Building Agricultural Resilience: Strategies for Climate Change Adaptation

ABSTRACT

The term "climate-resilient agriculture" refers to methods, tools, and frameworks aimed at adapting to and mitigating the effects of climate change on livelihoods, food security, and agricultural production. Crop productivity and food security are greatly impacted by climate change, which calls for creative agricultural methods to maintain food supply while reducing environmental damage. These difficulties are made worse by environmental changes and global population expansion, especially in poor countries. Climate change has a significant impact on India's agriculture, influencing environmental conditions, agricultural techniques, and production. Worldwide approaches to mitigating climate change prioritize resilience and climate adaptation, including the principles of sustainable development. Technological advancements, such as geospatial analysis, and eco-friendly farming technologies, play a crucial role in optimizing land use and enhancing food security. Crop variety adaptation and management of seed, water, land, livestock, soil and nutrients, pest management, risk management, and post-harvest management are examples of effective agricultural adaptation strategies. Technological developments like geographic analysis

1. INTRODUCTION

Climate-resilient agriculture denotes agricultural practices, technologies, and systems designed to adapt and mitigate the impacts of climate change on agricultural yields, food security, and livelihoods. It involves strategies that enable farmers to cope with climate variability, extreme weather events, and changing climatic conditions while ensuring sustainable agricultural production. Key elements of climate-resilient agriculture include the use of drought-tolerant crop varieties, efficient water management techniques, soil conservation practices, agroforestry, diversified cropping systems and innovative farming approaches that enhance resilience to climate-related risks. By promoting resilience at the farm level and across agricultural value chains, climate-resilient agriculture aims to build the ability of farmers and agricultural systems to endure and recover from climate-related shocks and stresses, ultimately contributing to food security, poverty reduction and environmental sustainability.

2. CLIMATE CHANGE IMPACT ON CROP PRODUCTION AND FOOD SECURITY

Over time, food security has become a worldwide concern due to the exponential increase in human population, less agricultural space, change in the worldwide environment, urban expansion and land use change (1). Reports from both the IPCC and FAO indicate that the agriculture sector in developing nations is among the most susceptible to climatic changes (2). Moreover, with the current global population reaching approximately 9.1 billion, there is a projected need for a 50 to 70% increase in worldwide food production by 2050 to sustain current dietary patterns (3) and it will again further increase by approximately 30% rise in greenhouse gas emissions worldwide from the agriculture (4) especially in Asian and African countries as the large population relies on agriculture and related livelihoods (5). Therefore, it's essential to innovate agricultural techniques to ensure food provision for future generations while minimizing environmental harm (6). The availability of ample food supplies will also diminish as the quality and availability of these goods rely on local agricultural production or imports (Food and Agriculture Organization (7).

3. CLIMATE CHANGE IMPACT ON INDIAN AGRICULTURE

- The climate change can be direct or indirect effects on agriculture, with varying degrees of impact depending on the extent of change in climate, geographic location, and agricultural methods employed. Evaluating these impacts involves conducting controlled experiments and simulation modeling. The findings from these experiments are then applied regionally to project how climate change may affect agriculture under different scenarios. The factors affecting:
- Alterations in productivity, considering both quantity and quality of crops.
- Shift in agricultural practices like water management and use of fertilizers, insecticides herbicides, etc.
- Environmental impacts, particularly regarding the frequency and intensity of soil drainage which may result in loss of nitrogen through leaching, soil erosion, and decrease of crop diversity

