biology and life sciences forum

MDPI

Proceedings

Can Precision Agriculture be the future of Indian farming? – A case study across South-24 Parganas district of West Bengal, India

Panchali Sengupta

Department of Zoology, West Bengal State University, Berunanpukaria, Malikapur, Barasat, West Bengal, India

Abstract: Agricultural practises such as tilling, sowing, cropping and harvesting along with land-use patterns in any agrarian economy depend on climate. Therefore any adverse climatic conditions can seriously affect the production or yield of the crops. Increased temperature enhances the susceptibility of crops to pests and various plant-diseases. Weeds are also known to multiply rapidly and decrease the nutritive value of soil in turn negatively affecting crop production. Our present study was designed to address similar problems faced by the farming community in the South-24 Parganas district of West Bengal, India and in turn suggest several probable technological solutions. Importantly, West Bengal is included under one of the six agro-climatic zones. Major crops from this study site are rice, wheat, maize, jute, green gram, black gram, pigeon pea, lentils, sugarcane, pulses, rapeseed, mustard, sesame, linseed and vegetables. Significantly cultivable land area has decreased in comparison to overall crop area in this region. Reduced interest in agriculture, irrigation problems, increased profit in non-agricultural economy, rapid conversion of agricultural land for commercial purposes (construction of plots, hatcheries for fishing practices) along with uncertainties associated with rainfall patterns and frequent cyclones are matters of grave concern in this study site. Agricultural scientists, researchers, environmentalists, local bodies and government organizations are suggesting alternatives for benefitting farmers. Thus Precision Agriculture or Crop Management is required to recognise site-specific variables within agricultural lands and formulate strategies for improving decision making regarding crop sowing, appropriate use of herbicides, weedicides, precision irrigation along with innovative harvesting technologies. Thus the present paper would provide a vision to the farming community of our study site to overcome their traditional practices and adopt different techniques of precision agriculture to increase flexibility, performance, accuracy and cost-effectiveness. Usage of soil temperature, humidity and moisture monitoring sensors could be beneficial. Precision soil management, precision irrigation, crop disease management, weed management along with harvesting technologies are the different modules being considered for discussion in this paper. Machine Learning algorithm such as Decision Tree, K-nearest neighbour (KNN), Gaussian Naïve Bayes (GNB), K-means clustering, Artificial neural network (ANN), Fuzzy logic System (FLS) and Support Vector Machine (SVM) could prove helpful for progressive farmers. Usage of AI powered weeding machines, drones, UAVs for rapid weed removal, localised application of herbicides, pesticides could also improve the accuracy and efficiency of agriculture. Utilizing drones fitted with high resolution cameras could help in gathering precision field images in turn proving quite helpful in crop monitoring and crop health assessment. Unmanned driverless tractors, harvesting machines using robotics integrated with data from GPS/GIS sensors or radars could also be considered as an effective and time-saving option. Thus Machine Learning along with innovative agricultural technologies could probably contribute towards improving the livehood of the farming fraternity.

Keywords: Titicaca Crop Management, Drones, Machine Learning Algorithm, Precision Agriculture, UAVs

Citation: Sengupta, P. Can Precision Agriculture be the future of Indian farming? -A case study across South-24 Parganas district of West Bengal, India. **2023**, *volume number*, x. https://doi.org/10.3390/xxxxx

