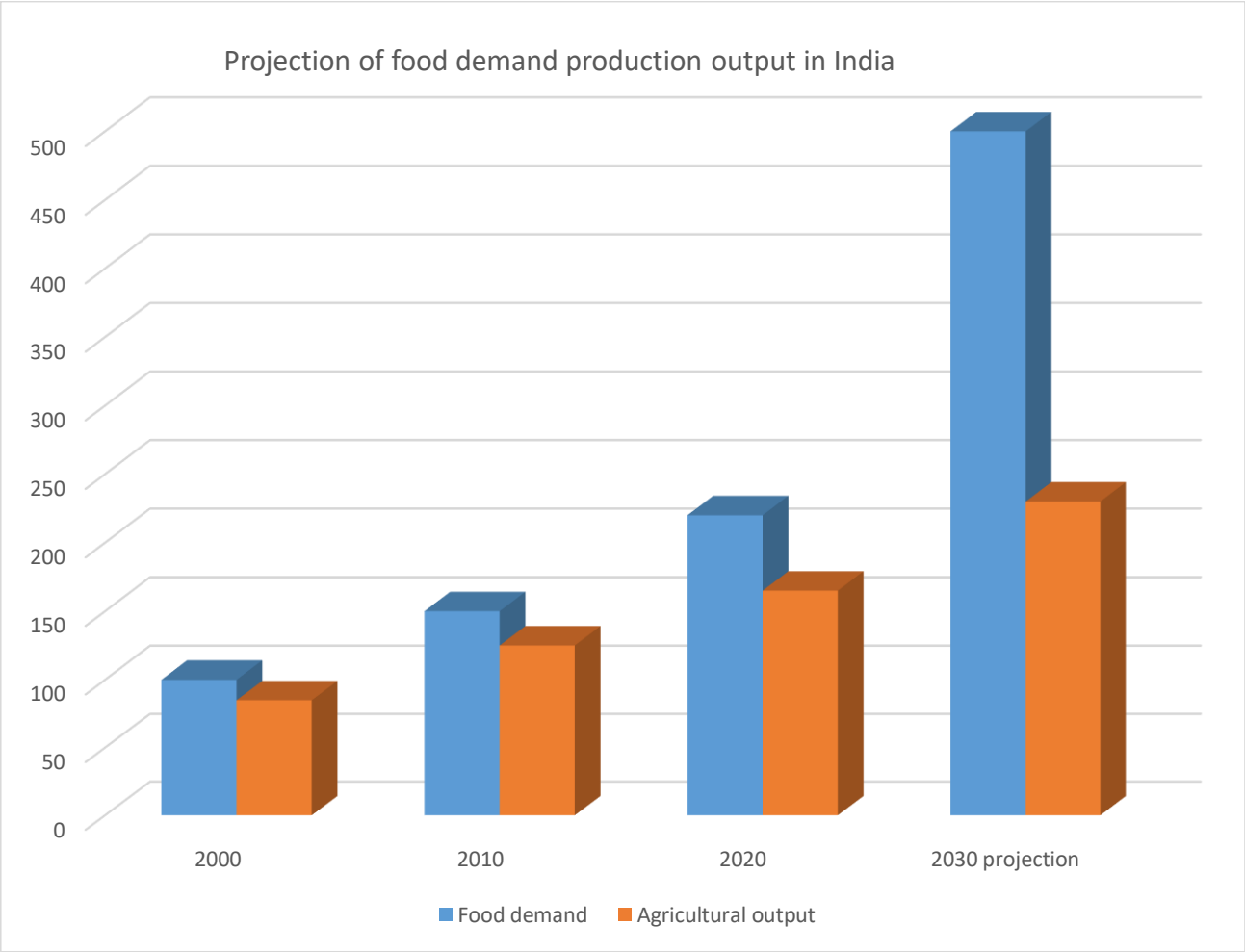


Figure 5. Analysis of the food demand and agricultural output: Source, Authors; (2023)

The above scenario estimated that by 2030, food production will be below the food demand in the country. As GHI (2014) indicated, the availability of resources of land, water and energy in agriculture will compete with growing demands for the same from industrial and urban sectors. Further study suggested that goals on combating climate change, conserving marine and terrestrial ecosystems shall also impact India's food production systems. Therefore, FAO (2014) alluded that India clearly needs to devise solutions in agricultural production systems for ensuring food security keeping in mind that these choices are extensively linked with other Sustainable Development Goals (SDGs) and thus impact our socio-economic-environment systems. Another study has estimated that about 70 percent of the growth in agricultural production can be attributed to increased fertiliser application (Mondal, 2014). However, introspection on results from the multiple long-term fertiliser trials in rice-wheat systems have revealed gradual deterioration of soil health and thus long-term productivity due to overuse and imbalanced use of synthetic fertilisers (Roy et al., 2009). Increasing use of fertilisers, which are energy intensive in their production, shall pressurise the energy systems in the usual scenario. It is noteworthy that India has a potential of 650 million tonnes of rural and 16 million tonnes of urban compost which is not fully utilised at present. The utilisation of this potential can solve the twin problems of waste disposal and providing manure to the soil (Mondal, 2014). Such interventions can be good synergies to the achievement of sustainable agriculture and solid waste management.

3.6 Climate change and Climate smart agriculture

Climate change threatens to reverse the progress made in agriculture system in the fight against hunger. Climate change augments and intensifies risks to food security for the most vulnerable countries and populations. Four key risks induced by climate change with direct consequences for food security:

- Food insecurity and breakdown of food systems
- Loss of rural livelihoods and income
- Loss of terrestrial and inland water ecosystems, and livelihoods
- Loss of marine and coastal ecosystems, and livelihoods

The earliest and the more impacted are the most vulnerable countries and populations, including in arid and semi-arid areas, landlocked countries and small island developing states. In addition to its potential to create new health concerns for people, climate change will also have wider consequences on trade flows, food markets, and price stability. The effects of climate change extend beyond the physical realm of the climate to include the environment, the productive sphere, economic dimensions, and social dimensions, posing a variety of additional risks to food availability, access to food, and utilisation, as well as the stability of these dimensions, for both farm and non-farm households.

