5. Innovative Agricultural Practices and Technologies to Tackle Climate Change

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Abstract:

The global agricultural sector is facing unprecedented challenges due to the climate change affects such as extreme weather events, scarcity of water, and pest outbreaks. As a result, there is a pressing need to adopt innovative technologies that can help mitigate these impacts and ensure sustainable food production for a growing population. Emerging technologies, such as precision agriculture, vertical farming, conservation agriculture, biotechnology and value addition offer promising solutions to address these challenges. By leveraging these advanced tools, farmers can optimize resource use, improve crop yields and reduce greenhouse gas emissions. This chapter will explore how these technologies are being used in agriculture to combat climate change, their potential benefits and limitations and the implications for policy makers and stakeholders in the agricultural sector. Ultimately, the adoption of these technologies will play a significant role in transforming agriculture into a more sustainable and resilient industry in the face of climate change.

Keywords:

Climate change, Biotechnology, Precision agriculture, Vertical farming, Value addition.

5.1 Introduction:

Over the past centuries, long-term changes in the climate patterns of the earth have been observed, leading to a gradual increase in the average global temperatures, a phenomenon known as global warming. The greenhouse gases (GHGs), such as methane, carbon dioxide, chlorofluorocarbons and nitrous oxide has increased, which is the main cause of the global warming. The Inter-governmental Panel on Climate Change (IPCC) estimates that between 2030 and 2052, greenhouse gas emissions will contribute to 1.0°C increase in global temperature over pre-industrial levels. The average global temperature might rise from 1.4 to 5.8 °C by 2050 (Fawzy *et al*. 2020). These temperature variations have a significant effect on different sectors but the most affected one is agriculture. Both agriculture and climate change are interlinked and change in climate is posing a threat to agriculture (IPCC, 2014). Agriculture is the most vulnerable to climate change and the losses caused by climate change affects the livelihoods of the farmers who are dependent on agriculture. Not only this, but the global population is also expected to reach 9.0 billion by the year 2050 (United Nations, 2015) and there will be higher requirements of food by 2050 (Alexandratos and Bruninsma, 2012). The poor and marginal farmers will be the most affected from the climate change and food insecurity would increase in these communities (Hoffmann, 2013). So, the development of suitable management strategies is necessary for enhancing the nutrient use efficiency and ensuring sustainability of environment. The emphasis must be given on the farming practices that can efficiently conserve the renewable resources by minimizing the greenhouse gas emissions and increases the crop yield (Sapkota *et al.*, 2015). Many advance technologies, such as improved crop varieties, precision farming, vertical farming, genetically modified organisms and adding value to the food products are widely adopted for gaining higher income from the agriculture sector. These options integrate both innovative techniques and traditional practices which are relevant for particular location and helps in reducing the effect of climate change and provides good opportunities to stand against changing scenario.

5.2 Challenges in Agriculture Related to Climate Change:

Current challenges in agriculture related to climate change present a multifaceted dilemma requiring urgent attention. The increasing frequency of extreme weather events, such as droughts and floods, poses a significant threat to crop production and yields worldwide. Additionally, the unpredictable patterns of precipitation and rising temperatures have accelerated soil degradation and nutrient loss, impacting the overall resilience of agricultural systems. The altered climate conditions also exacerbate pest and disease pressures, leading to reduced crop quality and quantity. Furthermore, the lack of access to appropriate technologies and knowledge-sharing platforms hinders farmers' ability to adapt to these changing environmental conditions effectively. Addressing these challenges demands innovative strategies that integrate cutting-edge technologies like precision agriculture, remote sensing, and climate-resilient crop varieties to enhance productivity while mitigating climate risks.

5.3 Overview of Emerging Technologies in Agriculture for Climate Change Mitigation:

The current emphasis on sustainable agriculture practices to combat climate change has led to the exploration and utilization of emerging technologies in the agricultural sector. Technologies such as precision agriculture, vertical farming, biotechnology, weather forecasting tools and preparation of value-added products from flood affected low value crops have the potential to revolutionize farming practices and mitigate the adverse effects of climate change on crop production and land management. Precision agriculture enables farmers to optimize resource use by employing sensors, GPS, and data analysis to tailor inputs like water and fertilizer to specific crop needs. Vertical farming offers a solution to urban food production challenges by maximizing growing space while minimizing environmental impact. Incorporating gene editing techniques can enhance crop resilience to climate stressors, ensuring food security in changing conditions. Weather forecasting tools aid farmers in making informed decisions for crop management, thereby adapting to changing climatic conditions effectively.

