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Contemporary Trends in Plant Health Care and Agriculture Extension Services

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Abstract: The present communication is a survey of digital tools related to plant health care which is beneficial for farmers. The computational methods are used by researchers these days for developing agricultural extension services. This research used more than 200 research papers in which nine diverse research issues are observed in this survey. We have identified 9 research areas in plant health care in which computational methods can be used. Image processing is the most common computational method used by researchers in solving plant health care related issues. The computational methods are also identified based on each research area separately. We have identified most commonly used computational tool for each of the nine plant health care issue. One of the observations is that the researchers use Decision Support Systems tools for sharing knowledge about plant health care. The results of this study will be helpful for computer scientists to select research gaps in plant health care related issues.

Keywords: Agriculture extension services, Computational methods, Digital tools, Plant health care.

I. Introduction

Modern technological evolution plays a vital role in the field of plant health management and plant care. Farmers can get instant help with information for crop management and disease management by using current digital technologies. Farmers can get acquainted with support services, facilities, schemes, and the schemes of the government on time with modern digital technologies that help them to recognize plant diseases early, cure ailments of plants timely, and improve crop production. Farmers can also get advisory services from scientists with the help of digital tools to adapt to modern agricultural practices. Fig. 1 represents applications of information technology for sustainable agriculture practices. These services include climate prediction, an online marketplace, field-level decision support systems, pest management, disease management, damage analysis, and plant health monitoring. Modern computational tools and technologies used in the published literature are studied. This information will also be helpful for researchers interested in plant health care services.

Fig. 1: Applications of IT for Sustainable Agriculture Practices

II. Digital Tools and Techniques

A. Knowledge Based Tools and Techniques

a. Knowledge Sharing

Knowing modern agricultural tools is necessary for farmers. The world faces local atmospheric uncertainties and variable weather patterns due to constant climatic change. Early and on-time information about local weather conditions is essential for a farmer to know. It is possible only when farmers can use modern tools and technology. The Internet of Things (IoT) can fill the gap between technology and the traditional agriculture system. Technological shifts toward agriculture and farming show a positive impact on agriculture services. Governments and NGOs are trying to fill this gap between farmers and technology by developing knowledge-sharing portals and websites. Knowledge is shared through meetings and discussions by the farmers traditionally. Farmers can also share their observations with their peers while working in farms and marketplaces. Modern technological innovations can provide farmers with an efficient and fast agriculture information-sharing platform. WeFarm [1] is a farmer-to-farmer digital network in which farmers can communicate with each other via SMS and online chats. Nearly 1.8 million small-scale farmers are using this platform. Agtech company Verdant connects African farmers to provide agricultural insight and extension services. It uses mobile technology to increase market accessibility [2]. International Fund for Agricultural Development (IFAD) and International Development Research Centre (IDRC) jointly develop a knowledge networking for rural development in the Asia Pacific. It is a knowledge-sharing tool [3]. Online and offline knowledge sharing can be effective if websites, blogs, and digital radios are used instead of specialized applications. Busoga Rural Open Source Development Initiative (Kampala, Uganda) (BROSDI) broadcasts a live monthly program that facilitates farmers about effective farming practices [4]. The knowledge disseminated by audio blogs can reach a wider audience [5]. WorldSpace radio uses two satellites named- AfriStar and AsiaStar, to broadcasts more than 100 digital-quality audio channels for farmers around the world. Agricultural blogging allows quick dissemination of information to the farmers. The Voices of Africa blog [6] and Kisan blog [7] show the contribution of blogging in sharing the experiences of rural farmers. The Collecting and Exchange of Local Agricultural Content (CELAC) blog is another blog where farmers and agriculture practitioners can post articles [8]. Some public and private organizations use mobile technology to provide market information to farmers. Tradenet.biz is an enterprise that covers 15 countries and 500 markets to offer information related to supply-chain, from price updates, harvests, transport, trading offers, disease outbreaks, and weather. The poor farmers in Tanzania use mobile phones to access market information in real-time under the First Mile Project [9-14]. It is a joint venture of the Government of Switzerland and the Government of Tanzania.