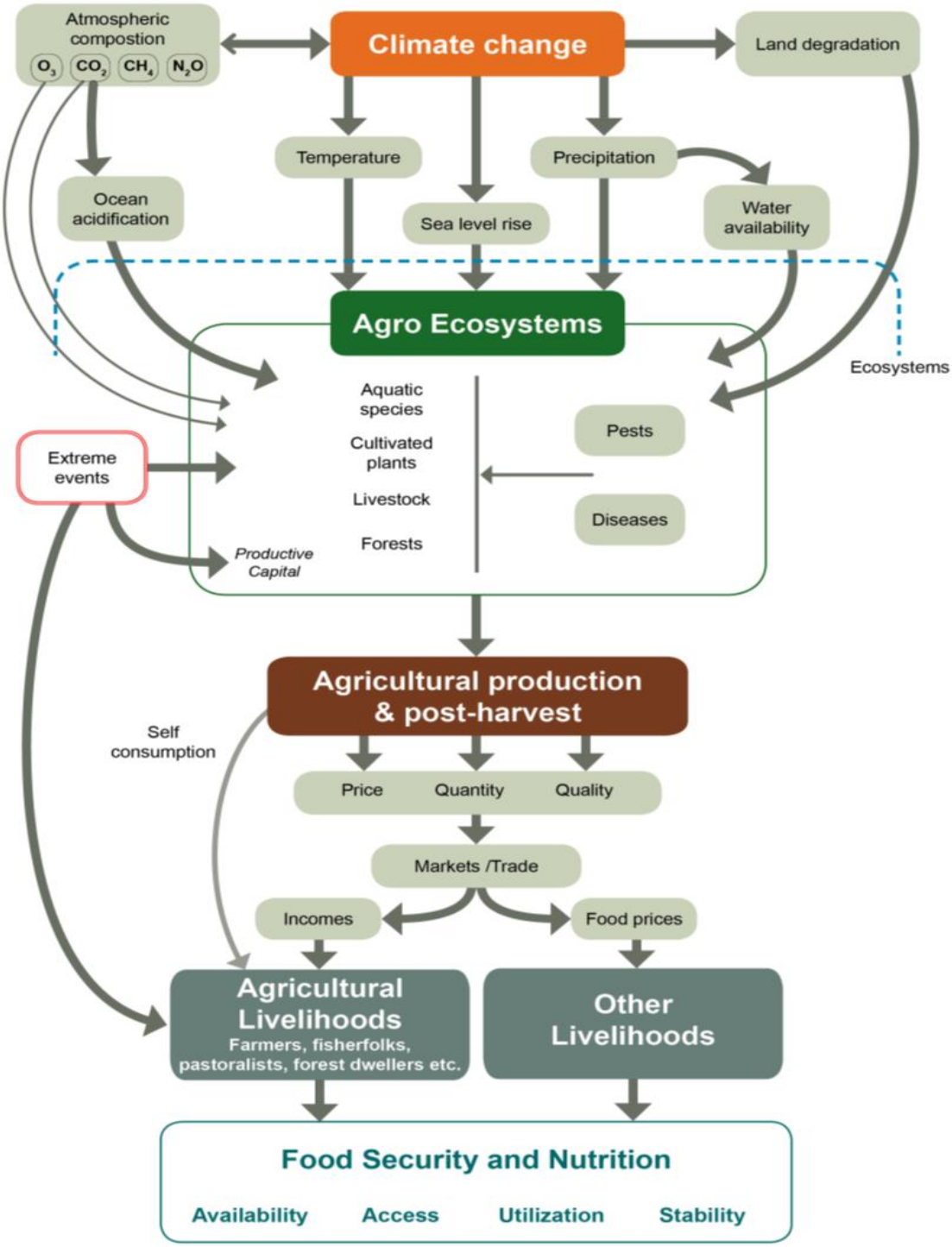


Figure 6. Schematic representation of the cascading effects of climate change impacts on food security: (FAO, 2015)

Therefore, to protect the ability of food systems to guarantee global decent security, significantly increased responses to climate change are required right away. The effects of climatic change in the food systems and food production, the agricultural production has to be responded accordingly. There are various options for reducing the undesirable effects of climatic change on the climate change. The transformation of agricultural systems for supporting the food security based on the climate change was collectively known as the Climate Smart Agriculture (CSA). The climate smart agriculture approach attempted to combine the climate change in the planning and appropriate implementation of the sustainable agriculture to decrease the global warming and to improve the resilience of adapting climatic change. Climate smart agriculture encompasses the reduction of greenhouse gas emission and achievement of food security in an eco-friendly approach (Ceballos et al., 2020). Therefore, in India, factoring in the operationalisation of a policy framework that relays various types of climate smart agricultural interventions like scientific technologies, indigenous technical knowledge, institutional innovations and information and communication technologies could help to promote sustainable livelihood and food security. Framers in India, through the agricultural policies can be encouraged to utilise climate smart agricultural models that incorporate several technologies on which institutional and governments aspects must be integrated. Example of models presented in the following figure below includes the factors influencing the technological development as well.