These emerging technologies demonstrate promising capabilities in addressing climate change challenges in agriculture while enhancing sustainability.

5.3.1 Precision Agriculture:

The food requirement has increased as a result of the growing world population. However, because of irrigation needs, this has also resulted in water shortages. Precision agriculture has emerged during 1980's with the development of Global Positioning System (Blackmore, 2003) and is a quickly developing farm management system that gathers and analyses data on the soil, plants, and animals using sensor technologies. It is different from conventional agricultural practices where a large area is managed regardless of topographic variations or soil quality. Precision farming has the potential to meet scarcity of labour, improves the soil biodiversity, prevents the overlap of certain farm tasks like fertilizer application or tilling, reduces the fuel consumption, minimizes input application and benefits the environment. It makes it possible to use inputs like water, fertilizer, plant nutrients, pesticides, seeds and labour more precisely. To achieve this, efficient management is necessary. Based on the feasibility, needs and resources, suitable technology can be adopted (Table 5.1). For example, a plant-based method called "Site Specific Nutrient Management" offers guidelines and resources for giving nutrients to plants only when they're needed in order to get higher yields. In comparison to blanket application, urea application based on leaf colour chart can reduce the global warming potential of rice-wheat system by 10.5% (Bhatia *et al*., 2012). Similarly, drones can be used for fungicides application against bacterial and fungal diseases (Subramanian *et al.*, 2021). Precision laser land levelling helps to minimize the water wastage, labour cost, electricity and increases the crop yield (Kanannavar *et al.*, 2020). Robotics are introduced in few regions of Uttar Pradesh, India for crop scouting which work by using radial basis function networking analysis (Halimi and Mussa., 2015). The data generated by precision agriculture technologies is interpreted by scientists in order to make correct decisions. In arid and semi-arid regions, micro irrigation helps to increase the crop productivity by reducing the water loss due to evaporation and increasing the water use efficiency through the use of precision devices for water application like pivots, drips, rain guns, sprinklers, etc.

Table 5.1: Few precision farming technologies used in agriculture:

Technologies used for data collection	Technologies used for data processing and decision making	Application technologies
Remote Sensing	Geo-informatics	Agricultural robots
Geo-spatial technology	Geo-statistics	Precision laser land leveller
Soil sampling and mapping	Crop modelling	Micro irrigation
Yield monitoring and mapping	Artificial intelligence	Drones
Field scouting	--	Site Specific Nutrient Management

Technologies used for data collection	Technologies used for data processing and decision making	Application technologies
--	--	Wireless data logger and sensor catalogue
--	--	Automated control system used in polyhouse cultivation

(Nikitha *et al.,* 2022)

A. Limitations:

Farmers have to spent lot of money on equipment, software and sensors. Skill is needed in handling the technologies. When large data sets are generated, it can be challenging and time consuming. Incorrect data interpretation can result in unforeseen consequences like excessive input consumption or mismanagement of resources. Concerns are raised regarding the data privacy and security with the acquisition of agricultural data. Restriction in adoption of the technology in rural areas with poor internet connectivity.

5.3.2 Vertical Farming:

Vertical farming is a markedly new approach which gives solutions to the challenges presented by climate change. Dickson Despommier is called as the father of vertical farming for his contribution in this area. It is the cultivation of crops vertically in staked layers making use of limited space and resources efficiently. Vertical farming uses LED lighting and nutrition systems under controlled conditions as a substitute of sunlight and rain. So, it is also called as indoor farming and gives more yield from a unit area. Vertical farming has evolved during 20th century and became very popular in the last few years to meet the needs of increasing human population and requirement of sustainable food grain production.