b) Climate Predictions

Due to climate change, fluctuations in the temperature and rainfall observed impose a diverse effect on agricultural production. The North-Eastern United States developed free, online decision-making tools for farmers in a Cornell Climate Smart Farming program. The developed tools combine local weather stations and agricultural data and inform farmers that are useful in decision-making [15]. The United States Environmental Protection Agency also developed a toolkit for farmers. The developed climatic tools include the growing degree day calculator [16], water deficit calculator [17], Nitrogen management tool [18], crop planting scheduler [19], drought monitor [20-21], EPA's climate resilience evaluation and awareness tool [22] for annual total precipitation, annual average temperature. The South-East Climate Consortium developed a web tool that deals with volatile weather patterns in Florida [23]. The Climate Predictability Tool is a software package designed by Columbia University for the seasonal Climate forecast Model [24]. Machine learning can also play role in Climate prediction [25-27]. Example of some of the contemporary tools are - outbreak risk prediction [28], seasonal precipitation [29-31], weather prediction [32], climate change prediction [33, 34], solar radiation prediction [35-36], to predict plant growth and yield [37-38]. Some researchers use GIS-based machine learning for climate downscaling prediction [39]. Fig. 2 is showing some eTools helpful for sustainable agricultural practices.

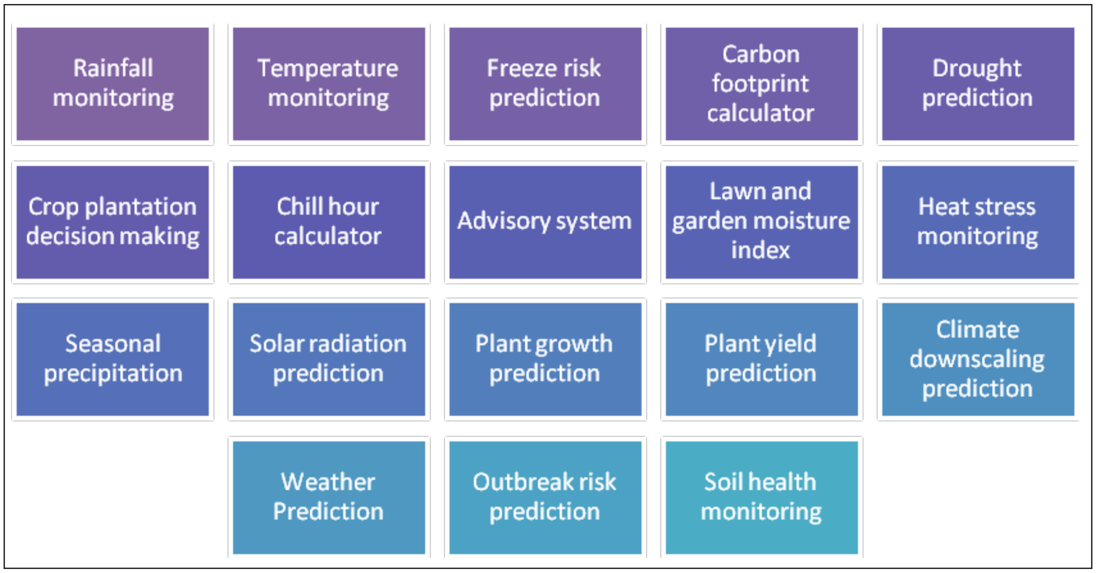

Fig. 2: eTools for Sustainable Agriculture Practices

c) Linkages with Agriculture Research Scientists and Local Advisors

Active Linkages between researchers and farmers are necessary. Agriculture-based research could be successful if it is helpful for farmers. This linkage of research and farmers such interactions lead to the design and delivery of appropriate technology practically suitable for the stakeholders [40]. Many gaps between agricultural research and extensions cause the complexity of agriculture research products [41-42]. Communication and digital knowledge-share are effective for this [43].