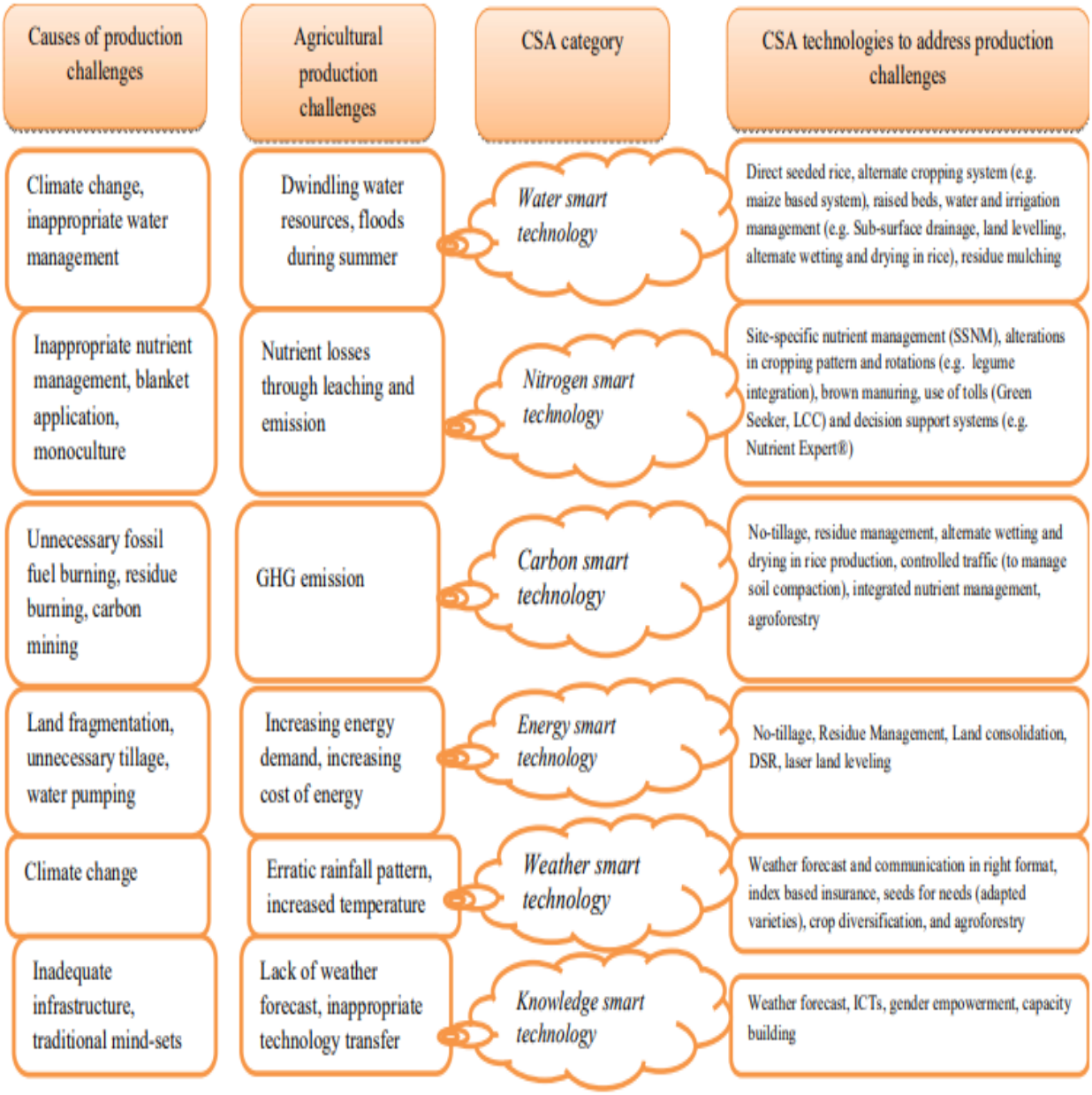


Figure 7. Production challenges and the climate smart agriculture: (Agarwal et al., 2021)