Three are three main types in vertical farming: Hydroponics, Aeroponics and Aquaponics. Each of them has its own benefits as listed below in Table 5.2. Although growing of crops in water is not a new idea, the commercialization of these technologies is a recent one. They require low maintenance with no tilling, no weeding, no fertilizer and pesticides applications (Specht *et al.,* 2015). Infestation by insects is eliminated virtually in the vertical farm environment (Graber *et al.,* 2015). Sequestration of carbondioxide and reduction of heat from urban island are the major advantages of vertical farming because less energy is needed to cool the indoor spaces especially during summer months and no emission of CO_2 takes place (Banerjee and Adenaeuer, 2014). A large number of developing countries are cultivating the crops by hydroponics technique. For example, ‘Eurofish’ farms of Arizona have sold around 128 million pounds of tomatoes making it the largest hydroponic greenhouse operator commercially. The researchers of NASA have found hydroponics as a better option for food production in the space (Lambin, 2012). Aeroponics is a useful technology for water strapped areas as it helps to save the water and the nutrient mix is circulated within the closed system. It also provides good aeration. Aquaponics on the other hand helps to meet the 3 R’s of reduce, reuse and recycle as the combination of fish farming and hydroponic crop production creates a symbiotic relationship between them.

All these technologies help to increase the employment opportunities and gives a business idea of supplying fresh fruits and vegetables from a single location.

Table 5.2: Key features and benefits of vertical farming technologies

Type	Key features	Benefits	Application technologies
Aeroponics	A replica of hydroponics in which the roots of the plants are applied with nutrient or media solutions	Less water is used	Monitoring is done by computerized systems, robots, solar energy, wind energy, geothermal energy, automatic racking and stacking systems and high-tech LED lighting systems that can be programmed.
Hydroponics	Water is used as a media for soilless cultivation of crops	No fertilizers or pesticides are used. Prevents soil related issues.	
Aquaponics	A combination of hydroponics and aeroponics	Establishment of healthy relationship between plants and fish by utilizing the refuse from fish tank as a fertilizer to the plants and few plants act as feed for fish.	

Mir *et al.* (2022)

A. Limitations:

The level of production from vertical farming is low than from conventional farming. The expansion of vertical farming could be time consuming and expensive. Renewable energy sources like wind turbines and photovoltaics produce less energy thereby one has to rely on electricity grid. Furthermore, the growers of vertical farming mostly distribute the vegetables to the restaurants and normal citizens cannot get the produce from vertical farming. Only a few varieties of crops can be grown by vertical farming like lettuce, onion, spinach, coriander, mint and strawberries. Some commodities such as wheat are also grown but remain unprofitable because of low value. Initial cost of land acquisition and setting up is high.

5.3.3 Agricultural Biotechnology:

Any method which uses the living organisms which are obtained from those organisms to modify a product and applied to all types of organisms from viruses and bacteria to plants and animals is described as biotechnology by Food and Agriculture Organization. It constitutes a variety of instruments from working at the genetic structure level to all the kinds of microbes to produce agricultural products without any environmental impact. For example, genetic engineering permits us to work with new varieties which are resistant to insect pests, diseases and also to the events of extreme floods or drought. *Bacillus thuringiensis* (Bt) gene is introduced into soybean, corn and cotton to impart resistance to pests such as the European corn borer and is environmentally benign as it doesn't affect human beings (Barrows *et al.*, 2014). Biotechnology also helps to lower the adverse effects of CO_2 emission by increasing the biofuel production both from traditional and GMO (genetically modified organisms) crops such as sugarcane, jatropa, rapeseed, and few oilseeds (Sarin *et al.,* 2007; Treasury, 2009). Furthermore, GMOs minimizes the carbon footprint because they need lesser agricultural tasks and minimizes the carbon which is released during crop production. It is evident from few studies that GM crops like Roundup Ready soybean (herbicide resistant) led to the sequestration of 63,859 million tons of carbondioxide (Brimner *et al.*, 2004; Kleter *et al.*, 2008). Also, varieties obtained from biotechnology approach gives higher yields from unit land area. Few biotechnological solutions such as biostimulants and biofertilizers improves the availability of nutrients to the crop plants by promoting the growth of beneficial microbes in the soil and helps in good crop growth and development. It also minimizes the dependence on chemical fertilizers.

Not only these, micro-organisms developed using biotechnology approaches helps in the improvement of soil structure and its physical properties resulting in the soil conservation. Biotechnology also contributes to overcome the increase in greenhouse gases in the environment through the lab development of mycorrhizal fungi such as *Glomus iranicum var. tenuihypharum* which forms a symbiosis with the crop plants and helps to extract the carbondioxide from the atmosphere, this carbondioxide ends up in the roots where symbiotic relationship is maintained between the plants and fungi. With the help of fungi, the carbon passes into the soil and it accumulates for long time in the soil resulting in carbon fixation.

