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Application of Artificial Intelligence (AI) in Agriculture

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Artificial Intelligence (AI), is one of the disruptive technologies that has changed processes and developments in the field of science, technology, and business in recent years. The development of AI has resulted in streams of research: the analysis of events and their correlation over time, and the search for relationships between phenomena that may cause general deductive or inferential rules. AI is a discipline of computer science that studies algorithms to develop computer solutions that copy the cognitive, physiological, or evolutionary phenomena of nature and human beings. Unlike the traditional model, it does not require knowledge of specific paths to the resolution of problems. Rather, it is the data, examples of solutions, or relationships between these that facilitate the resolution of diverse problems. AI exhibits, in certain aspects, "an intelligent behavior" that can be confused with that of a human expert in the development of certain tasks.

The introduction of AI to agriculture will be enabled by other technological advances, including big data analytics, robotics, the internet of things, the availability of cheap sensors and cameras, drone technology, and even wide-scale internet coverage on geographically dispersed fields. By analyzing soil management data sources such as temperature, weather, soil analysis, moisture, and historic crop performance, AI systems will be able to provide predictive insights into which crop to plant in a given year and when the optimal dates to sow and harvest are in a specific area, thus improving crop yields and decrease the use of water, fertilizers, and pesticides. Via the application of AI technologies the impact on natural ecosystems can be reduced, and worker safety may increase, which in turn will keep food prices down and ensure food security for the population. The application of AI techniques in the major sub domain of agriculture are furnished below-

Soil management

In agriculture, problems with soil and irrigation management are critical. Poor treatment of the soil resulted in crop loss and deterioration. An expert system based on rules was created by Brats *et al.* (1993) to assess the functionality and design of micro irrigation systems. Sicat *et al.* (2005) modelled a fuzzy-based crop recommendation system based on farmers' expertise and produced maps of land suitability produced by the fuzzy system. Knowledge of engineering for constructing the Soil Risk Characterization Decision Support System (SRCDSS) involves three stages: knowledge acquisition, conceptual design and system implementation.The authors Arif *et al.* (2013) developed an Artificial Neural Network (ANN) based system for estimating soil moisture in paddy fields. The ANN model predicts soil texture (sand, clay, and silt contents) by combining hydrographic parameters from a digital elevation model (DEM) with attributes obtained from existing coarse resolution soil maps. A higher-order neural network (HONN) incorporated in a remote sensing device measure and characterizes the dynamics of soil moisture.

Table 1 provides an overview of AI soil management strategies. Management-oriented modeling (MOM) minimizes nitrate leaching as it consists of a set of generated plausible management alternatives, a simulator that evaluates each alternative, and an evaluator that determines which alternative meets the user-weighted multiple criteria. MOM uses "hillclimbing" as a strategic search method that uses "best-first as a tactical search method to find the shortest path from start nodes to goals.

Table 1. AI in soil management strategy (Table by Eli- Chukwu, N. C., 2019)

Techniques	Strength	Limitation
MOM	Minimizes nitrate leaching, maximizes production. Takes time.	Limited only to nitrogen.
Fuzzy Logic: SRC-DSS	Can classify soil according to associated risks. Needs big data.	Only a few cases were studied.
DSS	Reduces erosion and sedimentary yield.	Requires big data for training.
ANN	Can predict soil enzyme activity. Accurately predicts and classifies soil structure.	Only measures a few soil enzymes. It considers more classification than improving the performance of the soil.
ANN	Can predict monthly mean soil temperature	Considers only temperature as a factor for soil performance.
ANN	It predicts soil texture Requires big data for training	Has restriction in areas of implementation.
ANN	Able to predict soil moisture.	The prediction will fail with time as weather conditions are hardly predictable.
ANN	Successfully reports soil texture.	It does not improve soil texture or proffers solution to bad soil texture.
ANN	Cost-effective, saves time, has 92% accuracy	Requires big data.
ANN	Can estimate soil nutrients after erosion.	Its estimate is restricted to only NH_4

Crop Management

Crop management systems, in general, offer an interface for managing crops holistically, encompassing every element of farming. It can be summed up as the endeavours to enhance the productivity and expansion of agricultural products. Decision-rule-based flexible crop management systems ought to be the standard. The drought's timing, severity, and predictability are crucial considerations when selecting between cropping options. A thorough awareness of weather patterns aids in making decisions that will provide a high-quality and productive crop output.

The idea of using AI technique in crop management was first proposed in 1985 by McKinion and Lemmon, (2020) in their paper "Expert Systems for Agriculture". AI techniques PROLOG utilizes weather data, machinery capacities, labor availability, and information on permissible and prioritized operators, tractors, and implements for evaluating the operational behavior of a farm system. It also estimates crop production, gross revenue, and net profit for individual fields and for the whole farm.

