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Artificial Intelligence in Agriculture: A Literature Survey

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***Abstract*— This paper presents a comprehensive literature survey on the applications of artificial intelligence techniques in agriculture. The domain of agriculture faces many challenges such as disease and pest infestation, improper soil treatment, inadequate drainage and irrigation, and many more. These leads to severe crop loss along with environmental hazards due to excessive use of chemicals. Several researches have been conducted to address these issues. The field of artificial intelligence with its rigorous learning capabilities have become a key technique for solving different agriculture related problems. Systems are being developed to assist the agricultural experts for better solutions throughout the world. This literature survey covers 100 important contributions where artificial intelligent techniques were employed to encounter the challenges related to agriculture. This paper addresses the application of artificial intelligent techniques in the major subdomain of agriculture so that the readers are able to capture the multidimensional development of agro-intelligent systems during last 34 years, from 1983 to 2017.**

***Keywords*— Artificial Intelligence; Agriculture; Literature Survey; Fuzzy logic; Artificial Neural Networks**

I. INTRODUCTION

Artificial Intelligence (AI) is one of the key areas of research in computer science. With its rapid technological advancement and vast area of application, AI is becoming pervasive very rapidly because of its robust applicability in the problems particularly that cannot be solved well by humans as well as traditional computing structures [1]. Such an area of extreme importance is agriculture where about 30.7% of the world population is directly engaged on 2781 million hectares of agricultural land. Such a venture is not so smooth running, it faces several challenges from sowing to harvest. The major issues are pest and disease infestation, inadequate application of chemicals, improper drainage and irrigation, weed control, yield prediction, etc.

The application of computers in agriculture was first reported in 1983 [2]. Different approaches have been suggested to solve the existing problems in the agriculture starting from the database [3] to decision support systems [4]. Out of these solutions, systems that apply AI have been found to be the most excellent performers as far as the accuracy and robustness are concerned. Agriculture is a dynamic domain where situations cannot be generalized to suggest a common solution. AI techniques have enabled us to capture the intricate details of each situation and provide a solution that is best fit for that particular problem. Gradually very complex problems are being solved with the development of various AI techniques.

This literature survey covers 100 important contributions where AI techniques were employed to encounter the challenges in agriculture. Three major AI techniques; Expert Systems, Artificial Neural Networks and Fuzzy systems are considered as the focused areas. This paper addresses the application of AI techniques in the major subdomain of agriculture so that the readers are able to capture the gradual development of agro-intelligent systems during last 34 years, from 1983 to 2017.

II. GENERAL CROP MANAGEMENT

In general, crop management systems provide an interface for overall management of crops covering each aspect of farming. The idea of using AI technique in crop management was first proposed in 1985 by McKinion and Lemmon in their paper "Expert Systems for Agriculture" [5]. Another corn crop protection expert system was proposed by Boulanger in his doctoral Thesis [6]. In 1987, Roach et al. proposed an expert system POMME for management of apple plantation [7]. Stone and Toman came up with an expert system for cotton crop management COTFLEX [8]. Another rule base expert system COMAX was formulated by Lemmon for cotton crop management [9].

A multi-layered feed forward artificial neural network based system was formulated by Robinson and Mort to protect citrus crops from frost damage in Sicily island of Italy [10]. The input and the output parameter(s) were coded in binary form to train and test the network. The authors used different configurations of inputs to get a model with the highest accuracy. The best model so found had an accuracy of 94% with two output classes and six inputs. An image based AI technique was proposed by Li, S. K. et al., for wheat crop [11], by using pixel labelling algorithm followed by Laplace transformation to strengthen the image information. The best network obtained had five hidden layers trained up to 300000 iterations and had an accuracy of 85.9% on average. A fuzzy

logic based soybean crop management system was developed by Prakash, C. et al. which provided advices regarding crop selection, fertilizer application and pest related issues [12].

III. Pest management

Insect pest infestation is one of the most alarming problems in agriculture that leads to heavy ecomonic 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 [13], SMARTSOY of Batchelor et al., [14-15], CORAC of Mozny et al. [16], Knight and Cammell [17], Mahaman et al. [18], Li et al. [19], Chakraborty et al. [20], and Ghosh [21].

The knowledge involved in agriculral 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 logic based expert systems were proposed including Saini et al. [22], Siraj and Arbaiy [23], Peixoto et al. [24], IPEST by Hayo et al. [25], Roussel et al. [26], Shi et al. [27], Jesus et al. [28].

An objected oriented approach to frame a rule base was taken by Ghosh et al., in developing TEAPEST, an expert system for pest management in tea [29]. Here also a phase by phase indentification and consultation process have been adopted. Later this system was redesigned by Samanta and Ghosh by employing a multi-layered back propagation neural network [30] and then reformulated by Banerjee et al., by using radial basis function model to achieve higher classification rates [31].

IV. Disease management

Crop diseases are also a matter of grave concern to a farmer. Significant expertise and experience is required in order to detect an ailing plant and to take necessary steps for recovery. Computer aided systems are being used worldwide to diagnose the diseases and to suggest control measures.

At very early stage, rule based systems were developed which includes Byod and Sun [32], Sarma et al., [33], Balleda et al. [34]. Tilva et al., proposed a fuzzy logic based model to forecast diseases based on leaf wetness duration [35].