Academic Editor: Francesco Marinello

Published: 1 November 2023

1. Introduction

Resonating the words of Mahatma Gandhi that "Agriculture is the soul of Indian economy" one needs to understand the importance of agriculture for livelihood. Among 2/3rd of the Indian population, only 1/2 of the cropped area is covered by irrigation. With the increase in food demand, there seems to be an urgent need for the scientists, agricultural researchers, farmers and government to formulate new techniques to increase production. Manual methods involving the usage of trained manpower are quite challenging in India due to lack of awareness and technological limitations of agricultural workers. In spite of being trained agricultural practitioners for generations; Indian farmers are still quite conservative and reluctant to adapt themselves with changing face of agriculture. Machine Learning (ML) algorithm assists in analysing massive volume of data with great speed and accuracy. ML thereby involves computational application for modifying or adapting their action for real time application. It is classified broadly into two different categories: supervised and unsupervised learning. Significantly application of information technology or more specifically data mining techniques in agricultural domain is targeted to fulfil the goals of Precision Agriculture (PA). PA is a comprehensive system developed with the aim to optimize production quality, improve efficiency ultimately conserving energy and protecting environment. Thereby PA is designed to obtain increased yield as compared to traditional cultivation. United Nations Environment Programme (UNEP) and The Club of Rome report (1972) has been warning us continuously for decades about serious consequences regarding increased temperature due to global warming. IPCC has warned about an increase of 3.7ºC-4.8ºC in global temperature by 2100 [1]. This would probably lead to change in crop pattern ultimately affecting agricultural production or yield rate [2]. Increased temperature is also associated with higher evapotranspiration leading to lowering of soil moisture. With agriculture sector being directly dependant on climatic conditions, higher temperature is associated with multiplication of weeds and spreading out of various pests and plant diseases. This adversely affects nutritive value and negatively influences the growth of saplings ultimately leading to malnutrition in turn decreasing crop yield [3,4]. With Indian agricultural system being totally dependent on monsoons, any irregularities associated with rainfall pattern leading to drought or floods would definitely create a serious impact [5].

PA or more specifically Crop Management involves identification of site-specific variables within agricultural lands in turn devising strategies for improving crop sowing, along with proper application of herbicides, weedicides, precision irrigation and other innovative harvesting technologies. Technological advancement powered by several ML algorithm could probably prove beneficial for improving the livelihood of farmers. Therefore the present study has been designed to explore the different application of ML algorithm among the farming community in the South 24-Parganas district of West Bengal, India.

2. Methodology

The Study Area of South 24-Parganas district of West Bengal, India extends between 22º12'13''N - 22º 46 '55'' N latitude and 87º58'45''E - 88º22'10''E longitudes. Covering an area of 9960 km2 this district is strategically surrounded by Bay of Bengal at one end along with the district of Kolkata and north 24-Parganas at the other side [6]. Temperature varies from 16ºC- 34ºC and the annual rainfall range is estimated to lies between 150 and 170 cm [7]. Importantly, maximum part of the district is included under saline coastal region with mostly alluvial, fine saline soil [8].

Initial step during implementation of Machine Learning (ML) Algorithm for predictive agriculture involves data cleaning and preprocessing. In this case, it should be assumed that the data set has no missing values. The data should have normal distribution for all its features. The outliners should be removed. While selecting the appropriate ML algorithm for a particular attribute, the data set would be split into training data set and testing data set.

Thus different ML Algorithm was used for investigation on various parameters predicting agriculture productivity. K-Nearest Neighbour (KNN) [9], a non-complex algorithm which can store all the available data and also further classify new cases based on similarity measure. Naïve Bayes Classifier (NBC) s a probabilistic classifier model working on the basis of assigning class labels to problem instances, which are represented as features of vector values[10], where the class labels are drawn from some finite set. Decision Tree Algorithm (DTA) is built using a labelled (training) dataset and it forms the basis of classifying an unlabelled (testing) dataset for solving problems. Iterative Dichotomizer 3 (ID3) algorithm is one of the most effective algorithms used to construct a Decision Tree [11]. K-means Clustering Algorithm is an unsupervised learning algorithm. In this case a set of dataset items are provided containing certain features along with values of these features. This algorithm operates by categorising these items into k-groups or clusters based on similarity [12]. Support Vector Machines (SVM) is the most popular supervised learning algorithm used for solving both classification as well as regression problems [13, 14]. Artificial Neural Network (ANN) is defined as information processing model composed of a large number of highly interconnected processing units (neurons) working in unison to solve a specific problem [13, 14]. Fuzzy Logic Systems (FLS) are recognised for generating acceptable but definite output in response to incomplete, ambiguous, distorted or inaccurate (fuzzy) input [15, 16].