d) Field-Level Decision Support System

Applications of decision support systems in agriculture have increased rapidly in the last decade [44-46]. A decision support system (DSS) is an interactive software-based system used to help decision-makers to compile information from a combination of raw data to identify and solve problems. It also makes an optimized decision [44, 45]. An effective DSS could be paper-based, software, or a mobile app. A study suggests that software is 28% more useful for a farmer than paper-based (22%) DSS, followed by mobile app based (10%) [47]. Nowadays, the evolution of agriculture steps into Agriculture 4.0, thanks to the employment of current technologies like the Internet of Things [48], Big Data [49], Artificial Intelligence, Cloud Computing [50], and Remote Sensing [51-53]. The applications of these technologies can improve the efficiency of agricultural activities significantly. A machine learning-based DSS could be more effective [54-55]. A decision support system used for farm management [56], assessment and management of soil functions [57], enhancing crop productivity [45, 110, 112], farm machinery management [58-59], agro-technology transfer [46], improving the efficiency of water use [60]. The Watson Decision platform for agriculture combines IBM's advanced capabilities in artificial intelligence, the Internet of things, and cloud computing [61].

e) Tools for Plant Protection

Early control of pests is a must in agriculture. Pesticides can harm the crop and human health, hazardous to the environment also. It is required to inform farmers about sustainable plant protection techniques [62].

f) Sustainable Plant Protection

The global impact of climate change is influencing plant production and constraining farmers' change crop monitoring and management strategies. Farmer finds difficulty in the present climatic scenario to get ecological and economic ROI (return on investment).

One factor is to protect plants from plant disease outbreaks. For this, a farmer must concentrate on plant type, soil-weather conditions, predictions and forecasting of disease outbreaks, and optimal timing and quantity of using pesticides. Smart field monitoring viz IoT-based soil monitoring systems improve the soil as per the crop [63] and proper irrigation [64-65].

g) Online Marketplace for Sustainable Plant Protection

To have sustainable plant products, farmers must have sustainable plant protection products such as biofertilizers and organic pesticides at affordable prices. All India Network Project on biofertilizers (aicrp BNF) is an example of such an initiative of The Indian Council of Agricultural Research (ICAR) [66]. Indian Farmers Fertilizer Cooperative Limited (IFFCO) [67] and e-Urvarak is a dashboard developed by National Informatics Center, India, ensures adequate and on-time delivery of sustainable fertilizers to the farmers and facilitates easy monitoring by various stakeholders [68].

B. Tools for Plant Health Care

a) Plant Health Care is an Important Issue

The production is directly dependent on the healthy crop. It is desirable to keep plants healthy by early detection of diseases and attack of pests. Continuous monitoring of plants is the main factor for disease monitoring. AI-enabled plant disease detection [69-70] and monitoring systems [71-72] are helpful in disease detection [73-74], monitoring [71-72], classification [75], and pest detection [76]. The computational techniques used in plant disease detection and monitoring digital tools are neural networks [73, 77], multimedia sensor networks [74], remote sensing [78], biosensors [79], image processing [69], and deep learning [75-76].

b) Detecting, Monitoring and Controlling Pest Threats

Climate change affects the behavior, distribution, life cycle, and outbreak potential of pests. An effective pest monitoring system is essential as an embedded feature of climatic predictions to eradicate potential threats. During the outbreaks, a real-time monitoring system must have pest risk prediction data and pest distribution observations. An effective digital pest control and monitoring system can have several modules as pest detection [76, 78, 80-85], pest management [86-88], pest monitoring [89], pest controlling [89-90], pest classification [85, 91], pest surveillance [80, 92-93] and, damage detection [94-95]. Researchers use deep learning [76, 96-97], remote sensing [78], SVM classification [84, 98], computer vision [81, 98, 99-101], Supervised learning [102], clustering [103], intelligent mobile applications [104], radio [105], multi-object detection method [104], image processing [83], bio-inspired methods [106], artificial intelligence [88], wireless sensors [90], AIoT [82] and electronic nose [107-108], artificial intelligence [109], sensing technologies [110] for pest detection and monitoring. PestinaNet [111] is an example of a real-time crop pest detection system.