Table 5.3: Various biotechnology approaches and their application

Measure	Biotechnology approach	Application	Reference
Mitigation of climate change	Incorporating herbicide resistance which reduces the number of sprays through genetic engineering	GM Canola and GM Soyabean	Kletter *et al.,* 2008
Carbon sequestration	Biofuel and Green energy production	GM energy rich crops like sugarcane (bioethanol) and jatropa (biodiesel)	Lybbert and Summer, 2010; Jain and Sharma, 2010
Tolerance to abiotic and biotic stress	Engineering salt, drought and heat tolerance	GM Arabdiopsis, GM tomato, bajra, tobacco, wheat, maize, brassica, cotton.	Yamanouchi *et al.,* 2002; Zhu, 2001 and Jaglo *et al.,* 2001
Reducing the fertilizer use	Agroforestry	Mycorrhizal symbiosis	Powlson *et al.,* 2011

Mtui, 2011

A. Limitations:

There are several doubts about public safety and health due to findings from agricultural biotechnology. Few of them are: Invention of oppressive pests and diseases, intensifying the existing pest effects, harming unwanted/untargeted species, interruption of biotic communities, species loss and diversity in species (Snow *et al.*, 2005). Socio economic as well as ethical issues such as losing traditional crops and fright about unknown future (Qaim, 2009). Polyamine role in abiotic stress tolerance is still to be understood. Effort is needed to know indetail about the molecular mechanism of spermidine and spermine in incorporation of abiotic stress (Kumar *et al.*, 2015).

5.3.4 Conservation Agriculture:

It is a technology which involves minimum disturbance of the soil and using of crop rotations or crop residues to cover the soil resulting in higher productivity (FAO, 2016). The term conservation agriculture is applied to zero tillage or minimum tillage practice along with 30 % crop residue cover on the soil surface and is often linked with the conservation of fuel, time, nutrients and increases the earthworm population as well as soil microbial population improving the biodiversity and microclimate of the soil (Baker *et al.*, 2007).

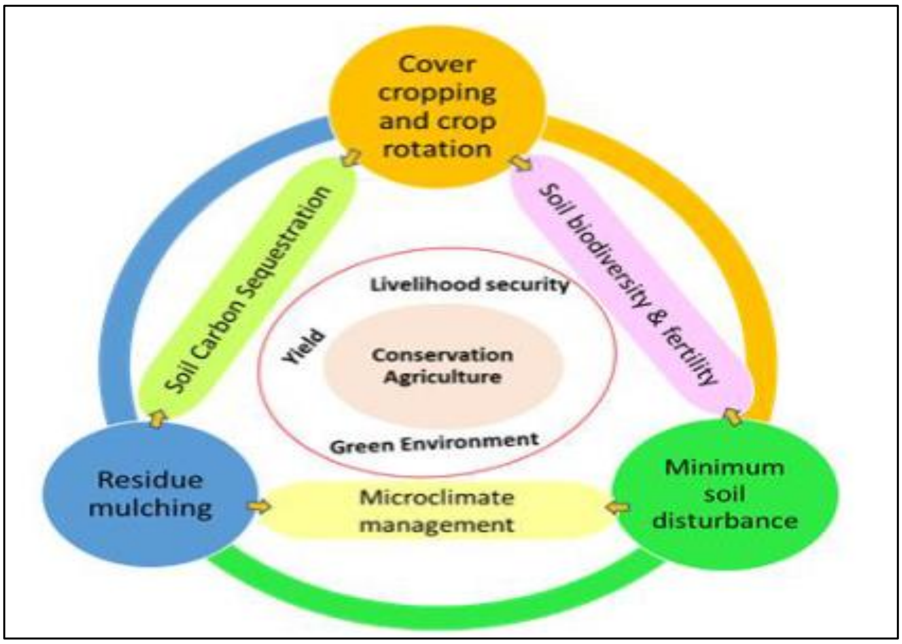

Figure 5.1: Positive Interaction of Conservation Agriculture Components with Environment

The concept revolves around the conservation of the resources and mitigation of the climate change. Conservation agriculture results in the buildup of more soil organic matter (SOM) compared to conventional tillage (Gathala *et al.*, 2011).