Crop prediction methodology is used to predict the suitable crop by sensing various soil parameters and parameter related to the atmosphere. Parameters like soil type, PH, nitrogen, phosphate, potassium, organic carbon, calcium, magnesium, sulfur, manganese, copper, iron, depth, temperature, rainfall, humidity.Demeter is a computer-controlled speed-rowing machine, equipped with a pair of video cameras and a global positioning sensor for navigation. It is capable of planning harvesting operations for an entire field, and then executing its plan by cutting crop rows, turning to cut successive rows, repositioning itself in the field, and detecting unexpected obstacles.

The use of AI in harvesting cucumber comprises of the individual hardware and software components of the robot including the autonomous vehicle, the manipulator, the end-effectors, the two computer vision systems for detection and 3D imaging of the fruit and the environment and, finally, a control scheme that generates collision-free motions for the manipulator during harvesting. Field-specific rainfall data and weather variables can be used for each location. Adjusting ANN parameters affects the accuracy of rice yield predictions. Smaller data sets required fewer hidden nodes and lower learning rates in model optimization.

The crop management techniques are summarized in Table 2. (Table by Eli- Chukwu, N. C., 2019)

Techniques	Strength	Limitation
CALEX	Can formulate scheduling guidelines for crop management activities.	Takes time
PROLOG	Removes less used farm tools from the farm.	Location-specific
ANN	Predicts crop yield	Only captures weather as a factor for crop yield
ROBOTICS Demeter	Can harvest up to 40 hectares of crop	Expensive: Uses a lot of fuel
ROBOTICS	Has 80% success rate in harvesting crops	Slow picking speed and accuracy
ANN	Above 90% success rate in detecting crop nutrition disorder.	A little number of symptoms were considered
FUZZY	Cognitive Map Predict cotton yield and improve crop for decision management.	It is relatively slow
ANN	Can predict the response of crops to soil moisture and salinity.	Considers only soil temperature and texture as factors
ANN and Fuzzy Logic	Reduces insects that attack crops.	Shows inability to differentiate between crop and weed
ANN	Can accurately predict rice yield. Time-consuming,	Limited to a particular climate

Disease Detection

Plant diseases pose a significant risk to the environment, the economy, and food security. Early detection of crop disease is critical for disease management. AI-based image recognition systems could accurately identify specific plant diseases, potentially paving the way for field-based crop disease identification using mobile devices such as smartphones. In "Scaling up agricultural research with artificial intelligence," Bestelmeyer (2020) developed AI-based tools that leverage site-based science and big data to assist farmers and land managers in making site-specific decisions. These tools alert farmers to pest and disease outbreaks and make it easier to choose sustainable cropland management practises.

Disease Management

To have an optimal yield in agricultural harvest, disease control is necessary. Plant and animal diseases are a major constraint to increasing yield. Genetic, soil type, rain, dry weather, wind, temperature, and other factors all play a role in the development of these plant and animal diseases. Because of these factors, as well as the erratic nature of some diseases' causative influences, managing the effects is a significant challenge, particularly in large-scale farming. A farmer should use an integrated disease control and management model that includes physical, chemical, and biological measures to effectively control diseases and minimize losses. To achieve these is time consuming and not at all that cost effective, hence the need for application of AI approach for disease control and management.

Explanation block (EB) gives a clear view of the logic followed by the kernel of the expert system. A novel approach of rule promotion based on fuzzy logic is used in the system for drawing intelligent inferences for crop disease management. A text-to-speech (TTS) converter is used for providing capability of text-to-talking user interface. It provides highly-effective interactive user interface on web for live interactions. A rule based and forward chaining inference engine has been used for the development of the system that helps in detecting the diseases and provides treatment suggestion in.

Table 3. List of AI techniques in disease management (Table by Eli- Chukwu, N. C., 2019)

Techniques	Strength	Limitation
Computer vision system (CVS), genetic algorithm (GA), ANN	Works at a high speed. Can multitask.	Dimension-based detection which may affect good species.
Rule-Based Expert, Data Base (DB)	Accurate results in the tested environment.	Inefficacy of DB when implementing in large scale.
Fuzzy Logic (FL), Web GIS	Cost effective, eco friendly.	Inefficiency due to scattered distribution. Takes time to locate and disperse data. The location of the data is determined by a mobile browser
FL Web-Based, Web-Based Intelligent Disease Diagnosis System (WIDDS)	Good accuracy. Responds swiftly to the nature of crop diseases.	Limited usage as it requires internet service. Its potency cannot be ascertained as only 4 seed crops were considered.
FL & TTS converter	Resolves plant pathological problems quickly.	Requires high speed internet. Uses a voice service as its multimedia interface.
Expert system using rule-base in disease detection.	Faster treatment as diseases are diagnosed faster	Cost effective based on its preventive approach. Time consuming. Needs constant monitoring to check if pest has built immunity to the preventive measure.
ANN, GIS	95% accuracy Internet-based.	Some rural farmers will not have access.
FuzzyXpest	provides pest information for farmers. It is also supported by internet services. High precision in forecast.	Internet dependent.
Web-Based	High performance.	Expert System Internet and web based.
ANN	Has above than 90% prediction rate.	The ANN does not kill infections or reduces its effect.