i) Pest Recognition

Pest recognition is finding pest attacks in plants using various computational techniques [112-113]. Researchers attempt to successfully recognize pests in plant leaves [114-115], roots [89] [102], tuber [89], fruits [116], and trunk [115]. Diverse computational techniques used by researchers in pest recognition. Some of this are-image processing [114, 117], attention-embedded lightweight network [112], artificial intelligence [119], SVM [120], K-means clustering [91, 121], machine learning [91], deep learning [116], embedded system [122], machine vision [99].

ii) Damage Analysis

Another issue related to pest control and management is detecting the amount of damage by pests [94, 95, 123]. Farmers use information about the severity of the infection and the damage to the plant. It may help farmers decide to apply for medicine or discard the plant. The computation techniques used by researchers for damage analysis are pattern recognition [94], RBF-SVM algorithm [124], artificial nose [125-126], remote sensing [127], computer vision [128], and image processing [123].

iii) Pest Management

An initiative is required to develop response plans to tackle crop health threats [129]. Digital pest management [130] helps farmers to elevate pest control by automating the monitoring of pests. These Intelligent and automatic systems improve pest monitoring and support pest managers smartly. An example of this is rodent traps using IoT Technology [131]. The classification and detection of insects in crops using intelligent pest management [132] is an efficient way of pest control. There is evidence of using climate-smart pest management systems [86], Automatic Moth detection [133], and Environment monitoring [134] in the literature. Information technology tools like Drones [135], Satellite images [136], and agricultural aircraft [137-138] for pest control and management system. The computing technologies used for this purpose include image processing [132, 133, 138-139], decision support systems [148], deep learning [132,140], GIS [141], and web technology [142].

c) Detection, Monitoring, Management and Controlling Plant Diseases

i) Disease Detection

Disease detection is the process of detecting diseases from infected plants. Many disease detection tools are discussed in the literature [143-144, 70, 79]. The digital techniques used for disease detection in plants are image processing [69, 145-152], sensors [153], robotics [154], deep learning [76, 149, 151-152, 155-161], hyperspectral imaging and image sensing [162-164], Internet of Things (IoT) [165-166], neural networks [167-168], machine learning [150,169], orthogonal learning [168], evolutionary computation [168], swarm intelligence [168], support vector machine (SVM) [170-171], soft computing [146, 149]. The AuToDiDAC [172] and pathology [154] are plant disease detection tools designed for plant disease detection.

ii) Disease Monitoring and Management

Combining modern plant disease monitoring and management tools with disease detection tools is required. It is beneficial for the development of integrated high-tech crop protection systems in the future [72, 173]. The computational methods used by the researchers for this purpose are IoT [174-178], neural networks [77, 179], robotics [154, 180], unmanned aerial vehicles [178, 181], soft computing [182], image processing [182- 183], remote sensing imaginary [184-186], deep learning [187], geographical Information system (GIS) [188], machine learning [176], data mining [189], wireless sensor network [178, 190], wearable sensors [191], online decision support system (DSS) [192] and, hyperspectral technology [193]. A playhouse is a plant monitoring system that uses a convolutional neural network (CNN) for disease monitoring [77]. Chlorophyll fluorescence imaging is another tool to monitor the progress of a root pathogen in a perennial plant [183].

A decision support system was developed by researchers for decision-making [194-195]. An expert system is used for this purpose [196]. Quant is a software to quantify disease severity [197-198]. IoT tools have been used in literature by researchers for detecting and controlling plant diseases [174].

III. Discussion

Pest detection, pest monitoring, disease detection, and disease monitoring issues are common research areas in the literature. Monitoring of field, soil and irrigation, damage detection, damage prediction, and predictions of real-time early pest approaches are some issues ignored by IT professionals. The development of intelligent computational methods for plant health care is required. Table I indicates the observed research areas related to plant health care and the computational methods used for that issue.