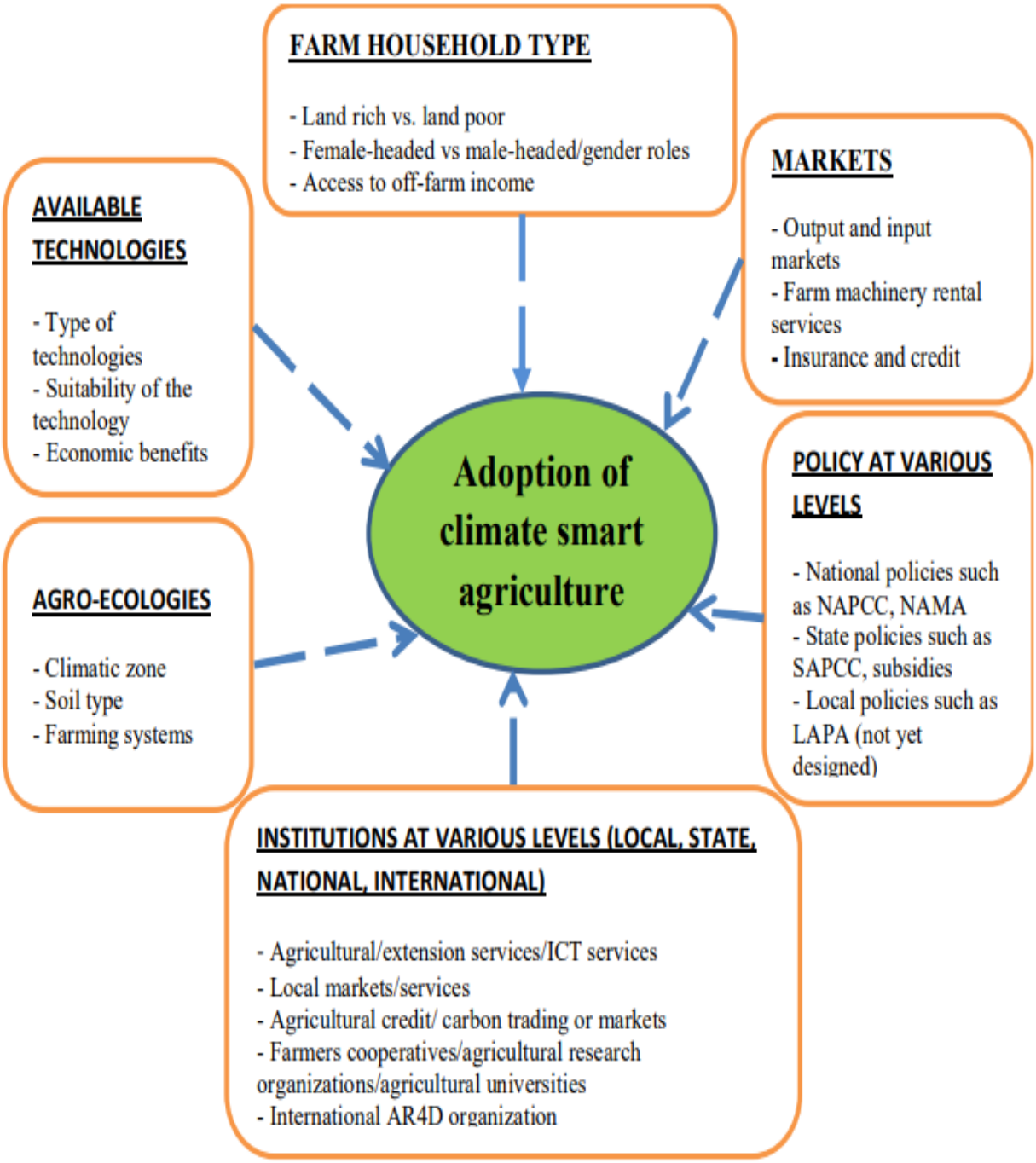


Figure 8. Factors influencing Climate Smart Agriculture: (Arora, 2019; Aryal et al., 2020)

Action on climate change to ensure food security for all for the current and future generation must start now. A series of risks are brought on by climate change from physical impacts to ecosystems, agro-ecosystems, agricultural production, food chains, trade and incomes, with economic and social impacts on livelihoods and food security. The people who are projected to suffer the earlier and the worst impacts from climate change are the most vulnerable rural populations, with livelihoods depending on agriculture sectors in areas vulnerable to climate change. In India, understanding the cascade of risks, as well as the vulnerabilities to these risks, is key to frame ways to adapt. Reducing vulnerabilities is key to reducing the net impacts on food security and to reducing long-term effects. Increasing resilience of food security in the face of climate change calls for multiple interventions, from social protection to agricultural practices and risk management.

The changes needed for adaptation to climate change in agriculture and food systems for food security will require to be enabled by investments, policies and institutions in various areas. To be the most effective such interventions need to be part of integrated strategies and plans. The strategies should be gender sensitive, multi-scales, multi-sector and multi-stakeholders. They should be elaborated in a transparent way and consider the

different dimensions (social, economic, environmental) of the issues and different time scales by which the changes will need to be implemented and supported. They should be based on assessments of risks and vulnerabilities, learn from experience and progresses, and be regularly monitored, assessed and updated. Middle- and high-income countries are increasingly carrying out regular assessments but countries without this capacity will need specific support. Actions by different stakeholders are needed in the short term to enable responses in the short, medium and long term. Some medium and long-term responses will need immediate enabling action, planning and immediate implementation of investments, especially those investments that require longer time frames to be developed and arrive in the field: forestry, livestock breeding, seed multiplication, Research and Development, innovation and knowledge transfer to enable adaptation (FAO, 2015).

For the developing countries, adapting to climate change and ensuring food security go hand in hand. A paradigm shift towards agriculture and food systems that are more resilient, more productive, and more sustainable is required, therefore countries need to act now, India not exceptional, to eliminate hunger and malnutrition, to enable the agriculture sectors to adapt to climate change and to mitigate climate change to keep it at levels where it is still possible to ensure and safeguard everyone's food security. In that effort, agriculture has also a role to play, keeping in mind that food security is the priority.

3.7 Integration of sustainable agriculture and food security: Food Systems Approach

This section presented the information from the published articles on the relationship and integration of food security and sustainable agriculture. The authors belonging to (Mukhopadhyay et al., 2021) highlighted the challenges and opportunities under climatic change. The mitigation methods like the amendments, appropriate irrigation, phytoremediation and other bioremediation methods are tackled successfully to improve the sustainable agriculture process. Such management practices will enhance the socio-economic conditions of the affected areas. The study also discussed the emerging reclamation methods like saline aquaculture for restoring the global food security and agricultural sustainability under climatic change scenario (Ulian et al., 2020). The access, availability, stability and utilization of the food supply over the period of time are considered as the pillars of food security that supports the nutritional outcomes. When addressing the problems around these terms, the sustainable agricultural services in a cost effective manner could be reached (Setsoafia et al., 2022). Hence this study (Calicioglu et al., 2019) has been performed to analyse the food system approach to focus on the trends and root causes, and to investigate the connections between the social network analyses (Spiertz, 2009). The improvement of the food security will possess positive effects on the utilization and food access. The clear outline of the relationships are presented to prioritize the decision makers (Kernecker et al., 2020). However the study suggested that appropriate quantitative analysis has to be taken for tackling the changes to be implemented (Kumar & Sharma, 2020).

The agricultural complexity and food supply has been emphasized in the presented study. The nexus between the sustainable agriculture and the food systems has been detected in this article to address the holistic indication for possible solutions (Janker & Mann, 2018). The efforts in obtaining the sustainability goal and the national governance frameworks on decreasing the environmental constrains due to climatic change has also been discussed in this article (Fleming & Vanclay, 2010). The urgency and magnitude of the complexities faced by the food security and sustainable agriculture needs deep modification in various aspects of human activity. The author (Barrios et al., 2020) suggested that real transformation and sustainability can be obtained accordingly. The identifying of the inherent problems in obtaining sustainability has been generally observed as a deterrent decision making system (Kookana et al., 2020). Based on these facts, ten elements like landscape for supporting the design of the agriculture and food security transformation has been investigated in this study. The governance, education, consumers and biodiversity are determined as the promising route for developing a structured process with the use of visual narratives. The study illustrated that nexus approaches are utilized for highlighting the salient interactions among various sectors. This articles also depicted that the manageable levels of complexity has to be encouraged to reduce the burden of transformation (Mukhopadhyay et al., 2021). (Qaim, 2020) reviewed the potential risks and the impacts of plant breeding schemes. The article stated that public misperceptions and the overregulation could obstruct the effective development of plant breeding schemes. Furthermore, it is also informed that regulatory reforms and science-oriented debate are needed for proving effective suggestions.