Different artificial neural network based model were designed for disease control in different crops including; Francl and Panigrahi [36], Babu and Rao [37], Ismail et al. [38], Karmokar et al. [39], Sladojevic [40], Hanson et al. [41] and Hahn et al. [42]. Some hybrid systems were also suggested. Huang proposed an image processing model coupled with artificial neural network model to classify phalanopsis seedling diseases [43]. Sannakki et al., enforced a fuzzy logic approach coupled with image processing to detected percentage of infection in leaf [44]. A system using k-means segmentation algorithm was developed by Al-Hiary, et al. [45] and Bashish et al. [46]. Dr. Wheat is a web based expert system developed by Khan et al., for diagnosis of wheat diseases [47].

V. Agricultural product monitoring and storage control

Apart from pests and diseases monitoring, storage, drying, grading of harvested crops are also very important aspects of agriculture. This section addresses various food monitoring and quality control mechanisms that employ the concept of artificial intelligence. Several fuzzy logic based systems were designed, which includes Kavdir et al. [48], Gottschalk et al. [49], and Escobar et al. [50]. The systems developed by using artificial neural networks are to be addresses such as Taki et al. [51], Yang [52], Nakano [53], Capizzi et al. [54], Melis et al. [55], Miranda and Castano [56], Perez et al., [57], Martynenko and Yang [58], Movagharnejad and Nikzad [59], Khazaei et al. [60], Higgins et al. [61], Chen and Yang [62] and Boniecki et al. [63].

VI. Soil and irrigation management

Issues pertaining to soil and irrigation management are very vital in agriculture. Improper irrigation and soil management lead to crop loss and degraded quality. This section highlights some researches carried out in soil and irrigation management assisted by artificial intelligent techniques. Brats et al. [64] designed a rule based expert system for evaluation of the design and performance of microirrigation systems.

Sicat et al. [65] used farmers' knowledge to model a fuzzy based system to recommend crops depending on land suitability maps generated by the fuzzy system. Other fuzzy based systems include Si et al. [66], Tremblay et al. [67]. Valdes-Vela et al. used a Takagi Sugeno Kang fuzzy inference system to estimate the stem water potential of a plant based on meteorological and soil water content data [68].

An artificial neural network based system for estimation of soil moisture in paddy was designed by Arif et al. [69]. Other popular systems using artificial neural network for soil and irrigation include Broner and Comstock [70]. Song and He [71]. Zhai et al. [72], Patil et al. [73], Hinnell et al. [74], Junior et al. [75] and Antonpoulos et al. [76]. Manek and Singh compared several neural network architectures in prediction of rainfall using four atmospheric inputs [77]. This study found that radial basis function neural networks perform best in comparison to other models.

VII. Weed management

Application of herbicides have a direct implication on human health and environment as well. Modern AI methods are being applied to minimize the herbicide application through proper and precise weed management. Pasqual [78] designed a rule based expert system for identifying and eliminating weed in crops like oats, barley, triticale and wheat. Burks et al. [79] used machine vision with a back propagation trained neural network to identify weeds of five distinct species. Burks et al. [80] compared three different neural network models mainly back propagation, counter propagation and radial basis function based model with the same set of inputs as the previous paper and found that back propagation network

performs best with 97% accuracy. In another approach by Shi et al., [81] was developed by using image analysis and neural network. The other works reported by Eddy et al. [82], Nebot et al. [83] and Barrero et al. [84] were very remarkable.

VIII. YIELD PREDICTION

The crop yield prediction is very beneficial for marketing strategies and crop cost estimation. Moreover, in the age of precision agriculture analysis of relevant factors that directly effects the yield can also be done through prediction models. Liu et al. [85], used an artificial neural network model employing back propagation learning algorithm to predict yield from the soil parameters. The other remarkable works include Kaul et al. [86], Uno et al. [87], Ji et al.,[88], Zhang et al. [89], Russ et al. [90], Singh [91], Alvarez [92] and Rahaman and Bala [93]. Ehret et al. built a neural model for predicting tomato yield, growth and water use in a greenhouse environment [94]. Thongboonnak and Sarapirome experimented on logan yield in different districts of Thailand using neural networks [95]. In a different approach, Pahlavan et al. used energy output as a measure of yield for basil plants in greenhouse [96]. The other important research works focused on prediction of yield includes Khoshnevisan et al. [97], Nabavi-Pelesaraei et al. [98] and Soheili-Fard et al. [99]. In 2014, Dahikar and Rode proposed a neural model for prediction of 7 different crop yield using atmospheric inputs and fertilizer consumption [100].

IX. CONCLUSIONS

This survey covers 100 research articles published in the field of application of AI techniques in agriculture during last 34 years starting from 1983 to 2017. A lot of works are left behind to be mentioned in this limited space. Only some representatives are chosen to be addressed to cover the multidimensional approaches. This paper has been prepared to make it as informative as possible with details of various AI techniques employed in agriculture. During the early 1980s and 1990s, the rule based expert systems were extensively used whereas from 1990 onwards, artificial neural network models and fuzzy inference systems have taken the dominant role. In present years an uprising use of hybrid systems such as neuro-fuzzy or image processing coupled with artificial neural networks are being used. It moves toward more automated and more accurate systems that act on real time. Further researches are being conducted with more advanced tools so that traditional agriculture can move towards precision agriculture with low cost.

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