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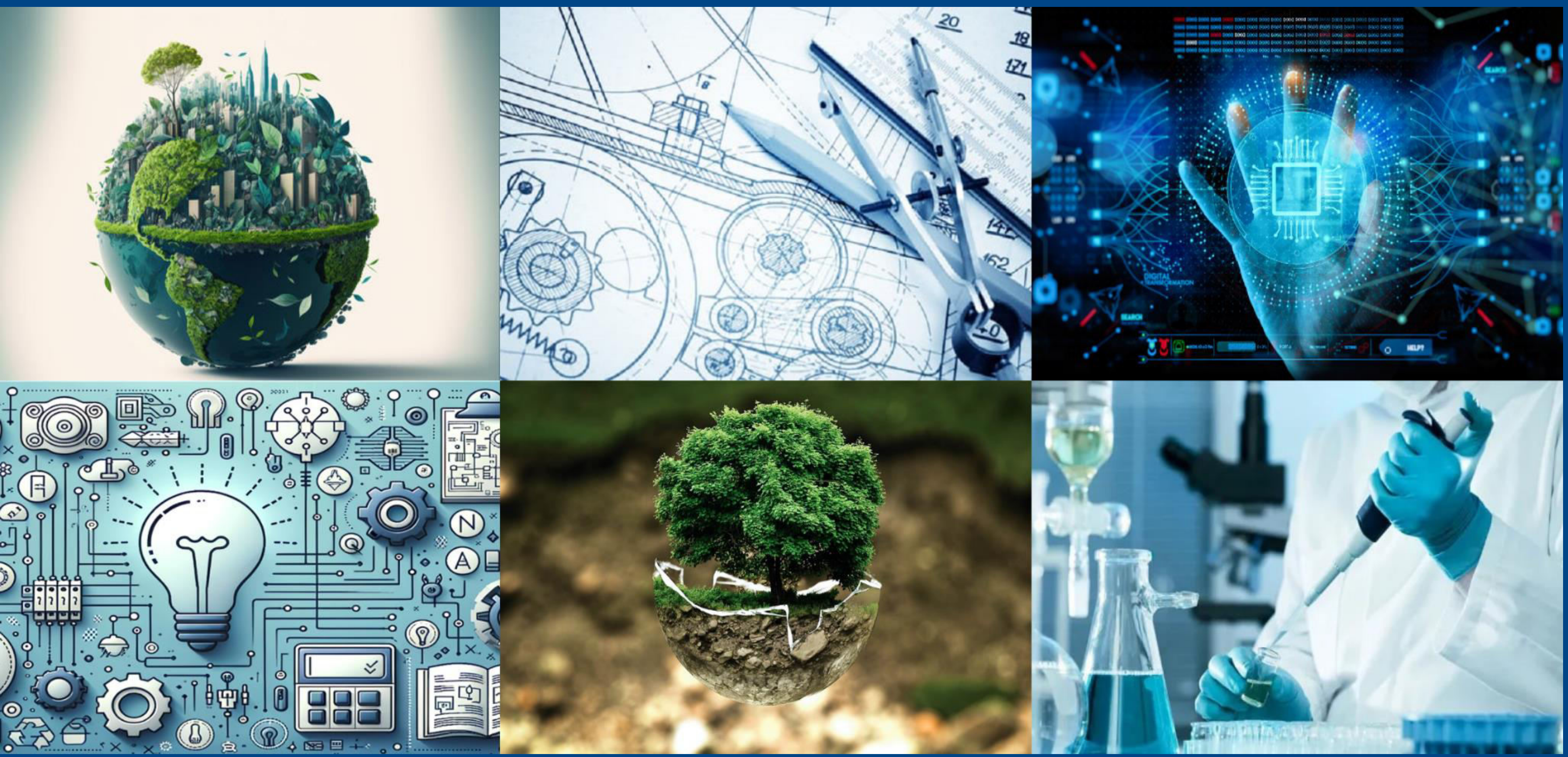