3.8 Farmers' perception and roles of key stakeholders in agriculture and food security

It is paramount to consider the farmers' perceptions during the integration of sustainable agriculture practices and food security. Perception is a mode of apprehending reality and experience through the senses, thus enabling discernment of figure, form, language, behaviour, and action. In this instance, farmer perception would influence attitude, knowledge, opinion, judgment, understanding of sustainable agriculture practices, meaning of and its role to food security and livelihood; and how the farmer responds to food insecurity. The higher the socio-economic status and the greater the access to information, the greater the perceived importance of sustainable agricultural practices. Interlinking of roles of the government, the farmers, Farmer Producer Organisations and civil societies as key stakeholders in sustainable agriculture practices for food security and livelihood strategies to rural communities is also very important (FAO, 2020). Farmers provide labour and indigenous knowledge to the farming programmes, when they are not hungry, they provide rural development and no conflict or political instability. Government spearhead and reinforce agriculture and food policy implementation to improve household income through direct agricultural payment and crop insurance programmes (Im & Jeong, 2014). The government intervenes in farming through several support programmes that include agriculture extension services, financial support, and subsidies (or tax exemptions) for agricultural machinery fuel, among others (FAO, 2020). Marketing of agriculture products remains a great challenge to the smallholder and marginal farmers in the rural communities. The farmers have been selling their produce to the intermediaries operate in the market sector. Therefore, Farmer Producer Organisations (FPOs) bring together the small and marginal farmers and other small producers to build their own agribusiness enterprise (Mahindapala et al., 2021). Farmer Producer Organisations offer small farmers opportunity to participate in the market more effectively and helps to enhance agricultural production, productivity, and profitability. Civil society organizations can play a crucial role in food security and poverty reduction, given their technical expertise, their proximity to and representation of the hungry and poor, and their increasing presence in the field. The model by civil societies focuses on strengthening the capacity of family farmers, including indigenous peoples, women, and youth, along with local and regional food systems (FAO, 2021). Suggesting that all aspects of food and agriculture must be reoriented in favour of family farmers. This should include technical, managerial and financial support, credit, and direct access to markets for farmers' associations.

The farmers need to understand that the government sustainable agricultural practices and policies are highly useful in adopting food security. The significance of sustainability among the farmers varies based on the determinants and characteristics due to socio economic characteristics (Siebrecht, 2020). This section analysed the degree of significance that the farmers used to define the term sustainability in order to meet their own needs. To ensure economic, environmental and social sustainability the farmers have to adopt various form level practices like appropriate usage of chemicals, proper care of animal and plant health, integrated pest management and enough irrigation. Particularly the relationship between the farmer behaviour on the pest sellers is more important (Knorr et al., 2020). The main objective of the study (Fusun et al., 2009) was to evaluate the quantitative perceptions of farmers on sustainable agriculture and too identified the influencing characteristics. This study enrolled twenty-one selected sustainable practices and availability with five-point scales. Additionally, this study observed that earning more profit with undesirable usage of pesticides must be reduced for improving the sustainability. This study had the following objectives that is to measure the significance of farmer's perspective based on the selected agricultural practices, to demonstrate the social economic characteristics of the farmers and to identify the information seeking behaviour in relation with the sustainable agriculture. The study concluded that if there enrolled characteristics or effectively handled by the policy makers are organisations the former can succeed in favourable disposing the harmful pesticide towards the policy of sustainable agriculture (Wall & Smit, 2005).

This article (Adeola & Adetunbi, 2015) analysed the perception of farmers in relation with sustainable agriculture for producing abundant food that is free of depletion of Earth's significant resources. The study used multistage sampling method that selected 480 crop farmers in among the regions of Nigeria. The study stated that extension services to be intensified through collaborative and non-governmental organisation to keep the farmers to adapt and maintain sustainable practices and their benefits.

3.9 Policy implications

The operationalization and implementation of agriculture policies that interlink the aims sustainable development goal number two would lead to the adoption and promotion of sustainable farming practices in India. The agriculture policies would be instrumental in the drive to adopt climate smart farming, restoration, and management of natural resources in and around farming lands. It is anticipated that environmentally

friendly farming will significantly enhance food security, improve people's standard of living and earnings. The population would experience food insecurity if sustainable practices were not adopted due to the quantity and distribution of rain being altered by climate change. However, additional elements such as land policy, use of land, field conditions, water supply, soil preparation, and diverse facilities for farming can also impact the cultivation of crops. Policy on agriculture land use change will be very important to address potential effects of agriculture land use changes. All aspects of sustainable agricultural practices are adversely affected by alterations in land use. In terms of society, along the way, indigenous knowledge, participation in the procedure and programme, acceptable technology, gender inclusivity, and household food security will be lost. Food distribution to the communities was the government's response to the food security crisis; no measures to improve the people's means of sustenance were taken. However, from the analysed schemes, it was revealed and observed that just one of the dimensions of food security was targeted by the food programme policies, and the stability factor was not included in any of the schemes. Household livelihoods and food security in the village will improve if all components are addressed in a food scheme. Instead, future agriculture and food policies as paramount instruments for food security strategies or programmes should consider all food security dimensions.