The conversion to zero tillage increases the soil organic carbon pool to around 9 Mg/ha in 15 years (Paustian *et al.,* 1997). Decreased bulk density, less impact of rain drops, higher soil moisture content, reduced evaporation, no surface crusting of soil and reduced runoff might be the reasons for the buildup of SOM in conservation tillage (Khan *et al.*, 2007). This increased SOM helps in nutrient cycling and increases the supply of macro and micronutrients. It also enhances the health, fertility and productivity of the soil in the long term (Saleeque *et al.*, 2009). Crop rotation favours recycling of nutrients from deeper layers of soil and crops with diverse root pattern are grown in rotation leading to development of diverse flora and fauna (Swaminathan *et al*., 2021). Inclusion of legumes in rotation helps in fixation of nitrogen into the soil. Crop rotation helps to minimize the production cost, improves the soil structure and enhances the plant growth and development (Selvakumar and Sivakumar, 2021).

Table 5.4: Variation between the conservation and conventional agriculture

Practice	Conservation agriculture	Conventional agriculture
Tillage	Minimum tillage or zero tillage	Intensive mechanical cultivation leading to erosion of soil
Soil management	Low wind erosion	High erosion
Residue management	Retention or incorporation of residues	Removal or burning of residues
Labour	Mechanized operation which reduces the labour need.	Heavy reliance on manual labour
Cropping system	Diversified crops under rotation	Monocropping
Cost of production	Low	High

Sharma *et al.* (2012)

A. Limitations:

Decomposition of the crop residues contributes to short-term immobilization of nitrogen due to higher activity of soil micro-organisms which lock up N_2 in their bodies (Verhulst *et al.,* 2010). Limited markets and shortage of improved legume seeds is a constraint for the inclusion of legumes in the crop rotation (Baudron *et al*., 2007; Haggblade and Tembo, 2003). Around 70-75 percent of the Indian farmers have only small and medium farm holdings and pay less attention to long term management of natural resources and can rarely afford inputs such as quality of seeds, heavy machines, fertilizers for nutrient application and herbicides for chemical weed management (Piyush *et al.,* 2018).

5.3.5 Value Addition:

The hunt for alternative food sources that are high in biologically active substances is prompted by the growing worldwide demand for food and the limited amount of land that is accessible. One of the principal ways to improve the food security is by reducing the post-harvest losses which contribute to food insecurity and shortage of food.

Diversifying agricultural products and increasing the food availability have received a lot of attention lately (Shafiee *et al.*, 2016). This can be attained by adding certain value to the agricultural products and reducing the post-harvest losses that play a crucial role in improving the profitability, viability and sustainability of agricultural products (Choudhury *et al.,* 2006). Edible flowers, medicinal plants and food industry trash (coffee peel and cacao shell) can all be used in the development of high-value food products (Hlavacova *et al.,* 2022). Paddy obtained from flood affected areas is sold at low prices because of poor quality. Such rice can be used in the preparation of value-added products like vermicelli which helps in improving the farmers income by finding alternate ways like value addition (Srinath and Uma Maheswari, 2016). Not only rice many fruits and vegetables affected by weather calamities are also used for the value addition as given in the Table 5.5.

Table 5.5: Outcome from the value addition of various food products

Various food products	**Value addition**	**End result**
Banana	Flour	Shelf life is increased, safe storage, easy to package and transport, better business opportunities
Malta Orange	Juice	Improves employment opportunities and income to the farmers
Indian gooseberry	Pickles, candy and juice concentrates	Development of capacity of the farmers and enterprises
Green chilli and mango	pickles	Improved productivity
Tulasi	Tea	Branding of the product

Hinai *et al*. (2022)

A. Limitations:

Inadequate infrastructure of the food processing sector in India. More risk is involved in selling the products. Competition and conflicts with the other products. Lack of communication between the farmers and investors to improve the products. High production costs and lack of scientific expertise with no workshops and educational programs to build the farmers skills. Increase in foreign labour that may affect the production efficiency of the value-added products. Lack of sufficient awareness to deal with post-harvest losses. Lack of transfer of technology to maximize the value addition production (El-Juhany Li *et al*., 2010).