4. GLOBAL APPROACHES TO ADDRESS CLIMATE CHANGE

Climatic adaptation entails achieving a balance among ecology, society, and economy to mitigate the adverse impacts of climate change. This involves modifying habits, consumption patterns, and infrastructures to minimize losses resulting from climate change, as outlined by (8). On the other hand, climate resilience involves cultivating the capacity of societies, including ecology, to endure the adverse effects of severe climatic changes with minimal or no harm. Certain natural and societal systems possess an inherent ability to adapt to adverse conditions, thus being considered resilient. Achieving this resilience often involves adopting the principles of sustainable development, as suggested by (9). To mitigate the impacts of climate change, embracing sustainable development strategies is beneficial on a global scale. Moreover, early adoption of these approaches is essential due to their gradual, methodical nature. Consequently, proactive planning for adaptation becomes imperative. Collaborative efforts are crucial in developing climate-land &water tactics to ensure food and water security for the generations to come, as emphasized by (10). Various research documents extensively describe climate-resilient practices aimed at addressing changes in climatic conditions. These practices are designed to boost the resilience of societies and ecosystems, enabling them to withstand and recover from climate-related challenges. Hallegatte (2009) outlined various adaptation strategies across different categories to mitigate the negative effects of climate change. For instance, to support the agriculture sector there are options such as utilizing resilient crop varieties with rotation, effective irrigation water use, and promoting agroforestry are considered effective alternatives. Similarly, measures like reducing water loss, implementing water reuse, and Improving treatment facilities are thought to produce more favorable results in minimizing the negative effects of climate change. Burke and Lobell (2010) recorded deliberate adaptation measures to address the detrimental effects of climate change. These measures include the development of improved crop varieties, creating accessible markets for marginalized farmers, integrating traditional knowledge with modern science, and enhancing irrigation infrastructure among others. The fundamental principles of the Climate-resilient agriculture concept involve improving agricultural productivity sustainably to ensure food security and income, building agricultural resilience against climate change,and reducing GHG emissions from agricultural practices. In the Climate Smart Agriculture approach, farmers should be provided with access to a range of advanced techniques, including resilient crop and animal varieties, agroforestry options, improved irrigation water management facilities, crop sequencing practices, insurance, and soil productivity protection (13).