Agricultural policies should quickly address land issues and concurrent with other relevant policies in other government ministries. The shortage of land affects agriculture production for farming of diversified products which could make the rural communities people start generation income as a livelihood strategy. The land provides most of the ecosystem services needed to produce food and conduct livelihood activities. Of the reviewed sustainable agriculture practices in this article, the researchers favour conservation farming over others as the best starting point as it is cheap and within the reach of the rural farming communities. However, the integration of farming systems would result in community self-sufficiency, resilience, sustainability and overall contribution to the national food security requirements. This would also contribute to climate change adaptation and mitigation, and disaster risk reduction by considering the three pillars of sustainable development, which are planet, people, and profit. Policies and land use should take these pillars into account, and the priority should not be adjusted to profit, people, and then environment. Changes in the hierarchy would lead to unsustainable, halting growth, making the populace vulnerable. The coherence and integration of conservation agriculture into national policies would provide strong reinforcement of the practices country wide. Agriculture policies must address the issues limiting women's ability to increase food security, particularly the issue of land ownership. As a result, women's contributions to enhancing household food security, reducing hunger and malnutrition in rural areas will be fully utilised. In also policies, interlinking of roles of the government, the farmers, Farmer Producer Organisations and civil societies as key stakeholders in sustainable agriculture practices for food security and livelihood strategies to rural communities is also very important.

Conclusion and research gap

The present study attempts to evaluate the nexus between food security, agricultural sustainability and climatic change. The evaluation has been performed from the prevailing literatures. The characteristics of agricultural sustainability in relation to food security and climatic change were assessed for the geographical regions around India. Climatic change could be able to destroy the soil salinity development in semi-arid and arid regions. Various mitigation technology like usage of gypsum, zeolites, subsurface drainage, salt tolerant genotypes and reply to micro irrigation systems and agro forestry has the capacity to retain the salt affected soils. This technology could improve the physical chemical and biological properties of the soil. Such mitigation methods or environmentally useful to the farmers across different agro ecological regions. Suitable agriculture research and development including extension services could also boost the food security and agriculture sustainability in Indian regions. Some of the future suggestions obtained from this review includes of following. Analysing agricultural point of view in terms of forest and dynamics has been found to be feasible and will be useful for many researchers. The prediction of agricultural sustainability for future scenario with climatic parameters has to be analysed in a careful manner.

It was very clear from the review that sustainable agriculture practices could enhance food security. Sustainable agriculture practices provide an adequate and dependable household income through reducing poverty and associated problem of population and reduce environmental degradation and conserve resources. The review indicated that India is beset with food insecurity as the food produced is not available to all people, not utilised, not accessed by everybody and there is instability in the period of getting the food to the people. The study reviewed that there is strong relationship between sustainable agriculture and food security to a country as

sustainable agriculture practices would mitigate climate change impacts to food production. When people are food secure, there would have opportunity to rise levels of income from different crops and livestock produced in different sustainable agriculture practices There will be poverty alleviation and reduction in vulnerability of rural livelihoods. When sustainable agriculture practices are religiously followed, it was clear that therefore the sustainable development goal number two will be achieved and there will be more other sustainable development gools that will be fulfilled. The food policies need to consider all the four food dimensions, that is food availability to the people, food utilistion, food accessibility and food stability. Despite tremendous growth, India is still home to a quarter of all the undernourished population in the world, therefore there is need to encourage both subsistence and intensive farmers to adopted sustainable agriculture practices. Market driven parameters must be carefully processed to identify the food secure regions in a more precise approach. Hence the present review suggested the importance of framing novel architectures that is based on the economy and climatic behaviours in a country.

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References

Abubakar M S & Attanda M L. (2013). The Concept Sustainable Agriculture: Challenges and Prospects. IOP Conf. Series: Materials Science and Engineering 53 (2013) 012001 doi:10.1088/1757-899X/53/1/012001

Adeola, R., & Adetunbi, S. (2015). Farmers' perception of sustainable agriculture in South-Western Nigeria: implications for rural economy. International Journal of Applied Agriculture and Apiculture Research, 11(1-2), 86-92.

Agarwal, T., Goel, P. A., Gartaula, H., Rai, M., Bijarniya, D., & Jat, M. (2021). Gendered impacts of climate-smart agriculture on household food security and labor migration: insights from Bihar, India. International Journal of Climate Change Strategies and Management, 14(1), 1-19.

Ansah, I. G. K., Gardebroek, C., & Ihle, R. (2019). Resilience and household food security: a review of concepts, methodological approaches and empirical evidence. Food Security, 11(6), 1187-1203.

Arora, N. K. (2019). Impact of climate change on agriculture production and its sustainable solutions. Environmental Sustainability, 2(2), 95-96.

Aryal, J. P., Sapkota, T. B., Rahut, D. B., & Jat, M. L. (2020). Agricultural sustainability under emerging climatic variability: the role of climate-smart agriculture and relevant policies in India. International Journal of Innovation and Sustainable Development, 14(2), 219-245.

Barrios, E., Gemmill-Herren, B., Bicksler, A., Siliprandi, E., Brathwaite, R., Moller, S., . . . Tittonell, P. (2020). The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives. Ecosystems and People, 16(1), 230-247.

Bathaei, A., & Štreimikienė, D. (2023). A Systematic Review of Agricultural Sustainability Indicators. Agriculture, 13(2), 241.

Calicioglu, O., Flammini, A., Bracco, S., Bellù, L., & Sims, R. (2019). The future challenges of food and agriculture: An integrated analysis of trends and solutions. Sustainability, 11(1), 222.

Ceballos, F., Kannan, S., & Kramer, B. (2020). Impacts of a national lockdown on smallholder farmers' income and food security: Empirical evidence from two states in India. World Development, 136, 105069.

Chioma Okoro. (2018). Evaluation of Impact of Unsustainable Agricultural Practices on Rural Poverty and Environmental Resource Management in Ogoni, Nigeria. International Journal of Education and Human Developments Vol. 4 No 4; August 2018 ResearchGate: https://www.researchgate.net/publication/332209156

Duong, T. T., Brewer, T., Luck, J., & Zander, K. (2019). A global review of farmers' perceptions of agricultural risks and risk management strategies. Agriculture, 9(1), 10.