5.4 Potential Impacts and Benefits of Adopting Innovative Technologies in Agriculture:

Adopting innovative technologies in agriculture has the potential to yield significant impacts and benefits. Precision agriculture, enabled by technologies such as drones and sensor-based systems, allows for more efficient use of resources like water and fertilizers, leading to higher crop yields and lesser impact on the environment (Dionysis *et al.,* 2022). Machine learning and artificial intelligence applications can analyze vast amounts of data to provide personalized recommendations for farmers, optimizing crop management practices. Implementing block chain technology in agriculture can enhance traceability and transparency in the supply chain, fostering consumer trust in food safety. Furthermore, the integration of autonomous vehicles and robots in farming operations can address labor shortages and improve overall productivity. Embracing these technologies holds the promise of revolutionizing the agricultural sector, making it more sustainable, productive, and resilient in the face of climate change challenges.

5.5 Conclusion:

In conclusion, the integration of innovative technologies in agriculture holds great promise for addressing the challenges of climate change. By harnessing tools such as precision agriculture, vertical farming, biotechnology, conservation agriculture and value addition, farmers can optimize resource use, reduce emissions, increase productivity and profitability. These technologies offer the potential to revolutionize the way we approach agriculture, making it more sustainable in the face of changing environmental conditions. However, for these technologies to be truly transformative, there must be widespread adoption and investment in research and development. Policy support and collaboration between governments, researchers, and the private sector will be crucial in driving the adoption of these technologies at scale. Ultimately, the success of these innovations will depend on our ability to effectively integrate them into existing agricultural systems and practices, while also ensuring equitable access for all farmers.

5.6 References:

1. Alexandratos N and Bruninsma J. 2012. World agriculture towards 2030/2050: The 2012 revision. ESA Working Paper No. 12-03. Rome, Italy: Food and Agriculture Organisation of the United Nations.
2. Baker CJ, Saxton KE, Ritchie WR, Chamen WCT, Reicosky DC, Ribeiro MFS, Justice SE and Hobbs PR. 2007. No- Tillage Seeding in Conservation Agriculture- 2nd (Edn.). CABI and FAO, Rome. 326.
3. Banerjee C and Adenaeuer L. 2014. Up, Up and Away! The Economics of Vertical Farming. *Journal of Agricultural Studies*. 2:40.
4. Barrows G, Sexton S and Zilberman D. 2014. Agricultural Biotechnology: The Promise and Prospects of Genetically Modified Crops. *Journal of Economic Perspectives.* 28 (1): 99–120.
5. Baudron F, Mwanza HM, Triomphe B and Bwalya M. 2007. Conservation agriculture in Zambia: A case study of Southern Province. Nairobi: African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Dévelopment, Food and Agricultural Organization of United Nations.
6. Bhatia A, Pathak H, Jain N, Singh PK, Tomer R. 2012. Greenhouse gas mitigation in rice – wheat system with leaf color chart-based urea application. *Environmental Monitoring and Assessment*. 70: 11-21.
7. Blackmore S. 2003. The Role of Yield Maps in Precision Farming. Ph.D. Thesis, Cranfield University, Cranfield, UK. 171.
8. Brimner TA, Gallivan GJ and Stephenson GR. 2004. Influence of herbicide-resistant canola on the environmental impact of weed management. *Pest Management Science*. 61(1): 47-52.