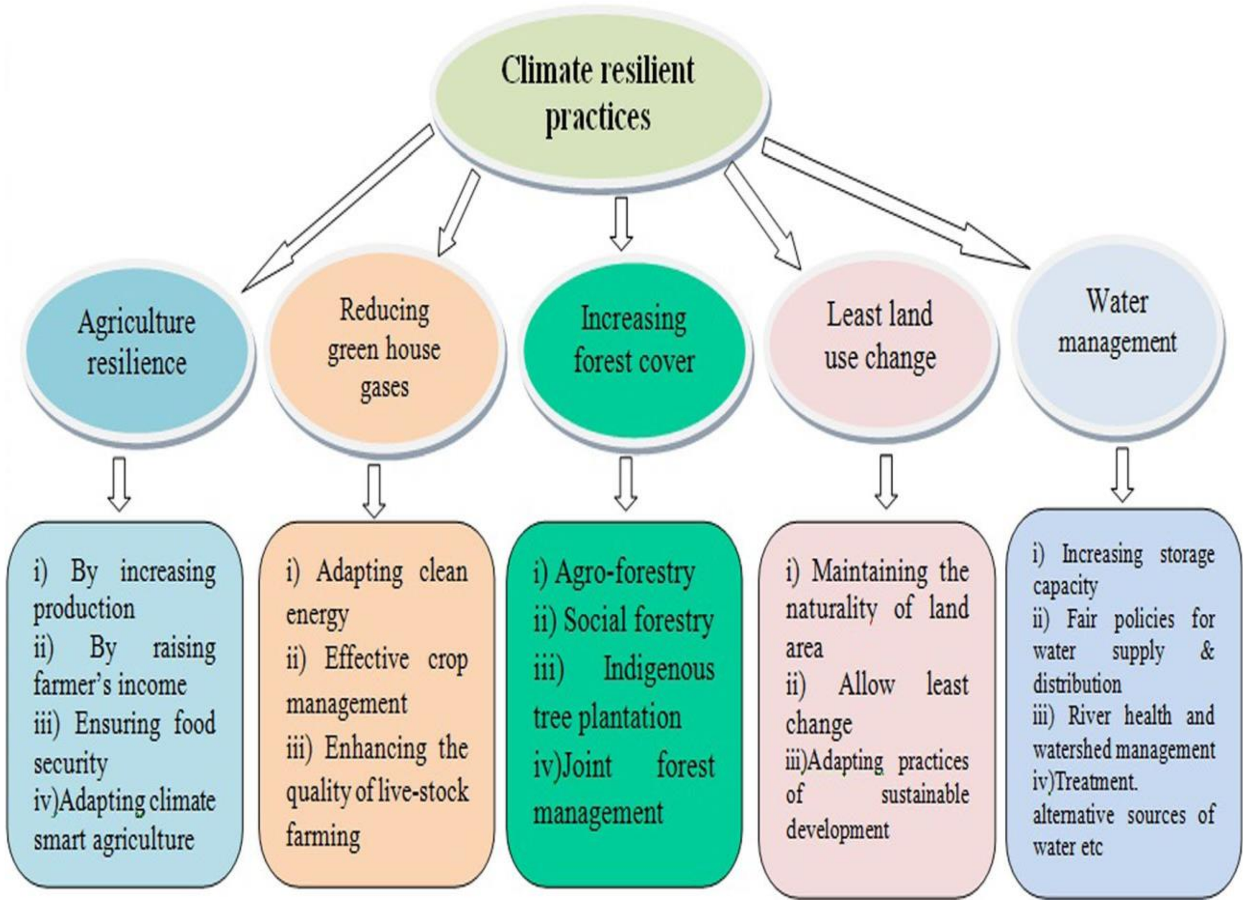

Fig 1 Climate resilience practices

Implementing eco-friendly resource management practices can improve agricultural yields within the existing farming land (14). Utilizing geospatial and data analysis approaches can enhance the agricultural industry and address food security challenges by optimizing land resources in response to changing climatic conditions (15). Soil evaluation for agricultural fitness is crucial for land-use planning (16). The advancement and adoption of eco-friendly farming technologies are essential for society, driving innovation (17). Furthermore, integrating sustainable practices into crop-specific farming is attained by utilizing remote sensing and associated technologies (6).

5. AN OVERVIEW OF A FEW CRA METHODS

5.1. Crop variety adaptation and management of seed

Techniques for managing crops encompass a range of traditional and modern methods aimed at modifying plant traits or cultivation practices to achieve desired yield, growth, and development. Since its inception, more than 6100 improved varieties of the crop have been released by the Indian Council of Agricultural Research, which include 1622 climate-adaptive cultivars. These improved varieties are widely favored among CSA adopters, who make up eighty percent of the targeted group evidenced by a study in the Karnal district of Haryana and Vaishali district of Bihar. According to Khatri-Chhetri et al. (2016) in the rice-wheat cropping system, the adoption of better varieties has increased overall output by 19% and net return per hectare by Rs 15,712. The adoption of improved varieties has led to a 19% increase in total production in the rice-wheat system and a net return increase of Rs 15,712 per hectare (18). Seed banks play a crucial role in ensuring food security by preserving plant genetic species and providing long-term viability. Shortages of seeds can be mitigated by preserving a variety of crop cultivars in seed banks. For instance, by using a variety of finger millet which is appropriate for late planting in the event of delayed monsoons, Nanganahalli village in Tumkur, Karnataka, attained self-sufficiency (19). Regional variances in the timings of planting and harvesting depart from the average due to variations in climate. Planning agricultural production and developing mitigation and adaptation measures, therefore, depend on anticipating changes in these dates in response to climate change (20).