Soil moisture sensor, precipitation sensor and temperature sensor for determining the humidity and temperature profile of the agriculture field could help in creating a dataset. On the basis of answers to the "yes" or "no" questions, the Decision Tree would be split into parts. Questions regarding the content of Sodium, Carbon, Magnesium, Nitrogen, Potassium and Phosphate of soil would be answered and the soil containing the above nutrients in best combination would prove beneficial. Accordingly the fertilizer would be selected for increasing productivity. KNN algorithm would be used to detect the greatest "similarity" in the new case or dataset with the temperature and precipitation of the already available dataset. The goal of SVM algorithm was to create the best line or decision boundary to segregate "n" dimensional space into classes so that one can easily assign the new dataset regarding the diseased or healthy plant into the correct category. This could benefit the farmers and act as reference manual for the future. Naïve Bayes, probabilistic classification algorithm would predict on the basis of probability the best soil profile. This would segregate soil based upon its loamy / clayey / saline / alluvial nature for a particular crop. Determination of soil nature would enable the farmers to decide upon the application of the suitable fertilizer. Usage of Fuzzy Logic Systems to devise approximate pest control and disease management tool would benefit farmers. Thus based on the results obtained from FL algorithm proper detection and differential spraying of pesticides would be undertaken for diseased crops. K-means clustering would benefit the farmers in segregating the diseased and healthy plants.

3. Discussion

Globally, the geometric rise in population has a direct influence on agriculture stressing on the importance of newer and innovative technological advancement for sustaining and improving agricultural practices. The induction of AI including Big data Analytics, Robotics, IoT, sensors and cameras, drone technologies and widespread coverage of internet on geographically dispersed fields are becoming an indispensible part of Indian farming. Traditional farming entails a lot of uncertainties along with problems due to weeds and pests, soil degradation and climate change.

Precision Agriculture (PA) refers to merging of all technologies for augmenting agricultural productivity with input use efficiency [17, 18]. Thus PA can simply be defined as data-cum-technology driven farming practice used to detect, analyse and formulate effective measure to manage the variations in field parameters. With Indian agriculture being predominantly managed by small and marginal farmers, further technological advancement associated with integration of a farmer's knowledge in precision agricultural practices and designing of simulation modelling could prove beneficial for poor performing patches in farming sector [19].

Management Oriented Modelling (MOM) uses a set of management alternative techniques including using a simulator to evaluate each alternative and an evaluator to determine which alternative satisfies the user weighed multiple criteria. MOM also employs "hill-climbing" a strategic search method working on the principle of "best –first" as a tactical search method to determine the shortest path from start nodes to reach the goals [20].

Precision Crop Management (PCM) is a popular agricultural system devised to target crops and inputs in accordance to field requirements in order to increase profitability [21]. Cropping alternatives are selected based upon timing, intensity and predictability of drought conditions [22]. A well planned crop prediction methodology is targeted to protect the suitable crops by sensing several parameters (soil type, pH, nitrogen, phosphate, potassium, organic carbon, calcium, magnesium, sulphur, manganese, copper, iron) along with temperature, rainfall and humidity [23].Similar result in the present study using Decision Tree Algorithm would help to predict the presence of sodium, carbon, iron, sulphur, nitrogen and its oxides, potassium, phosphates, magnesium in the soil profile across agricultural fields.

Support system (SRC-DSS) follows three steps: knowledge gain, planning a conceptualised design followed by system implementation [24]. Additionally soil texture (sand, clay and silt content) can be predicted based on pre-existing coarse resolution soil maps, combined with hydrological parameters derived from digital elevation model (DEM) working using ANN [25]. ANN is also reported to provide above 90% success in predicting crop nutritional problems [26]. Remote sensing device associated with a higher order neural network can be used to investigate and characterise the dynamics of soil moisture control [27]. Robots are an innovative computer controlled speed rowing machine, equipped with a pair of video cameras along with global positioning sensors. Thus robotics have reported a 80% success rate in harvesting [28].

The principle of Precision Irrigation Management (PIM) employs the most popular irrigation tool i.e. Arduino and Raspberry Pi. Further for communicative purposes of the measured parameters i.e. soil temperature, humidity, radiation and air temperature, Zigbee has been employed successfully. This also includes web server along with IoT-controlled water pumps [29]. Thus water management involving water quality and irrigation are an essential component in crop management system. Machine learning has also benefitted different areas of irrigation i.e. crop yield prediction, crop disease identification, crop weed detection and livestock welfare [29]. Most popular tools of ML algorithm being applied for the benefit of irrigation sector include: linear logistic regression (LR), classification and regression tree (CART), k-nearest neighbour (KNN), gaussian naïve Bayes (GNB) and support vector machine (SVM). Farmers' knowledge and potential was tapped to utilize a FL based model system to identify suitable crops based on land suitability maps [16]. Workers have recommended the use of ANN method to estimate the soil moisture content in paddy [30].