Table I: Computational Methods Used in Different Research Areas Related to Plant Health Care

Sr. No.	Major Research Area	Sub Areas	Computational Method Used
1	Knowledge Based Tools & Techniques	Knowledge Analysis	Decision Support System [44, 45-46, 50, 56-59]
			GIS [39]
		Knowledge Sharing	Digital Knowledge Sharing Tools [43]
			Mobile Apps [47]
			Internet of Things [48, 61]
			Big Data [49]
			Artificial Intelligence [50, 61]
			Cloud Computing [50, 61]
			Remote Sensing [51-53]
			Machine Learning [54-55]
2	Field Monitoring	Field Monitoring	Smart Applications [202-204]
		Soil Monitoring	IoT [63]
		Irrigation Monitoring	IoT [64-65]
			Decision Tool [205]
		Crop Productivity Monitoring	Decision Support System [206]
3	Plant Health Monitoring	Disease Detection	Neural Networks [73, 87]
			Multimedia Sensor Networks [74]
		Disease Classification	Remote Sensing [78]
			Biosensors [79]
			Image Processing [69]
			Deep Learning [75-76]
4	Pest Detection	Pest Detection	Deep Learning [76, 96-97]
			Remote Sensing [78]
			SVM Classification [98, 114]
			Computer Vision [81, 98-101]
			Supervised Learning [102]
			Clustering [103]
			Smart Phones Applications [104]
			Radio [101]
			Multi Object Detection Method [104]
			Image Processing [83]
			Bio-Inspired Methods [106]
			Artificial Intelligence [19, 109]
			Wireless Sensors [90]
			AIoT [82]
			Electronic Nose [107-108]
			Sensing Technologies [110]
5	Pest Recognition	Pest Recognition	Image Processing [114, 117]
			Attention-Embedded Lightweight Network [118]
			Artificial Intelligence [119]
			SVM [120]
			K-means Clustering [91, 121]
			Machine Learning [91]
			Deep Learning [116]
			Embedded System [122]
			Machine Vision [99]

Sr. No.	Major Research Area	Sub Areas	Computational Method Used
6	Pest Management (Monitoring, Controlling, and Surveillance)	Climate-Smart Pest Management Systems Automatic Pest Detection Environment Monitoring	Drones [137] Satellite Images [136] Agricultural Aircraft [137-138] Image Processing [132-133, 138-139] Decision Support System [148] Deep Learning [132, 140] GIS [141] Web Technology [142]
7	Damage Analysis	Damage Detection Damage Severity Analysis	Pattern Recognition [94] RBF-SVM Algorithm [124] Artificial Nose [125-126] Remote [127] Computer Vision [128] Image Processing [123]
8	Plant Disease Detection	Plant Disease Detection	Image Processing [69, 112, 145-147, 149-152] Sensors [153] Robotics [154] Deep Learning [76, 149, 151, 155-157, 158-161, 199, 201] Hyperspectral Imaging and Image Sensing [162-164] Internet of Things (IoT) [165-166] Neural Networks [167-168] Machine Learning [150,169] Orthogonal Learning [168] Evolutionary Computation [168] Swarm Intelligence [168] Support Vector Machine (SVM) [170-171] Soft Computing [149]
9	Disease Monitoring and Management	Disease Monitoring Disease Management Disease Control	IoT [172, 176-178] Neural Network [77, 179] Robotics [154, 180] Unmanned Aerial Vehicles [178,181] Soft Computing [182] Image Processing [182-183] Remote Sensing Imaginary [184-186] Deep Learning [187] Geographical Information System (GIS) [188] Machine Learning [176] Data Mining [189] Wireless Sensor Network [178, 190] Wearable Sensors [191] Online Decision Support System (DSS) [192] Hyper Spectral Technology [193] Expert Systems [196]

It is required to identify computational methods before solving an issue related to plant health. A review of more than 200 already published research papers has been performed to answer this query. Fig. 3 shows commonly used computational methods in already published research papers for plant health care. Fig. 3 is a frequency distribution chart of computational methods by computer scientists used for plant health care issues. It is observed that image processing and image analysis is the most frequently used computational method for solving plant health care issues, followed by the internet of things (IoT) and decision support system (DSS).