5.2. Water management

India possesses around four percent of the water resources of the world, with 80% of this water being utilized by the agricultural sector. To improve agricultural profitability and expand irrigation coverage, the Govt. of India has launched projects like "Har Khet Ko Pani" and "Per Drop More Crop". However, with changing circumstances, the government may need to implement additional interventions to meet the growing water demand. Since dry zones make up around 12% of India's land area and have little access to water, they are especially vulnerable to the negative effects of climate change, such as decreased rainfall. A method called supplemental irrigation (SI) can help ensure adequate yields, especially during periods of insufficient rainfall. Combining SI with water harvesting can enhance water utilization efficiency and boost productivity in dryland and semi-arid areas. In comparison to their prior methods, farmers in the Chenchu hamlet of Petrallachenu (Telangana) increased food security, water productivity, and nutrient availability, according to research conducted by (21). They also saw favorable economic returns. Research conducted by Reddy et al. (2020) found that the water table had risen as a result of recharging tube wells positioned in front of existing wells. Maintaining a distance of around 100 meters between two recharge tube wells and employing silt basins and filters can ensure the endurance of tube wells. Water shortage was a major problem in Sitaram village, Bharatpur, Rajasthan, and this intervention significantly raised the levels of the shallow aquifer (2.5–4 metres). 242 hectares of land could be irrigated as a consequence of the next years' recharging of around 60 tube wells, which raised the water table by 8 to 10 feet (19). It is crucial to evaluate the possibility of water recharge, and an investigation on geo-electrical could be required to find appropriate locations for tube well recharge.

5.3. Land management

Compared to monocropping, intercropping increases yield on a given plot of land by growing many crops near together. producing intercropping is more profitable than producing a single crop, according to studies. By lengthening the growing seasons, relay intercropping has further enhanced land-use efficiency. This has led to greater yields per unit of land and increased total resource capture (23).

5.4. Livestock management

According to Herrero et al. (2010), a successful adaptation technique for increasing food security is to improve the crop-livestock system. By increasing fertility and plant density, a two-year study conducted in Karnal, Haryana, secured green fodder of higher quality (25). Improved feeding techniques can improve cattle production efficiency indirectly as an adaptive approach (26). Henry *et al.* (2012) stated that breeding practices can be changed to improve an animal's ability to resist infections and heat stress, which will encourage growth and reproduction. Establishing global gene banks, similar to the In-Trust plant collections for plants, might be a useful tactic to support breeding programs and act as an insurance policy (28). To create data banks, research has been done on native livestock genetic resources by the National Bureau of Animal Genetic Resources (Bureau) at Karnal, Haryana, India. Better-quality ruminant diets result in lower methane emissions per unit of milk and meat produced as well as better milk and meat output. Animal health may be impacted directly or indirectly by climate change, especially by increased temperatures (29). Emerging technological interventions, customized to animal, pet, and livestock needs, include products like medication patches, electronic saddle optimization, and tracking collars, which witness increasing rates of adoption (30). Farmers face ongoing challenges during intense heat or rainfall seasons, which can predispose small ruminants to diseases and increased mortality. Therefore, effective shelter management is crucial for animal well-being. Livestock yields may be greatly increased by putting into practice better grazing management techniques like rotational grazing and stocking rate management.

5.5 Soil and nutrient management

Precision farming, cover crops, composting, and the use of manures are establishing methods for managing soil. Farmers gain from micro-dosing, the practice of applying the right amount of fertilizers and other agrochemicals at the right time throughout the planting and development stages, as does the long-term sustainability of the environment. Crop rotation has been effectively introduced in several Indian states, including Punjab and Rajasthan, and has improved production over the long term (31). Cover crops are cost-effective and have several positive effects on moisture content, microbial activity, and soil water, hence, they are essential for improving soil health and fostering biodiversity (32). Soil aeration supports plant root metabolism and promotes the activity of enzymes like redoxase, which enhances nutrient absorption rates and root growth (33). According to Jakhar et al. (2018), residue retention and decomposition in fields improve soil health, and nutrient recycling, and boost crop yields. Tutua et al. (2019) stated that retaining harvest residue greatly increases the nitrogen and carbon levels of the soil. Mulching offers several advantages weed suppression, reduced evaporation, and maintenance of soil temperature, ultimately enhancing grain yields and water use efficiency (36). Organic fertilizers, including farmyard manure and vermicompost, are widely used worldwide and effectively enhance soil nitrogen content over time. Green manure, consisting of leguminous and forage crops, plays a vital role in nitrogen input through nitrogen-fixing plants left in the field (37).