According to the temperature sensor used in the study site, recorded value of temperature varied from a low of 5ºC to a high of 48ºC. However the values remained between 20ºC-30ºC for most of the year. Precipitation sensor recorded rainfall between 100 cm during drier conditions to a maximum of 300 cm during monsoons in the study site.

Significantly a reduction in productivity per unit area, decrease in natural resources associated with growing threats in global warming and climate change leads to reduction in farm income. In such cases Precision Crop Management is required to recognise site specific variables within agricultural lands and design management strategies for improving capabilities of decision making. Importantly, progressive farmers are quite aware of the variation in crop yield as per previous experiences [31].Instead of manually selecting a field for crop plantation purpose farmers have the option of utilizing GPS/GIS data. Soil preparation techniques using specific sensors for monitoring temperature, humidity or volatile matter could be employed. Instead of levelling of land using bullocks and tractors, high quality laser-guided precision land leveller could be a much better option. Automatic tools such as precision drills, seed drills, air seeders, broadcast seeders can be quite effective against manual seeding and plantations [31]. Automated and controlled fertigation system powered by IoT is being successfully employed for irrigation purposes [32]. ML technologies can be employed for the creation of Chat-Bot [33] for communication with farmers providing them relevant suggestions about modern agricultural technologies. Unmanned aerial vehicles (UAV) are capable of monitoring, taking pictures and collecting data about a particular location. By manoeuvring over a large area, UAVs create new avenues for increasing crop yield through spraying, counting of crops and detecting any sort of abnormalities etc. ML technologies also assist in detecting movement and predicting activities of UAVs. Usage of driverless, unmanned tractors and machine driven harvesting technologies can be possible by the usage of robots. Instead of conventional harvesting techniques robotic arms can prove to be highly efficient and time saving [31]. Robotic arms assist in harvesting by interpreting the ripening state of the crops. Data from GPS/GIS, radars and sensors could be successfully sorted out using ML to locate any obstacle and decide on the application of farm input [34]. Automated irrigation along with conventional weather forecasting can be useful for water-resource management. Such ML based technologies could prove beneficial for maintaining the level of water and nutrients in soil [31].

AI is effectively utilised for crop disease management [21]. With AI a farmer can efficiently control crop diseases by successfully adopting an integrated disease management and control system encompassing physical, chemical and biological measures [35]. Rule promotion using Fuzzy logic (FL) along with webGIS is required for predicting intelligent interferences for crop disease management. Text-to-Speech converter (TTS) is capable of text to talking user interface. Additionally FL web based along with web based intelligent disease diagnostic system (WIDDS) predicts and responds swiftly to any type of crop disease with sufficient accuracy. However being a web-based system, limited internet connectivity can compromise its affectivity [36]. Although ANN and GIS provides 95% accuracy in crop disease management, but limited accessibility to internet among rural folks may be challenging at times [37]. However web based expert system provides excellent performance under some instances [15]. Some workers proposed a FL based intelligent technique to predict crop disease based on leaf wetness duration [38]. Further work has proposed a FL based method and integrated it with image processing to predict the percentage of leaf damage [39]. Also in disease management ANN was coupled with image processing to detect disease in seedlings [40].

An intensive AI based weed management system has been designed to minimise harmful effect of weeds on crops [21]. Unmanned aerial vehicles (UAV) have been employed successfully in several instances to monitor weeds [41]. Crop row algorithm operates to classify, distinguish and segregate weed and crop pixel. Online weed detection using digital image analysis employing drones (UAV), computer based decision and global positioning system (GPS) controlled patch spraying [42] are also quite rewarding. Optimization using invasive weed optimization (IWO) along with ANN is cost effective and increases performance [43]. Employing mechanical control of weeds using robotics and a sensor machine learning (Sensor ML) is known to be time saving and also remove resistant weeds [44]. Although requiring big data and high usage expertise, Saloma expert system designed for evaluation, prediction and weed management possess high adaption rate and an impressive prediction level [45].