Weed managment

Weed consistently reduces expected profit and yield for farmers. A report confirms that weed infestations reduce yield by 50% for dried beans and maize crops. Weed competition causes a 48% decrease in wheat yield. These losses can sometimes reach 60%. The variation in yield losses can be attributed to the length of crop exposure to weeds and the spatial heterogeneity of weeds. Weed has both positive and negative effects on the ecosystem. Some weeds are poisonous, causing allergic reactions and even endangering public health. Over the last few decades, intensive herbicide management has been used to reduce its impact on crops. However, even with this management pattern, it was predicted that crop losses due to weed crops are estimated to be very high, hence the need for a more expert weed management technique to compensate for this loss emerges.

A system can utilize an unmanned aerial vehicle (UAV) -imagery to divide image, compute and convert to binary the vegetation indexes, detect crop rows, optimize parameters and learn a classification model. Since crops are usually organized in rows, the use of a crop row detection algorithm helps to separate properly weed and crop pixels, which is a common handicap given the spectral similitude of both. Weed control in sugar-beet, maize, winter wheat, and winter barley, can be done by applying online weed detection using digital image analysis taken by an UAV (drone), computer-based decision making and global positioning system (GPS)-controlled patch spraying. The drone in travelled at a speed of 1.2km/h, with 58.10ms and 37.44ms execution time to find the tomato and weed locations to the spray controller respectively.

Pest management

Insect pest infestation is one of the most alarming problems in agriculture that leads to heavy economic losses. Over decades researchers have tried to mitigate this menace by development of computerized systems that could identify the active pests and suggest control measures. Many rule based expert systems were proposed which includes Pasqual and Mansfield (1988). The knowledge involved in agricultural management is most of the times imperfect, vague and imprecise hence the rule base expert system may lead to uncertainty. To capture this uncertainty, several Fuzzy logics based expert systems were proposed including Saini *et al.*,(2002)An objected oriented approach to frame a rule base was taken by Ghosh *et al*.,(2003) in developing TEAPEST, an expert system for pest management in tea. Here also a phase-by-phaseidentification and consultation process have been adopted. Later this system was redesigned by Samanta and Ghosh, (2012) by employing a multi-layered back propagation neural network and then reformulated by Banerjee *et al*., (2017)by using radial basis function model to achieve higher classification rates.

Challenges in AI adoption in agriculture

Despite the fact that AI offers enormous opportunities in agricultural applications, there is still a lack of familiarity with advanced high-tech machine learning solutions in farms around the world. Farming is extremely vulnerable to external factors such as weather, soil conditions, and pest attack. A crop raising plan planned at the beginning of the season may not appear to be good at the start of harvesting because it is influenced by external parameters. AI systems, too, require a large amount of data to train machines and make accurate forecasts or predictions. Only in the case of a very large area of agricultural land could spatial data be collected easily, whereas temporal data is difficult to obtain. The various crop specific data could be obtained only once in a year when the crops are grown. As the database takes time to mature, it involves a substantial amount of time to construct a robust AI machine learning model.This is a major reason for the utilization of AI in agronomic products like seeds, fertilizer and pesticides than that of on field precision solutions. In conclusion the future of farming in the times to come is largely reliant on adapting cognitive solutions. Though a vast research is still on and many applications are already available, the farming industry is still not having sufficient service, remains to be underserved. While it comes down in dealing with realistic challenges and demands faced by the farmers, using AI decision making systems and predictive solutions in solving them, farming with AI is only in a nascent stage.

To exploit the tremendous scope of AI in agriculture, applications should be more robust. Then it will be able to handle frequent shifts and changes in external conditions on its own. This would allow for real-time decision making and the sequential use of appropriate models/programs for efficiently gathering contextual data. Another critical factor is the exorbitant cost of the various cognitive farming solutions on the market. AI solutions must become more viable in order for this technology to reach the farming community. If AI cognitive solutions are offered on an open-source platform, they will become more affordable, resulting in faster adoption and greater insight among farmers.

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