5.6. Pest management

Three groups of bio-pesticides are micro-organisms, semiochemicals and biochemicals. More than 300 different species of organisms, including a wide range of bacteria, viruses and fungi, can act as bio-control agents or be the source of bio-control agents. Bio-fungicides such as Pseudomonas and Trichoderma, bio-herbicides with Phytophthora spp., and bio-insecticides with Pseudomonas spp. and Bacillus spp. are examples of commonly used bio-pesticides (38). Gaur (2020) stated that with different strains accounting for 2% of all insecticide consumption, *Bacillus thuringiensis* is the most frequently used microbial pesticide in the world. The commercial manufacture and marketing of fungus (*Trichoderma viride, Beauveria bassiana*,and*Trichoderma harzianum*) and bacteria-based bio-control formulations are managed by Bio-Control Research Laboratories in India. (40). Some bio-pesticides offer additional benefits beyond controlling pests, such as the management of soil nutrients and the promoting growth of the crop. They are environment-friendly, and user-friendly, leave no harmful residues, and user-friendly, aligning well with sustainable agriculture practices. However, adherence to proper dosing and safety guidelines during application is essential. Importation (traditional biological control), augmentation, and conservation are examples of biological control tactics used in pest management. Reducing the need for pesticides and minimizing the negative effects of invasive pests on native plants and animals are two advantages of biological management (41). Modifying vegetation is one easy and affordable way to conserve natural enemies that have adapted to the environment and the pests they target.

5.7. Management of risk

Failure of crops stands as a major catalyst for the government's implementation of insurance schemes aimed at addressing uncertainties. In Bihar, India, maize cultivation sees substantial investments with expectations of good yields, yet recurrent crop failures have tragically led to farmer suicides. Evaluating market failures and financial uncertainty in risk management techniques is essential to averting such catastrophes. In the case of crop failure, tools like forward contracting and crop insurance might give farmers cash help as well as credit for the following growing season. Crop insurance, however, usually only covers a limited range of crops and natural disasters, including those brought on by the effects of climate change. The General Insurance Department of the Life Insurance Corporation of India launched India's first insurance plan in 1972. It was followed by several later failed insurance plans. Introduced in 1999–2000, the National Agriculture Insurance Scheme (NAIS) offered coverage for all food crops at premiums ranging from 1.5% to 3.5% of the guaranteed amount.A different approach, the Farm Income Insurance Scheme (FIIS), compensated for losses in minimum support prices on commodities like wheat and rice and concentrated on yield and price protection under single insurance. In 2016, the Pradhan Mantri Fasal Bima Yojana replaced NAIS and MNIAS, addressing their shortcomings by reducing premium rates to 2% and 1.5% for Kharif and Rabi crops, respectively. Meanwhile, livestock has emerged as a primary livelihood and supplemental income source for farming households, contributing significantly to income, especially for small farm households. However, despite its importance, livestock insurance remains low, with estimates suggesting coverage of about 9% in Haryana and negligible coverage in Rajasthan (42). Lack of trust in insurers, high premiums, poor delivery mechanisms, absence of indemnity for losses, insufficient renewal information, and difficulties in accessing insurance contribute to approximately 90% of households hesitating to renew their livestock insurance policies.