Ultimately, prediction and estimation of crop yield seems to be a serious issue for designing marketing estimation and subsequently prepare crop cost estimation. Workers utilized ANN and employed back propagation learning algorithm to predict crop yield from soil parameters [46]. Thus, [47] successfully harnessed the possibilities of crop yield by estimating profitability while reducing environmental impact by decreasing the usage of fertilizers. Detection of different crop diseases ie. blight, rot, mildew, wilt, leaf spot, scotch scab disease of potato and mould using FL algorithm could prove beneficial for the farming community in the study area. Subsequent application of pesticides (methyl parathion, imidaeloprid, phorate) in proper composition in the study area could prove immensely beneficial.

Exploring different opportunities associated with the application of robotics in the agriculture sector is worth mentioning [48]. Utilization of the benefits associated with IoT by the farming community is also note worthy. By overcoming any constraints associated with the availability of internet, a farmer can provide timely data regarding crop sowing, flowering, ripening and harvesting. The usage of soil or moisture sensors, temperature sensors, pH sensors, CO2 sensors, wind speed detection sensors associated with UAV or drones could prove effective in monitoring soil topographic and climatic parameters required for proper management of crops. This could lead to improvement in crop productivity leading to advancement in food sector. Automatic robots could also help in crop harvesting at higher volume and faster rate than human labourers. Green seeker sensors access the demands of plant and determine the amount of fertilizers to be applied and pesticides required. Modern countryside is also developing sensor based small electric motors which are remotely controlled. Such small agricultural robot successfully differentiates between crops and weeds using AI by performing camera imaging and high precision spraying. Precision spraying helps in overcoming the harmful effects of blanket spraying of pesticides or weedicides or insecticides. A detailed 3D map of the farmland, its terrain, irrigation, soil viability is developed by a drone. Additionally, Soil N2 level monitoring can be conducted by a drone. Aerial spraying of pods with seeds and plant nutrients directly into the soil can also be performed by a drone [49].

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available upon request from the corresponding authors.

Acknowledgments: The author is highly grateful to Prof. Narayan Ghorai for his valuable suggestion and cooperation during the study. The constant support and encouragement of the faculty members of the Department of Zoology, West Bengal State University is also acknowledged.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. IPCC Report 2007. Climate Change 2007: Synthesis Report, Contribution of Working Group I, II and III to the Fourth Assessment Report of the Intergovermental Panel on Climate Change.
2. Rosegrant, M. W., Perez, N., Pradesha, A. Thomas,T. S. The Economy wide impacts of climate change on Philippine Agriculture, Research Program on Climate Change and Food Security. International Food Policy Research Institute, 2015.
3. Kim, C.-G. Strategies for implementing green growth in agricultural sector In: Proceedings in Green Korea 2009-Green Growth and Cooperation. National Research Council for Economics, Humanities and Social Science. Proceedings in Green Korea, 2009. https://scholar.google.com/citations?user=QTYL6IsAAAAJ&hl=en.