Dutta Swarup. (2012). Green Revolution Revisited. The Contemporary Agrarian Situation in Punjab, India. Social Change. 42 (2): 229–247. doi: 10.1177/004908571204200205. ISSN 0049-0857. S2CID 55847236.

Edmundo Barrios, Barbara Gemmill-Herren, Abram Bicksler, Emma Siliprandi, Ronnie Brathwaite & Soren Moller. (2020). The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives. Pages 230-247: Published online: https://doi.org/10.1080/26395916.2020.1808705

El-Ramady, H. R., El-Marsafawy, S. M., & Lewis, L. N. (2013). Sustainable agriculture and climate changes in Egypt. Sustainable Agriculture Reviews: Volume 12, 41-95.

FAO. (2014). The State of Food Insecurity in the World. UN. Food and Agriculture Organization of the United Nations, Rome, Italy

FAO. (2015). Climate change and food security: risks and responses. Food and Agriculture Organization of the United Nations, Rome, Italy

FAO. (2017). Tracking adaptation in Agricultural sectors: Climate change adaptation indicators. Rome. Italy.

FAO. (2020). Supporting civil society participation in committee on World Food Security, Rome, Italy

FAO. (2021). FAO Strategy for partnership with Civil society organisations. Rome, Italy.

FAO. (2022). Hunger and food insecurity. Food and Agriculture Organization of the United Farm Table. (2018). What are some examples of sustainable farming practices. Farm Smarter, Not Harder - Report. https://farmtable.com.au/examples-sustainable-farming-practices/Fleming, A., & Vanclay, F. (2010). Farmer responses to climate change and sustainable agriculture. A review. Agronomy for sustainable development, 30, 11-19.

Füsun Tatlıdil, F., Boz, İ., & Tatlidil, H. (2009). Farmers' perception of sustainable agriculture and its determinants: a case study in Kahramanmaras province of Turkey. Environment, development and sustainability, 11, 1091-1106.

Gahukar RT. (2009). Sustainable agriculture in India: Current situation and future needs. Perspectives International Journal of Agricultural Sciences, Vol. 5 Issue 1, January to May 2009: 1-7. FAO Technical Advisor (Retd.), Arag Biotech Pvt. Ltd., Plot 220, Reshimbag, NAGPUR (M.S.) INDIA

Gharsallah O, Gandolfi C and Facchi A. (2021). Methodologies for the Sustainability Assessment of Agricultural Production Systems, with a Focus on Rice: A Review. Sustainability 2021, 13, 11123. https://doi.org/10.3390/su131911123

GHI. (2014). Global Agricultural Productivity Report. Global Harvest Initiative. (2014)

Gupta Niti, Shanal Pradhan, Abhishek Jain & Nayha Patel (2021). Sustainable Agriculture in India 2021: What We Know and How to Scale Up. CEEW Report April 2021. Council on Energy, Environment and Water, New Delhi - 110067, India

Hardin Lowell S. (2008). Meetings That Changed the World: Bellagio 1969: The Green Revolution. Nature (25 Sep 2008):470-71.

Huang, J.-k., & Wang, Y.-j. (2014). Financing sustainable agriculture under climate change. Journal of Integrative Agriculture, 13(4), 698-712.

Im J B & Jeong I J. (2014). The frame of agricultural policy and recent major agricultural Policy in Korea. FFTC-COA international workshop on collection of relevant agricultural policy information and its practical Use, June 23-27, 2014, Taipei, Taiwan R.O.C.

Janker, J., & Mann, S. (2018). The social dimension of sustainability in agriculture. A review of sustainability assessment tools. Ettenhausen, Switzerland: Agroscope.

Janker, J., Mann, S., & Rist, S. (2019). Social sustainability in agriculture–A system-based framework. Journal of rural studies, 65, 32-42.

Jatav, S. S., Nayak, S., Singh, N. P., & Naik, K. (2022). Measuring and Mapping Food Security Status of Rajasthan, India: A District-Level Analysis. Front. Sustain. Food Syst. 6: 831396. doi: 10.3389/fsufs.

Kernecker, M., Knierim, A., Wurbs, A., Kraus, T., & Borges, F. (2020). Experience versus expectation: Farmers' perceptions of smart farming technologies for cropping systems across Europe. Precision Agriculture, 21, 34-50.

Knorr, D., Augustin, M. A., & Tiwari, B. (2020). Advancing the role of food processing for improved integration in sustainable food chains. Frontiers in Nutrition, 7, 34.

Kookana, R. S., Drechsel, P., Jamwal, P., & Vanderzalm, J. (2020). Urbanisation and emerging economies: Issues and potential solutions for water and food security. Science of the total environment, 732, 139057.

Kumar, P., & Sharma, P. K. (2020). Soil salinity and food security in India. Frontiers in Sustainable Food Systems, 4, 533781.

Lathi B J & Parag Narkhede. (2010). “Food Security in India: Concepts, Realities & Innovations” ResearchGate. https://www.researchgate.net/publication/228096218

Leggett, A. (2020). Bringing green food to the Chinese table: How civil society actors are changing consumer culture in China. Journal of Consumer Culture, 20(1), 83-101.

Leung, C. W., & Tester, J. M. (2019). The association between food insecurity and diet quality varies by race/ethnicity: an analysis of national health and nutrition examination survey 2011-2014 results. Journal of the Academy of Nutrition and Dietetics, 119(10), 1676-1686.

Mahindapala K G J P, Wijaya M, Jayathilaka A P & Jayawardana L N A C. (2021). A Review of The Role of Farmer Organizations in Agriculture Sector: Some African And Asian Lessons for Sri Lanka, Journal of Management and Tourism Research, Vol IV Issue I, pp.1-22,

M. Tahat, M., M. Alananbeh, K., A. Othman, Y., & I. Leskovar, D. (2020). Soil health and sustainable agriculture. Sustainability, 12(12), 4859.