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The Role of Artificial Intelligence and Machine Learning in Agriculture

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ABSTRACT: Artificial intelligence (AI) is the field of science concerned with the creation of machines that can simulate human intelligence. Machine learning (ML) is a subset of AI in which the machine learns automatically from data without specific programming. Agriculture is always under pressure to yield more with fewer resources. AI and ML methods have the potential to maximize resource usage by evaluating agricultural data. It has transformed the modern-day image of agriculture by forecasting different input parameters and predicting post-harvest life of a crop. This chapter presents various AI and ML methods that exist and how they have been implemented in various stages of the life cycle of agriculture. This chapter encompasses huge range areas in agriculture that need AI and ML. It encompasses soil, irrigation, and disease managements. Significance of AI in plant phonemics also covered in this chapter. The likely application of geographic information system (GIS) and remote sensing combined with AI covered in this chapter.

I. INTRODUCTION

Artificial intelligence (AI) is the field of study concerning tools and technologies that are applied to solve tasks that need human intelligence. Examples of such tasks include natural language understanding, processing, generation, visual perception, decision making, and so many others. Two of the most popular AI methodologies are machine learning and deep learning. With advancement technologies, AI has revolutionized every sector of life, including agriculture. With over 50% of employees in agriculture, low expert to farmer ratio necessitates the required AI interventions such as automatic diagnosis and suggestion of appropriate advisories. The key challenges in agricultural production are decision making in crop production, disease pest infestation, weather forecasting, yield estimation, advisory systems for improved crop productivity, etc. Agricultural productivity is generally dependent on temperature, soil fertility, water availability, quality of water, etc. To predict these parameters accurately, advanced AI methods are being utilized. Though the technology boom has rendered farming slightly easier, small, and marginal farmers continue to confront numerous challenges. In contrast to other technologies AI can reach individual farmer much more easily and enhance farmer's life. The scenario of two life cycle, i.e., agriculture and farmers possess a humongous scope to intervene and massively enhance the same.

Agricultural life cycle begins from preparation of the field for the crop and then sowing of seeds, irrigation, weeding, application of fertilizers, pest and disease control, harvesting, post-harvest treatment, storage, and marketing. Different AI methods can influence and enhance all the steps of the life cycle, some of which are already developed and some still await development. In an optimum smart environment, a farmer would be assisted by an artificially intelligent aid which would recommend the ideal date and procedure to get the land prepared in accordance with GIS and remote sensing data of the area. Based on a block chain and recom- mender system enabled supply chain, farmer would gather good quality seeds to plant once land preparation was over. Scheduled weeding would be addressed by cost-effective smart weeding and fertigation systems. The pest and disease identification with their appropriate management practices could be addressed by AI powered mobile apps. The yield forecasting could be carried out using drone based smart application and the forecasted yield would assist in determining the right market and buyer to be chosen (Fig. 1.1).

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1.2 Artificial Intelligence, Machine Learning, and Deep Learning

The artificial intelligence is an extremely ancient area of research and has a long history. Contemporary AI was formalized by John McCarthy, who is regarded as father of AI. It was designated as a field of computer science in the early 1950s. The term artificial intelligence (AI) is used mainly to describe a set of techniques to allow a machine or a computer to replicate the behavior of humans in problem-solving tasks. Formally, AI has been defined as 'the study of how to make the computers do things at which, at the moment, people are better' (Rich and Knight 1991; Rich et al. 2009). The primary objective of AI is to program the computer for doing some tasks in humanly style like knowledgebase, reasoning, learning, planning, problem solving, etc.