5.8. Post-harvest management

Evaporation Cooling Chambers represent a post-harvest management technology centered around cooling through evaporation. During this process, the cooling effect arises from the energy extracted from the environment during water evaporation. Compared to electric vapour compression refrigeration systems, evaporative cooling uses a great deal less energy to transport water and air (43). According to reports, insufficient storage facilities cause 20–40% of produce to be wasted in India. The Central Institute of Post Harvest Engineering and Technology (ICAR-CIPHET) in Abohar, Punjab, has assessed several cooling chamber designs, including pot-in-pot, charcoal coolers, and zero-energy cooling chambers (44).

6. CONCLUSION

CRA represents a scientifically robust approach to sustainable agricultural production, aimed at enhancing resilience to climate-related risks and contributing to food security, poverty reduction, and environmental sustainability. By integrating genetic improvement, efficient water and soil management, diversified cropping systems, and advanced technological innovations, CRA addresses the multifaceted challenges posed by climate change. The adoption of CRA practices ensures that agricultural systems can withstand and recover from climatic shocks and stresses, maintaining productivity and stability. Through the strategic application of scientific principles, CRA not only mitigates the adverse impacts of climate change but also fosters long-term environmental health and socioeconomic resilience, ultimately securing food provision for future generations.

REFRENCES

Rotolo, G. C., Montico, S., Francis, C. A., Ulgiati, S. How land allocation and technology innovationaffectthe sustainability of agriculture in Argentina Pampas: An expanded life cycle analysis. AgriculturalSystems. 2015; 141: 79-93.

2. Manuamorn, O. P., Biesbroek, R., Cebotari, V. What makes internationally-financed climate change adaptation projects focus on local communities? A configurational analysis of 30 Adaptation Fundprojects. Global Environmental Change. 2020; 61: 102035.

3. McIntyre, L., Thille, P., Rondeau, K. Farmwomen's discourses on family food provisioning: Gender, healthism, and risk avoidance. Food and Foodways. 2009; 17(2): 80-103.

4. Tubiello, F. N., Salvatore, M., Cóndor Golec, R. D., Ferrara, A., Rossi, S., Biancalani, R., Flammini, A. Agriculture,forestry and other land use emissions by sources and removals by sinks. Rome,Italy. 2014.

5. Sapkota TB, Vetter SH, Jat ML, Sirohi S, Shirsath PB, Singh R, Jat HS, Smith P, Hillier J, Stirling CM.Costeffective opportunities for climate change mitigation in Indian agriculture. Science of the TotalEnvironment. 2019; 655: 1342-1354.

6. Akpoti, K., Kabo-bah, A. T., Zwart, S. J. Agricultural land suitability analysis: State-of-the-art and outlooks for of climate change analysis. Agricultural systems. 2019; 173: 172-208.

7. Food and Agriculture Organization (FAO) Food Security. Policy Brief. Food and Agriculture Organization of the United Nations. The availability of sufficient quantities of food of appropriate quality, supplied throughdomestic production or imports. 2006.

8. UNFCCC (2020) https://unfccc.int/topics/adaptation-and-resilience/thebig-picture/what-do-adaptation-to climate change-and-climateresilience-mean; accessed on 20.8.2020.

9. Tompkins, E. L., Adger, N. W. Building resilience to climate change through adaptive management of natural resources. Tyndall Centre for Climate Change Research. 2003; 1–24.

10. Rockström, J., Brasseur, G., Hoskins, B., Lucht, W., Schellnhuber, J., Kabat, P., Nakicenovic, N., Gong, P.,Schlosser, P., Máñez Costa, M., Humble, A. Climate change: The necessary, the

possibleand the desirableEarth League climate statement on the implications for climate policy from the 5th IPCCAssessment. Earth's Future. 2014; 2(12): 606-611.

11. Hallegatte, S. Strategies to adapt to an uncertain climate change. Global environmental change. 2009; 19(2): 240-247.

12. Burke, M., Lobell, D. Food security and adaptation to climate change: What do we know?. Climate change and foodsecurity. Adapting agriculture to a warmer world. 2010; 133-153.