9. Choudhury ML. 2006. Recent developments in reducing post-harvest losses in the Asia-Pacific region. From: Post harvest Management in Fruit and Vegetables of Asia-Pacific Reg.
10. Dionysis D, Bochtis Simon Pearson, Maria Lampridi, Vasso Marinoudi, Panos M and Pardalos. 2022. Information and Communication Technologies for Agriculture—Theme IV: Actions. *Springer Nature.* 03-07.
11. El-Juhany LI. 2010. Degradation of date palm trees and date production in Arab countries: causes and potential rehabilitation. *Australian Journal of Basic and Appllied Science*. 4(8):3998–4010.
12. FAO. 2016. Climate change, Agriculture and Food Security, Rome, Italy; Food and Agriculture Organization of the United Nations (FAO).
13. Fawzy S, Osman AI, Doran J, Rooney DW. 2020. Strategies for mitigation of climate change: a review. *Environmental Chemistry Letters.* 18:2069-2094.
14. Gathala MK, Ladha JK, Kumar V, Saharawat YS, Sharma PK, Sharma S and Pathak H. 2011. Tillage and crop establishment affects sustainability of South Asian rice-wheat system. *Agronomy Journal.* 103: 961–972.
15. Graber A, Schoenborn A and Junge R. 2011. Closing water, nutrient and energy cycles within cities by urban farms for fish and vegetable Production. *International Water Association Newsletter*. 37: 37-41.
16. Haggblade S and Tembo G. 2003. Development, diffusion and impact of conservation farming in Zambia. Food Security Research Project. Lusaka, Zambia: Michigan State University.
17. Halimi K and Moussa T. 2015. A guelph intelligent greenhouse automation system (GIGAS) for greenhouse-based precision agriculture. *IEEE Transactions on Neural Systems and Rehabilitation Engineering.* 25(6): 686-693.
18. Hinai AA, Jayasuriya H, Pathare PB and Shukaili TA. 2022. Present status and prospects of value addition industry for agricultural produce-A review. *Open Agriculture*. 7: 207-216.
19. Hlavacova Z, Ivanisova E, Hlavac P, Kubik L, Kunecova D, Bokicova M and Vozarova V. 2022. Value added foods: Characteristics, benefits and physical properties. *Trends and Innovations in Food Science.* DOI: 10.5772/intechopen.104971.
20. Hoffmann U. 2013. Section B: Agriculture - a key driver and a major victim of global warming, in: Lead Article, in: Chapter 1, in Hoffmann. pp. 3, 5.
21. IPCC. 2014. Summary for policymakers. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. In: Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. pp. 1-32.
22. Jaglo KR, Kleff S, Amunsen KL, Zhang X, Haake V, Zhang JZ and Deits T. 2001. Thomas how MF. Components of Arabidopsis Crepeat/dehydration response element binding factor or cold-response pathway are conserved in Brasicca napus and other plant species. *Plant Physiology*.127: 910–917.
23. Jain S and Sharma MP. 2010. Prospects of biodiesel from Jatropha in India: A review. *Renewable and Sustainable Energy Reviews*. 14(2): 763–771.
24. Kanannavar PS, Premanand BD, Subhas B, Anuraja B, Bhogi PB. 2020. Laser land levelling: an engineering approach for scientific irrigation water management in irrigation command areas of Karnataka, India. *International Journal of Current Microbiology and Applied Sciences*. 9(5): 2393-2398.

25. Khan AH, Iqbal M and Islam KR. 2007. Dairy manure and tillage effects on soil fertility and corn yields. *Bioresource Technology*. 98 1972-1979.
26. Kleter GA, Harris C, Stephenson G and Unsworth J. 2008. Comparison of herbicide regimes and the associated potential environmental effects of glyphosate-resistant crops versus what they replace in Europe. *Pest Management Science*. 64: 479-488.
27. Kumar S, Bansode R, Malavv MK and Malav L. 2015. Role of biotechnology in climate change mitigation. *International Journal of Applied and Pure Science and Agriculture.* 48-53.
28. Lambin EF. 2012. Global land availability: Malthus versus Ricardo. *Global Food Security*. 83-87.
29. Lybbert T and Sumner D. 2010. Agricultural technologies for climate change mitigation and adaptation in developing countries: Policy options for innovation and technology diffusion. ICTSD-IPC Platform on Climate Change, Agriculture and Trade, Issue Brief No.6, International Centre for Trade and Sustainable Development, Geneva, Switzerland and International Food & Agricultural Trade Policy Council, Washington DC, US.
30. Mir MS, Naikoo NB, Kanth RH, Bahar FA, Bhat MA, Nazir A, Mahdi S, Amin Z, Singh L, Raja W, Saad AA, Bhat TA, Palmo T and Tanveer AA. 2022. Vertical farming: The futrure of Agriculture-a review. *The Pharma Innovation Journal.* 11(2): 1175-1195.
31. Mtui GYS. 2011. Involvement of biotechnology in climate change adaptation and mitigation: Improving agricultural yield and food security. *International Journal of Biotechnology and Molecular Biology Research*. 2(13): 222-231.
32. Nikitha P, Rani VS, Naik VR, Padmaja B, Nirmala A and Aruna K.2022. Status of Precision Farming Technologies in Indian Context-A Review. *International Journal of Environment and Climate Change*.12(6):117-125.
33. Paustian K, Collins HP and Paul EA. 1997. Management controls on soil carbon. In: Paul EA (ed.) Soil organic matter in temperate agro-ecosystems” CRC Press, Boca Raton, FL, USA. 15-49 pp.
34. Piyush P, Verma A and Kumar M. 2018. Need of Conservation Agriculture in India: Sustainability. *International Journal of Current Microbiology and Applied Science.*7(01): 308-314.
35. Powlson DS, Whitmore AP and Goulding KWT. 2011. Soil carbon sequestration to mitigate climate change: A critical re-examination to identify the true and false. *European Journal of Soil Sciences.* 62: 42–55.
36. Qaim M. 2009. The economics of genetically modified crops. *Annual Review of Resource Economics.* 1: 665-693.
37. Saleeque MA, Mahmud MNH, Kharun A, Haque MM, Hossain ATMS and Zaman S K. 2009. Soil qualities of saline and non-saline deltas of Bangladesh. *Bangladesh Rice Journal.* 14 (1&2): 99- 11.
38. Sapkota TB, Jat ML, Aryal JP, Jat RK, Khatri-Chhetri A. 2016. Climate change adaptation, semi-arid tropics of southern India. *Soil & Tillage Research.* 156:131-139.
39. Sarin R, Sharma M, Sinharay S and Malhotra RK. 2007. Jatropha palm biodiesel blends: An optimum mix for Asia. Fuel. 86(10-11): 1365-1371.
40. Selvakumar S and Sivakumar K. 2021. Conservation Agriculture: A Way for Soil Water Conservation. Agricultural reviews.DOI: 10.18805/ag. R-2045.