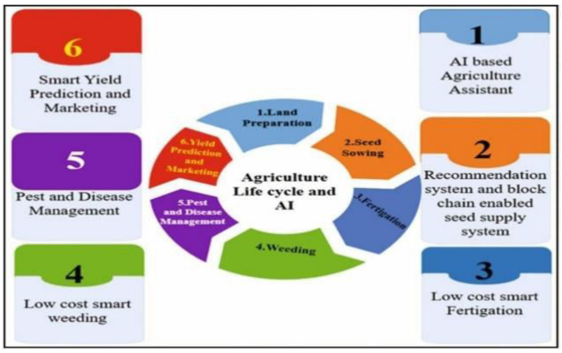

Fig. 1.1 An ideal smart ecosystem for farmer

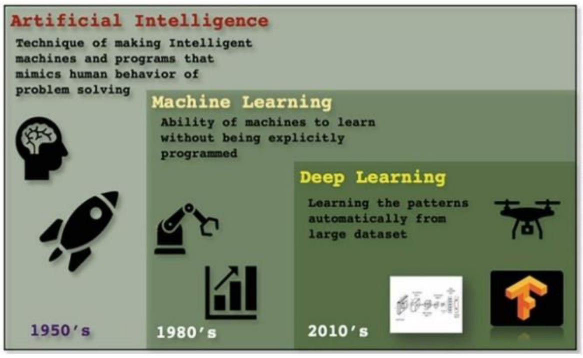

Fig. 1.2 Chronology of artificial intelligence, machine learning, and deep learning concepts

The machine learning (ML) methods are the branch of AI that empowers the computers/machines /programmers to learn and execute tasks without explicit training. The ML methods are not only the method of simulating human action but the method of simulating human learning. The primary features of machine learning are 'learning from experience' for the solution of any type of problem. The learning methods can be divided into three categories: (a) supervised learning algorithm is provided with labelled data and the output to be obtained, while (b) unsupervised learning algorithm is provided with unlabeled data and determines the patterns from the input data, and (c) reinforcement learning algorithm enables the ML methods to learn the learnable aspects based on rewards or reinforcement. Today, deep learning (DL) methods are the sophisticated form of machine learning algorithms acquired enormous popularity in the field of artificial intelligence based applications. methods enable a machine to learn patterns in the dataset with multiple abstractions levels. DL models consist of a sequence of non-linear layers where each one of the layers is capable of converting the low-level representations to higher-level representations, i.e. to more abstract representations. There are a number of DL algorithms present these days like deep convolutional neural networks (also known as CNNs or convents), recurrent neural networks (RNNs), long short-term memory (LSTM) networks which are being used in various fields of engineering, bioinformatics, agriculture, medical science, and many more (Fusco et al. 2021) (Fig. 1.2).

1.3 Major Applications of AI and ML Techniques in Agriculture

In the current scenario, AI and ML methods are being exponentially used in the different fields of the agricultural sector.

These fields can be divided into the following categories: soil and water management, crop health management, crop phenotyping, recommender-based systems for crops, semantic web and ontology driven expert systems for crops and Geo-AI.

1.3.1 Soil and Irrigation Management

Soil and irrigation are the most probable parts of agriculture. The soil and irrigation are the controlling factors for the maximum yield of the crop. To achieve the improved crop yield and to preserve the properties of the soil, there is a need for the right kind of knowledge regarding the soil resources. Irrigation scheduling becomes important when water resources are limited. Thus, the issues of soil and irrigation need to be taken care of and handled cautiously to get a possible yield in crops. In this respect, AI and ML based methods have proved to have potential capability to solve soil and irrigation problems in crops. A variety of machine learning models like regression-based models, support vector machines (or repressors), artificial neural networks, and random forest algorithm are utilized. Remote-sensed data have been utilized by numerous researchers along with the machine learning methods for estimating soil health parameters. Some important studies in this regard have been discussed in the subsequent sections.