4. Chatterjee, A. Climate Change and Indian Agriculture, 2021. https://www. devalt.org/newsletter/nov03/of_5.htm.
5. Climate Change and Agriculture in India, 2016. Climate change and its impact on agriculture-MANAGE https://www.manage.gov.in
6. District Census Handbook, South Twenty Four Parganas, Village and Town Directory, Directorate of Census Operations, West Bengal, 2011.
   a. https://censusindia.gov.in/2011census/dchb/DCHB_A/19/1917_PART_A_DCHB_SOUTH%20TWENTY%20FOUR%20PARGANAS.pdf.
7. Dhole, M., Topno, S. Change in climatic elements impact on agriculture: a case study on 24 PGS(S). International Journal of Health Sciences 2022, 6, 5685-5705.
8. West Bengal State Action Plan on Climate change (2017-2020). Government of West Bengal
9. Bazmara, M., Jafari, S. K- Nearest Neighbor Algorithm for finding soccer talent. J. Basic Appl. Sci. Res. 2013, 3, 981-986.
10. Sibyan, H., Svajlenka, J., Hermawan, H., Faqih, N., Arrizqi, A.N. Thermal comfort prediction accuracy with machine learning between Regression Analysis and Naïve Bayes Classifier. Sustainability 2022, 14, 15663.
11. Bishnoi, S., Hooda, B. K. Decision Tree Algorithms and their Applicability in Agriculture for Classification. Journal of Experimental Agriculture International 2022, 44, 20-27.
12. Hassan, I.H., Abdullahi, M., Ahmad, B.I., Ali, Y.S. K-means clustering algorithm based classification of soil fertility in north-west Nigeria. FUDMA Journal of Sciences 2020, 4, 780-787.
13. Russell, S., Norvig, P. Artificial Intelligence: A Modern Approach, 3rd edition, Pearson, 2009, pp. 1152.
14. Patrício, D. I., Rieder, R. Computer vision and artificial intelligence in precision agriculture for grain crops: A systematic review. Computers and Electronics in Agriculture 2018, 153, 69-81.
15. Virparia, P. A web based Fuzzy Expert System for insect Pest Management in Groundnut crop Prajna. Journal of Pure and Applied Sciences 2007, 15, 36-41.
16. Sicat, R. S., Carranza, E. J. M., Nidumolu, U. B. Fuzzy modelling of farmers' knowledge for land suitability classification. Agricultural systems 2005, 83, 49-75.
17. Hakkim, V. M. A., Joseph, E. A., Gokul, A. J. A., Mufeedha, K. Precision Farming: The future of Indian Agriculture. Journal of Applied Biology & Biotechnology 2016, 4, 68-72.
18. Shafi, U., Mumtaz, R., García-Nieto, J., Hassan, S. A., Zaidi, S. A. R., Iqbal, N. Precision Agriculture Techniques and Practices: From Considerations to Applications. Sensors 2019, 19, 3796.
19. Oliver, Y.M., Robertson, M.J., Wong, M.T.F. Integrating farmer knowledge, precision agriculture tools, and crop simulation modelling to evaluate management options for poor performing patches in cropping fields. Eur. J. Agron. 2010, 32, 40-50.
20. Li, M., Yost, R. Management-oriented modelling: Optimizing nitrogen management with artificial intelligence. Agricultural Systems 2000, 65, 1-27.
21. Eli-Chukwu, N. C. Applications of Artificial Intelligence in Agriculture: A Review. Engineering , Technology and Applied Science Research 2019, 9, 4377-4383.
22. Debaeke, P., Aboudrare, A. Adaptation of crop management to water-limited environments. European Journal of Agronomy 2004, 21, 433-446.
23. , S. S., Sandeep, S. V. Agricultural crop yield prediction using artificial neural network approach. International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering 2014, 2, 683-686.
24. Lopez, E. M., Garcia, M., Schuhmacher, M., Domingo, J. L. A fuzzy expert system for soil characterization. Environment International 2008, 34, 950-958.