Mukhopadhyay, R., Sarkar, B., Jat, H. S., Sharma, P. C., & Bolan, N. S. (2021). Soil salinity under climate change: Challenges for sustainable agriculture and food security. Journal of Environmental Management, 280, 111736.

Mutea E, Bottazzi P, Jacobi J, Kiteme B, Speranza C I & Rist S (2019) Livelihoods and Food Security Among Rural Households in the North-Western Mount Kenya Region. Front. Sustain. Food Syst. 3:98. doi: 10.3389/fsufs.2019.00098.

Patel, S. K., Sharma, A., & Singh, G. S. (2020). Traditional agricultural practices in India: an approach for environmental sustainability and food security. Energy, Ecology and Environment, 5, 253-271.

Prabhakar Adhikari, Hailu Araya, Gerald Aruna, Arun Balamatti, Soumik Banerjee & Baskaran P. (2017). System of crop intensification for more productive, resource-conserving, climate-resilient, and sustainable agriculture: experience with diverse crops in varying agroecologies. Pages 1-28 Published online: 20 Nov 2017 https://doi.org/10.1080/14735903.2017.1402504

Qaim, M. (2020). Role of new plant breeding technologies for food security and sustainable agricultural development. Applied Economic Perspectives and Policy, 42(2), 129-150.

Rafael Perez-Escamilla & Ana Maria Segall-Correa (2008). Food insecurity measurement and indicators. Rev. Nutr., Campinas, 21(Suplemento):15s-26s, jul./ago., 2008

Rajesh Kumar Singh, H R Murty, S K Gupta & A K Dikshit. (2009). An overview of Sustainability assessment methodologies. Ecological Indicators 9 (2009) 189-212. doi:10.1016/j.ecolind.2008.05.011

Reddy, A. A. (2016). Food security indicators in India compared to similar countries. Current Science, 111(4), 632–640. http://www.jstor.org/stable/24908538

Rockstrom Johan, Williams John, Daily Gretchen, Noble Andrew, Matthews Nathanial, Gordon Line, Wetterstrand Hanna, DeClerck Fabrice & Shah, Mihir (2016). "Sustainable intensification of agriculture for human prosperity and global sustainability". Ambio. 46 (1): 4–17. doi:10.1007/s13280-016-0793-6

Roy D, Chattopadhyay P & Tirado D. (2009). Subsidizing Food Crisis:. Greenpeace India.

Sagar Mondal. (2014). Text Book of Agricultural Extension with Global Innovations Paperback. Kalyani Publishers.

Sandhu, Jashandeep Singh. (2014). Green Revolution: A Case Study of Punjab. Proceedings of the Indian History Congress. 75: 1192–1199 – via JSTORSara & Ovi. (2015). Ten Sustainable Agriculture Methods and Farming Practices.

Green Tumble Sustainable Farming https://greentumble.com/10-sustainable-farming-methods-and-practices/Setsoafia, E. D., Ma, W., & Renwick, A. (2022). Effects of sustainable agricultural practices on farm income and food security in northern Ghana. Agricultural and Food Economics, 10(1), 1-15.

Shalaby, M., Al-Zahrani, K., Baig, M., Straquadine, G., & Aldosari, F. (2011). Threats and challenges to sustainable agriculture and rural development in Egypt: implications for agricultural extension. The Journal of Animal & Plant Sciences, 21(3), 581-588.

Shirsath, P. B., Jat, M., McDonald, A., Srivastava, A. K., Craufurd, P., Rana, D., . . . Singh, R. (2020). Agricultural labor, COVID-19, and potential implications for food security and air quality in the breadbasket of India. Agricultural Systems, 185, 102954.

Siebrecht, N. (2020). Sustainable agriculture and its implementation gap—Overcoming obstacles to implementation. Sustainability, 12(9), 3853.

Spiertz, J. (2009). Nitrogen, sustainable agriculture and food security: a review. Sustainable agriculture, 635-651.

Sudheesh Manalil. (2015). An analysis of polygenic herbicide resistance evolution and its management based on a population genetics approach, Basic and Applied Ecology, Volume 16, Issue 2, 2015, Pages 104-111, ISSN 1439-1791, https://doi.org/10.1016/j.baae.2015.01.004.

Trigo, A., Marta-Costa, A., & Fragoso, R. (2021). Principles of sustainable agriculture: Defining standardized reference points. Sustainability, 13(8), 4086.

UC. (2021). University of California, Sustainable Agriculture Research and Education Program. "What is Sustainable Agriculture?" UC Agriculture and Natural Resources. https://sarep.ucdavis.edu/sustainable-ag

Ulian, T., Diazgranados, M., Pironon, S., Padulosi, S., Liu, U., Davies, L., . . . Pérez-Escobar, O. A. (2020). Unlocking plant resources to support food security and promote sustainable agriculture. Plants, People, Planet, 2(5), 421-445.

United Nations. (2008). Organic Agriculture and Food Security in Africa. (UNCTAD/DITC/TED/2007/15), 2008, http://www.unep-unctad.org/cbt

UNEP. (2021). A beginner's guide to sustainable farming. United Nations Environment Programme, https://www.unep.org/news-and-stories/story/beginners-guide-sustainable-farming

Vinodini Ramesh M, Guntha R, Arnhardt C, Singh G, Kr V, Rao P, Halan G, & Malamud B (2021). Spatial Temporal Tracking of Landslide Events: A Crowdsourced Mobile App, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-16104, https://doi.org/10.5194/egusphere-egu21-16104, 2021.

Viswanathan P K, Kavya K & Chandra Sekhar Bahinipati. (2020). Global Patterns of Climate-resilient Agriculture: A Review of Studies and Imperatives for Empirical Research in India. Review of Development and Change 25(2) 169–192, 2020 DOI: 10.1177/0972266120966211

Wall, E., & Smit, B. (2005). Climate change adaptation in light of sustainable agriculture. Journal of sustainable agriculture, 27(1), 113-123.