41. Shafiee JM and Cai X. 2016. Reducing food loss and waste to enhance food security and environmental sustainability. *Environment Science and Technology.* 50(16): 8432–43.
42. Sharma AR, ML Jat, YS Saharawat, VP Singh and R Singh, 2012. Conservation Agriculture for Improving Productivity and Resource-use Efficiency: Prospects and Research Needs in Indian Context. Indian Journal of Agronomy. 57 (IAC Special Issue). pp. 131–140.
43. Snow AA, Andow DA, Gepts P, Hallerman E.M, Power A. 2005. Genetically engineered organisms and the environment: Current status and recommendations. *Ecological Application.*15(2): 377-404.
44. Specht K, Siebert R, Thomaier S, Freisinger U, Sawicka M and Dierich A. 2015. Zero-Acreage Farming in the City of Berlin: An Aggregated Stakeholder Perspective on Potential Benefits and Challenges. *Sustainability.* 7: 4511-4523.
45. Srinath D and Uma Maheswari K. 2016. Formulation, standardization and quality evaluation of rice vermicelli prepared from flood affected paddy. *International Journal of Development Research.* 7357-7362.
46. Subramanian KS, Pazhanivelan S, Srinivasan G, Santhi R and Sathiah N. 2021. Drones in insect pest management. *Frontiers in Agronomy*. 3:640- 885.
47. Swaminathan C, Sobhana E, Pandian K and Yassin MM. 2021. Principles, positives and limitations of conservation agriculture - A Review. *Agricultural reviews.* 1-9.
48. Treasury HM. 2009. Green biotechnology and climate change. Europian Biology. p.12. Available online at http://www.docstoc.com/docs/15021072/Green-Biotechnology-and-Climate-Change.
49. United Nations. 2015. Department of Economic and Social Affairs Population Division. World Population Prospects: The 2015 Revision. Working Paper No. ESA/P/WP.241. New York, NY: The Department of Economic and Social Affairs of the UN Secretariat.
50. Verhulst N, Govaerts B, Verachtert E, Castellanos-Navarrete A, Mezzalama M and Wall P. 2010. Conservation agriculture improving soil quality in sustainable production systems. In [R. Lal and B. Stewart (Edn.)]. Food Security and Soil Quality. Boca Raton, FL: CRC Press.
51. Yamanouchi U, Yano M, Lin H, Ashikari M and Yamada K. 2002. A rice spotted leaf genesp17 encodes a heat stress transcription factor protein. *Proceedings of the National Academy of Sciences of the United States of America.* 99: 7530-7535.