1.3.1.1 Soil Management

Besalatpour et al. (2012), Aitkenhead et al. (2012), and Sirsat et al. (2017) applied various machine learning algorithms including multiple-linear regression (MLR), support vector regressors (SVR), random forests regressors (RFR) in predicting the physical and chemical behavior of soil. Rivera and Bonilla (2020) and Azizi et al. (2020) performed estimation and classification of aggregate stability of soil based on traditional machine learning methods and deep learning methods from the publicly available soil properties datasets. Jha and Ahmad (2018) performed prediction of microbial dynamics in soils based on regression-based approaches which is extremely important to enhance the soil fertility. Patil and Deka (2016) and Taghizadeh-Mehrjardi et al. (2016) have predicted the evapotranspiration rate of crops with the help of a number of machine learning methods. Scientists conducted studies to map soil properties digitally with the help of machine learning methods as well as deep CNN methods (Taghizadeh-Mehrjardi et al. 2016; Kalambukattu et al. 2018; Padarian et al. 2019; Taghizadeh-Mehrjardi et al. 2020). In these soil property mapping studies, various remotely sensed data and past weather- based data have been utilized.

1.3.1.2 Irrigation Management

Zema et al. (2018) applied data envelopment analysis (DEA) with multiple linear regression (MLR) based techniques to improve the irrigation performance of the Water Users Zema et al. (2018) utilized multiple linear regression (MLR) based and data envelopment analysis (DEA) based techniques to enhance the irrigation efficiency of the Water Users Associations.

1.3.2 Crop Health Management

Every year a significant amount of yield is damaged due to the attack of disease causing pathogens and insect-pest infestation. In order to manage the spread of the To address diseases and insect pests effectively, it is essential to apply proper management practices as early as possible. This highlights the need for an automated system for identifying diseases and pests. In this context, image-based diagnosis has become the standard method for automatic stress identification.

1.3.3 Plant Phenotyping

High throughput imaging combined with non-destructive phenotypic measurement is rapidly gaining popularity. A high throughput imaging system generates a lot of pictures. Image analysis allows for the rapid and precise inference of phenotypic traits. Phonemics analysis can be used for a variety of phenotypic studies. This field is more accurate and efficient when high throughput imaging systems are combined with sophisticated AI technologies like deep learning. Numerous phenotypic traits, such as spike detection and counting, yield forecasting, plant senescence quantification, leaf weight and count, plant volume, convex hull, water stress, and many more, have been studied using phonemics,

1.3.4 Recommender Systems

Recommender systems (RS) help online users in decision making regarding products among a pile of alternatives. In general, these systems are software solutions which predict liking of a user for unseen items. RSs have been mainly designed to help users in decision making for areas where one is lacking enough personal.

1.3.5 Semantic Web, Knowledge Base, and Natural Language Processing

The field of agriculture is a wealth of information. However, much of that information is stored in unstructured form. Such unstructured knowledge is only understandable by machines, and has little accessibility for humans. The main purpose of the semantic web and knowledge base system is to make unstructured data into structured data. The semantic web and knowledge base are primarily facilitated by the ontology in the back end. An ontology is an explicit formal specification of a shared conceptualization (Gruber, 1991). We can make ontologies to facilitate semantic web and knowledge base system for the agricultural domain to turn unstructured data into structured data. There are many ontologies that have been developed, according to Bedi and Marwaha (2004) in the agriculture domain. Saha (2011) developed an ontology on the selection of dynamic maize varieties in different climatic conditions, Sahiram (2012) developed an ontology on oil seed rape and mustard for the variety identification in multiple languages; Das et al.

(2017) developed an ontology for USDA soil taxonomy and Deb et al. (2015) extended the ontology. Biswas et al. (2013) developed an ontology on microbial taxonomy and Karn (2014) extended the ontology.

1.3.6 GIS and Remote Sensing Coupled with AI

GIS and remote sensing are helping agricultural community since long. The land use planning, land cover analysis, forest distribution, water distribution, water use pattern, crop rotation, and crop calendar analysis can be done by GIS and remote sensing. But when AI and machine learning are coupled with this technology it becomes more powerful. Machine learning and AI efficiently used for correct land classification and phonological change detection. From digital soil mapping to yield forecasting, from phenology detection to leaf area index a vast range of the area in agriculture can be handled by GIS and Remote sensing.