13. Food and Agriculture Organization (FAO) Sourcebook on climate-smart agriculture, forestry and fisheries. Food and Agriculture Organization of the United Nations (FAO). Food and Agriculture Organization, Rome,Italy. 2013.

14. Montgomery, B., Dragićević, S., Dujmović, J., Schmidt, M. A GIS-based Logic Scoring of Preferencemethod for evaluation of land capability and suitability for agriculture. Computers and Electronics inAgriculture. 2016; 124: 340-353.

15. Bonfante, A., Monaco, E., Alfieri, S. M., De Lorenzi, F., Manna, P., Basile, A., Bouma, J. Climate change effects onthe suitability of an agricultural area to maize cultivation: application of a new hybrid land evaluationsystem. Advances in Agronomy. 2015; 133: 33-69.

16. Yu, J., Chen, Y., Wu, J., & Khan, S. Cellular automata-based spatial multi-criteria land suitabilitysimulation forirrigated agriculture. International journal of geographical information science. 2011; 25(1): 131-148.

17. Makate, C. Effective scaling of climate smart agriculture innovations in African smallholder agriculture: A reviewof approaches, policy and institutional strategy needs. Environmental science & policy. 2019; 96:37-51.

18. Khatri-Chhetri, A., Aryal, J. P., Sapkota, T. B., Khurana, R. Economic benefits of climate-smartagriculturalpractices to smallholder farmers in the Indo-Gangetic Plains of India. Current Science. 2016; 1251-1256.

19. Prasad, Y. G., Maheswari, M., Dixit, S., Srinivasarao, C., Sikka, A. K., Venkateswarlu, B., Mishra, A. Smart practices and technologies for climate resilient agriculture. 2014.

20. Marcinkowski, P., Piniewski, M. Effect of climate change on sowing and harvest dates of spring barley and maizein Poland. International Agrophysics. 2018; 32(2).

21. Reddy, A. A., Ricart, S., Cadman, T. Driving factors of food safety standards in India: learning from street-food vendors’ behaviour and attitude. Food Security. 2020; 12(6): 1201-1217.

22. Kaledhonkar, M. J., Sharma, D. R., Tyagi, N. K., Kumar, A., Van Der Zee, S. E. A. T. M. Modeling for conjunctiveuse irrigation planning in sodic groundwater areas. Agricultural WaterManagement. 2012; 107: 14-22.

23. de la Fuente, E. B., Suárez, S. A., Lenardis, A. E., Poggio, S. L. Intercropping sunflower and soybean inintensive farming systems: Evaluating yield advantage and effect on weed and insect assemblages. NJASWageningen Journal of Life Sciences. 2014; 70: 47-52.

24. Herrero, M., Thornton, P.K., Notenbaert, A.M., Wood, S., Msangi, S., Freeman, H.A., Bossio, D., Dixon, J.,Peters, M., van de Steeg, J., Lynam, J. Smart investments in sustainable food production: revisiting mixed crop-livestock systems. Science. 2010; 327(5967): 822-825.

25. Choudhary, M., Ghasal, P. C., Kumar, S., Yadav, R. P., Singh, S., Meena, V. S., Bisht, J. K. Conservation agriculture and climate change: an overview. Conservation agriculture: an approach to combat climate change in Indian Himalaya. 2016; 1-37.

26. Havlík, P., Valin, H., Mosnier, A., Obersteiner, M., Baker, J. S., Herrero, M., Rufino, M.C., Schmid, E. Cropproductivity and the global livestock sector: Implications for land use change and greenhouse gasemissions. American Journal of Agricultural Economics. 2013; 95(2): 442-448.

27. Henry, B., Charmley, E., Eckard, R., Gaughan, J. B., Hegarty, R. Livestock production in a changing climate: adaptation and mitigation research in Australia. Crop and Pasture Science. 2012; 63(3): 191-202.

