Artificial Intelligence (AI) in Soil Science and Agriculture

S. C. Gaikwad
M. Sc. Scholar, Division of Soil Science. Dr. Sharadchandra Pawar college of Agriculture, Baramati
*Corresponding Author: suyashgaikwad111@gmail.com

Artificial Intelligence (AI) stands as a pivotal field within computer science, marked by rapid technological progress and broad applications. Its pervasive integration is notably pronounced in agriculture, a sector crucially employing approximately 30.7% of the global population across 2,781 million hectares of agricultural land. However, this domain encounters challenges spanning from sowing to harvest, encompassing issues such as pest and disease infestation, suboptimal chemical usage, inadequate drainage and irrigation, weed control, and yield prediction Computers started being used in agriculture back in 1983. Over time, different methods have been proposed to tackle problems in farming, ranging from databases to decision support systems. Among these solutions, those employing Artificial Intelligence (AI) have proven to be the most effective in terms of accuracy and reliability. AI techniques help by understanding the unique details of each situation and providing the best-fitting solution for specific problems. As AI advances, it's increasingly solving complex issues in agriculture.

What is AI?

Let's formally define Artificial Intelligence (AI). It's a field in computer science that focuses on creating systems whether tangible or intangible, capable of intelligent behavior equivalent to human thinking and actions. This involves achieving human-like performance in cognitive tasks through logical reasoning. The term "artificial" refers to non-biological aspects, while "intelligence" denotes the ability to accomplish complex goals or tasks. AI encompasses cognitive processes like speech recognition, natural language understanding, translation, knowledge management, image analysis, decision-making, and learning, making systems both powerful and useful.

History of AI

Artificial Intelligence officially entered the historical scene in 1956, marked by the introduction of a dedicated session on AI at Dartmouth College. Marvin Minsky, in his book "Stormed Search for Artificial Intelligence," expressed optimism, stating that the problem of AI modeling would be solved within a generation. The initial AI applications, developed during this period, focused on logic theorems and chess games. These programs, distinct from geometric forms used in intelligence tests, sparked the notion that intelligent computers were achievable.

Types of AI

AI can be classified in different ways. There are three types of artificial intelligence in terms of functionality.

1. Artificial Narrow Intelligence (ANI)

The machine is extremely good at doing one task but limited to extending its capacity to perform another task. It is widely known as narrow AI or weak AI. Narrow AI is limited to a specific area to perform a single task.

2. Artificial General Intelligence (AGI)

Strong AI is commonly known as Artificial General Intelligence (AGI). It is the Superintelligence that suppresses human intelligence. It can mimic the cognitive abilities of the human brain.

3. Artificial Super Intelligence (ASI)

Artificial Super Intelligence (ASI) is the logical progression of AGI. It is a hypothetical AI that is beyond the human brain. In ASI, decision-making and problem-solving will be superior to human think Artificial Super Intelligence (ASI).

Why AI in Soil Science & Agriculture

Recognizing the transformative potential of artificial intelligence (AI) across various sectors, the Indian government has embarked on leveraging this technology to revolutionize agriculture, a crucial pillar of its economy. Soil science, a fundamental aspect of agriculture, has been significantly impacted by AI advancements. It encompasses a range of applications including soil testing, monitoring, land cover analysis, fertilization assessment, nutrient deficiency identification, carbon sequestration, and more. AI-driven tools such as robotics, drones, predictive

analytics, sensor-based monitoring devices, satellite imagery, and automated irrigation systems hold immense promise in reshaping Indian agriculture. These innovations empower farmers to precisely evaluate soil conditions, monitor weather patterns, and optimize crop management practices, ultimately enhancing yields and sustainability.

Applications of AI in Soil

The Internet of Things (IoT) in the context of Artificial Intelligence (AI) refers to the integration of AI technologies with IoT devices to enhance the capabilities and functionality of connected systems. Different sensors like Time Domain Reflectometry sensor (TDR) this sensor gives the output in the form of the waves and this can be used to calculate the average of moisture content. Amplitude Domain Reflectrometry sensor (ADR), can be used to measures the Soil water content. To detect the deficiency of the nutrients Nitrogen (N), Phosphorus (P), and Potassium (K) in the soil NPK sensor is developed. The advantage of this sensors to reduce the undesired use of fertilizers to be added in the soil.

Fig. 1: **Different IoT Sensors**

Machine learning (ML) is a subset of artificial intelligence (AI) that focuses on developing algorithms and statistical models that enable computers to perform tasks without explicit programming. With the help of a Machine Learning algorithm, a system will be developed that can select crops, irrigate them autonomously and recommend fertilizers. The increasing availability of soil data that can be efficiently acquired and freely available open-source algorithms, have led to an accelerated adoption of ML techniques to analyse soil data. Several well-known ML applications in soils science include the prediction of soil types and properties.

IBM devised a compact soil testing system capable of assessing five indicators through colorimetric tests. Embedded within a micro-fluidic chip, the system conducts chemical analyses, while an AI-powered machine vision algorithm provides more accurate estimations compared to human observation. The application of AI in remote sensing data analysis has gained popularity. Supervised learning models trained with ground truth data are commonly employed to classify land cover. Another method involves comparing remote sensing data captured at different times to detect changes, referred to as compound classification. AI-driven autonomous vehicles are also utilized for tasks related to soil, land cover and land management.

Potential of AI in Indian agriculture-

Crop Health Monitoring Systems

Remote sensing methods, hyperspectral imaging, and artificial intelligence (AI) contribute to the development of crop health monitoring systems that efficiently track the well-being of crops, saving time and resources.

Smart Irrigation Systems

By implementing sensor-based automated irrigation systems, the challenges related to the low irrigation efficiency in Indian agriculture (approximately 38%) can be significantly addressed.

Agriculture Risk Management

AI-based technologies assist farmers in mitigating risks and uncertainties by enhancing their readiness to effectively manage crises in agriculture.

Identification of Optimal Agronomic Product Mix

AI assists in producing tailored recommendations for individual farms by analyzing various factors such as soil condition, weather predictions, seed varieties, and pest presence. While these recommendations already offer optimal crop and technology suggestions for each farm.

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