1.4 Framework for Phenology Study Using Artificial Intelligence

Based on the critical analysis of the reviews on the topic, one framework (as shown Fig.1.3) has been deducted which depicts the mode of working of the methodologies of AI and Machine learning models used in agriculture. The whole framework can be subdivided into three distinct layers. The description of the layers are as follows:

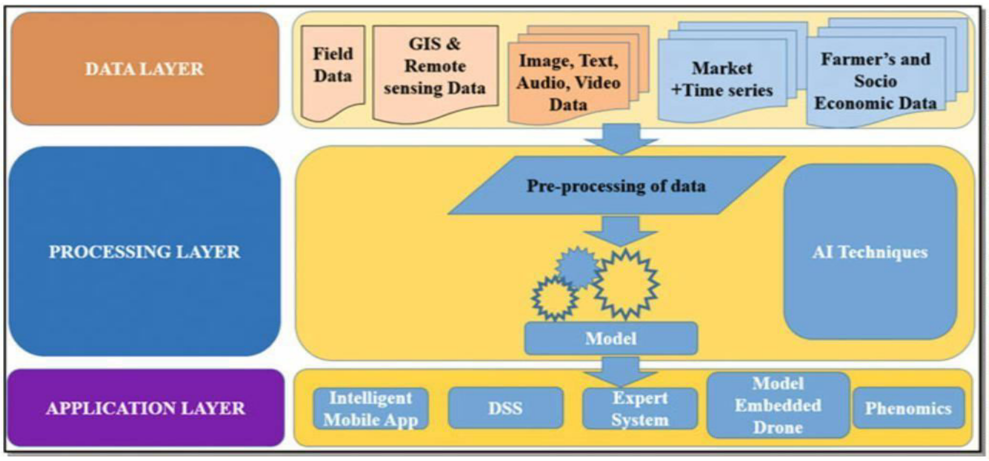

Fig. 1.3 Framework depicting mode of working of the methodologies of AI and machine learning models used in predictive modelling of phenology

1.4.1 Data Layer

This layer of the framework deals with the relevant data. As we know agriculture is a vast source of data with a wide range type. The remote sensing data with a longer period of time also has an importance along with the climatic data. With improvement of the technology, the image data coupled with time series data from Unmanned Aerial Vehicle (UAV) has been used in many studies. This layer is also used for any kind of pre-processing and making the data ready to use for the study

1.4.2 Processing Layer

This layer of the framework deals with the core part AI. It takes the input, i.e. the ready to use data from the data layer. It also takes care of the model development part of the framework. The ultimate product of the layer is a model that has promising result in the training and testing framework of the machine learning.

1.4.3 Application Layer

This layer has a countless number of uses for the end users. Model which is developed in the previous layer has a great potential to be embedded and can be used in many platforms. The followings are the applications that supports model embedding. In the present discussion Sect. 1.3 covers the application layer of this framework.

1.5 CONCLUSION

The deployment of Artificial Intelligence (AI) and Machine Learning (ML) will reduce many of the challenges faced in agriculture such as soil health monitoring/management, irrigation scheduling, crop health monitoring/management, pest

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and disease identification, crop phonemics, etc. This chapter discusses the gloss of the usefulness of artificial intelligence (AI) and machine learning (ML) in the agriculture domain and surveys different AI related technologies. The survey converges to prescribe a generic framework towards precision agriculture that will enhance the overall production of crops. AI will enable the best solutions as we scour the agricultural landscape through accurate prediction of weather, forewarning of pests/diseases, and supporting the end-user to accurately predict in real-time several factors which will promote yield while minimizing cost. AI will transform agriculture through better agricultural practices that will lead to best practices for farmers, that will result respectively in farms that produce more but costs will remain low.

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