28. Thornton, P. K., Herrero, M. T., Freeman, H. A., Okeyo Mwai, A., Rege, J. E. O., Jones, P. G., McDermott, J.J. Vulnerability, climate change and livestock-opportunities and challenges for thepoor. Journal of Semi-Arid Tropical Agricultural Research. 2007.

29. Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M. S., Bernabucci, U. Effects of climate changes on animal production and sustainability of livestock systems. Livestock Science. 2010; 130: 57–69.

30. Neethirajan, S. Recent advances in wearable sensors for animal health management. Sensing and Bio Sensing Research. 2017; 12: 15-29.

31. Rani, S., Yadav, R. M., Pravasi, R., Sharma, M., Hooda, R. A case study of crop rotation analysis of Panipat district and its development blocks using geoinformatics. International Journal of EngineeringResearch & Technology. 2015; 4(11): 3677-3684.

32. Sharma, P., Singh, A., Kahlon, C. S., Brar, A. S., Grover, K. K., Dia, M., Steiner, R. L. The role ofcover cropstowards sustainable soil health and agriculture—A review paper. American Journal ofPlant Sciences.2018; 9(9): 1935-1951.

33. Li, Y., Niu, W., Cao, X., Wang, J., Zhang, M., Duan, X., Zhang, Z. Effect of soil aeration on rootmorphology andphotosynthetic characteristics of potted tomato plants (Solanum lycopersicum) at different NaCl salinity levels. BMC plant biology. 2019; 19: 1-15.

34. Jakhar P, Rana KS, Dass A, Choudhary AK, Kumar PR, Meena MC, Choudhary MU. Tillage and residue retentioneffect on crop and water productivity of Indian mustard (Brassica juncea) under rainfed conditions.Indian Journal of Agricultural Sciences. 2018; 88:47–53.

35. Tutua, S., Zhang, Y., Xu, Z., Blumfield, T. Residue retention mitigated short-term adverse effect of clear-cutting onsoil carbon and nitrogen dynamics in subtropical Australia. Journal of soils and sediments. 2019; 19(11):3786-3796.

36. Priya, H. R., Shashidhara, G. B. Effect of crop residues as mulching on maize-based cropping systems in conservation agriculture. Research on Crops. 2016; 17(2): 219-225.

37. Fageria, N. K. Green manuring in crop production. Journal of plant nutrition. 2007; 30(5): 691-719.

38. Meena, R. K., Mishra, P. Bio-pesticides for agriculture and environment sustainability. Resources use efficiency in agriculture. 2020; 85-107.

39. Gaur, A. Bacterial bio-pesticides: prospects and limitations in Insect science and experiment (Ed. Lall et al), Chapter 12. AkiNik Publications. Delhi 110085. 2020.

40. Mishra J, Dutta V, Arora NK Biopesticides in India: technology and sustainability linkages. 3 Biotech. 2020; 10(5):1–12.

41. Heimpel, G. E., Ragsdale, D. W., Venette, R., Hopper, K. R., O'Neil, R. J., Rutledge, C. E., Wu, Z. Prospects for importation biological control of the soybean aphid: anticipating potential costs and benefits. Annals of the Entomological Society of America. 2004; 97(2): 249-258.

42. Chand, S., Kumar, A., Bhattarai, M., Saroj, S. Status and determinants of livestock insurance in India: A micro level evidence from Haryana and Rajasthan. Indian Journal of Agricultural Economics.2016; 71(3): 335-346.

43. Xuan, Y. M., Xiao, F., Niu, X. F., Huang, X., Wang, S. W. Research and applications of evaporative cooling in China: A review (II)—Systems and equipment. Renewable and Sustainable EnergyReviews.2012; 16(5): 3523-3534.

44. Kale, S. J., Nath, P., Jalgaonkar, K. R., Mahawar, M. K. Low cost storage structures for fruits and vegetableshandling in Indian conditions.Indian Horticulture Journal. 2016; 6(3): 376–379.