25. Zhao, Z., Chow, T. L., Rees, H. W., Yang, Q., Xing, Z., Meng, F. R. Predict soil texture distributions using an artificial neural networks. Computers and Electronics in Agriculture 2009, 65, 36-48.
26. , H., He, Y. Crop Nutrition Diagnosis Expert System Based on Artificial Neural Networks. 3rd International Conference on Information Technology and Applications 2005, Sydney, Australia.
27. Elshorbagy, A., Parasuraman, K. On the relevance of using artificial neural networks for estimating soil moisture content. Journal of Hydrology 2008, 362, 1-18.
28. van Henten, E. J., Hemming, J., van Tuijl, B. A. J., Kornet, J. G., Meuleman, J., Bontsema, J., van Os, E. A. An Autonomous Robot for Harvesting Cucumbers in Greenhouses Autonomous Robots 2002, 13, 241-258.
29. Singh, D. K., Sobti, R., Malik, P. K., Shrestha, S., Singh, P. K., Ghafoor, K. Z. IoT-driven model for weather and soil conditions based on precision irrigation using machine learning. Security and Communication Networks 2022, 10. https://doi. org/10.1155/2022/7283975.
30. Arif, C., Mizoguchi, M., Setiawan, B. I. Estimation of soil moisture in paddy field using Artificial Neural Networks. arXiv preprint arXiv 2013, 1303, 1868.
31. Bhattacharyay, D., Maitra, S., Pine, S., Shankar, T., Peera Sk, P. G. Future of Precision Agriculture in India. In: Protected Cultivation and Smart Agriculture, Maitra, S., Gaikwad, D. J., Shankar, T., (eds), 2020, New Delhi Publishers, New Delhi, 289-299.
32. Maitra, S., Shankar, T., Sairam, M., Pine, S. Evaluation of Gerbera (Gebera jamesonii L.) cultivars for growth, yield and flower quality under protected cultivation. Indian Journal of Natural Sciences 2020, 10, 20271-20276.
33. Mostaco, G. M., Ramires, C. S. I. L., Campos, L., Cugnasca, C. E. Agronomobot: A smart answering chatbot applied to agricultural sensor networks. Proceedings of the 14th International Conference on Precision Agriculture 2018, 14.
34. Chunhua, Z., John, K. The application of small unmanned aerial systems for precision agriculture: A review Precision Agriculture 2012, 13, 11119.
35. BEA, Value Added by Industry as a Percentage of Gross Domestic Product 2018, https://apps.bea.gov/iTable/iTable.cfm?
36. Kolhe, S., Kamal, R., Saini, H. S., Gupta, G. K. A web-based intelligent disease-diagnosis system using a new fuzzy-logic based approach for drawing the interferences in crops. Computers and Electronics in Agriculture 2011, 76,16-27.
37. Liu, G., Yang, X., Ge, Y., Miao, Y. An artificial neural network-based expert system for fruit tree disease and insect pest diagnosis. International Conference on Networking, sensing and Control, 2006, Lauderdale, USA
38. Tilva, V., Patel, J., Bhatt, C. Weather based plant diseases forecasting using fuzzy logic. Proceedings (NUiCONE), IEEE, 2013.
39. Sannakki, S. S., Rajpurohit, V. S., Nargund, V. B., Kumar, A., Yallur, P. S. Leaf disease grading by machine vision and fuzzy logic. Int. J. of Comp. Tech. Appl. 2011, 2, 1709-1716.
40. Huang, K. Y. Application of artificial neural network for detecting Phalaenopsis seedling diseases using color and texture features. Computers and Electronics in Agriculture 2007, 57, 3-11.
41. Ortiz, M. P., Gutierrez, P. A., Pena, J. M., Sanchez, J. T., Granados, F. L., Martinez, C. H. Machine Learning Paradigms for Weed Mapping via unmanned Aerial Vehicles. Symposium Series on Computational Intelligence, Athens, Greece 2016.
42. Gerhards, R., Christensen, S. Real-time weed detection, decision-making and patch-spraying in maize, sugerbeet, winter wheat and winter barley. Wiley Online Library, 2003, 43, 385-392
43. Moallem, P., Razmjooy, N. A multi-layer perception neural network trained by invasive weed optimization or potato color image segmentation. Trends in Applied Sciences Research 2012, 7, 445- 455.
44. Swanton, C. J., Harker, K. N., Anderson,R. L. Crop losses due to weeds in Canada. Weed Technology 1993, 7, 537-542

45. Stigliani, L., Resina, C. Seloma: Expert system for weed management in herbicide-intensive crops. Weed Technology, 1993, 7, 550-559.
46. Liu, G., Yang, X., Li, M. An artificial neural network model for crop yield responding to soil parameters. Proceedings of International Symposium on Neural Networks 2005, Springer, Berlin, Heidelberg.
47. Liu, S. Y. Artificial Intelligence (AI) in Agriculture. IT Professional, IEEE Computer Society 2020, 22, 14-15.
48. Talaviya, T., Shah, D., Patel, N., Yagnik, H., Shah, M. Implementation of artificial intelligence for optimisation of irrigation and application of pesticides and herbicides 2020, 4, 58-73.
49. Dharmaraj, V., Vijayanand, C. Artificial Intelligence (AI) in Agriculture. International Journal of Current Microbiology and Applied Sciences 2018, 7, 2122-2128.