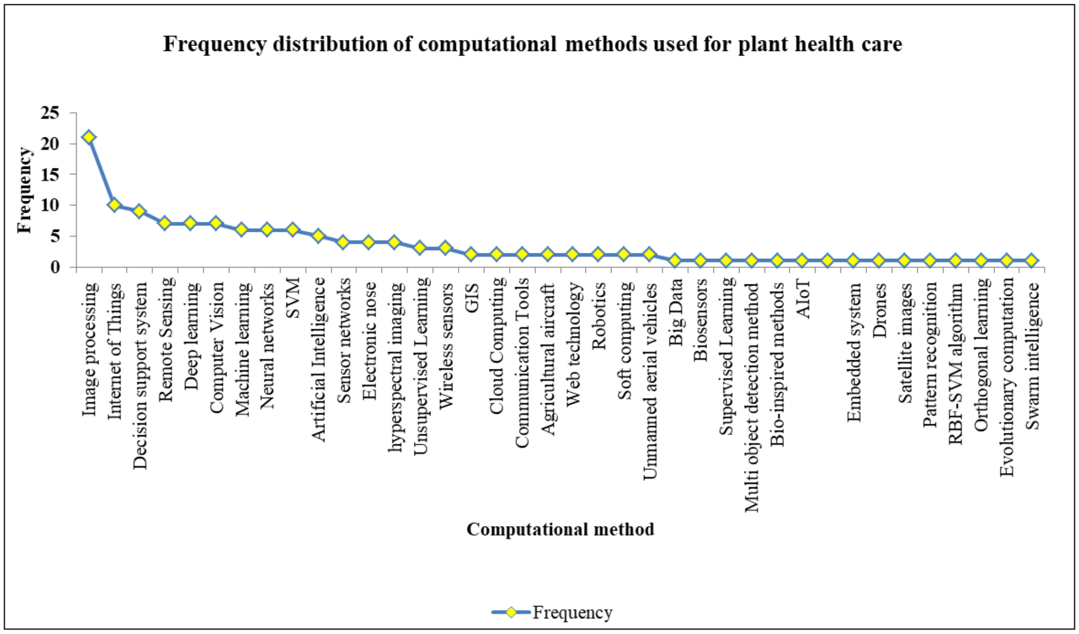

Fig. 3: Frequency Distribution Graph for Computational Methods Opted by Researchers for Development of Plant Health Care Related Tools and Applications

Fig. 4 is showing the share of various computational methods used in different research areas observed in the survey. For knowledge Analysis and sharing of plant related information, decision support systems (35%) and remote sensing (13%) is most commonly used, followed by cloud computing (9%) and artificial intelligence (9%). For Field Monitoring related issues smart application tools and internet of things shares 50-50% part.

In plant health management applications, Biosensors (36%), neural networks (18%) and deep learning are most commonly used by the researchers. For pest detection, computer vision (19%), deep learning (12%) and support vector machines (8%) are given importance. For pest monitoring and management systems agriculture aircrafts (15%) and drones (8%) and, GIS (8%) are used with support of image processing (31%) and deep learning (15%) etc. For pest recognition image processing (18%) and unsupervised learning (18%) is most commonly used by the researchers. Electronic nose is a modern technology used in 29% research papers reviewed for damage analysis. Some other methods used for this damage analysis are- pattern recognition (14%), support vector machines (14%), remote sensing (14%), image processing (14%) and computer vision (14%). For plant disease detection deep learning (29%) is most commonly used followed by image processing (24%).

IV. Conclusion

Plant health is an important issue that has direct effect on crop production. In the present survey of more than 200 papers it was observed that image processing, followed by Decision Support System (DSS), Internet of Things (IoT), computer vision and deep learning are contemporary computational

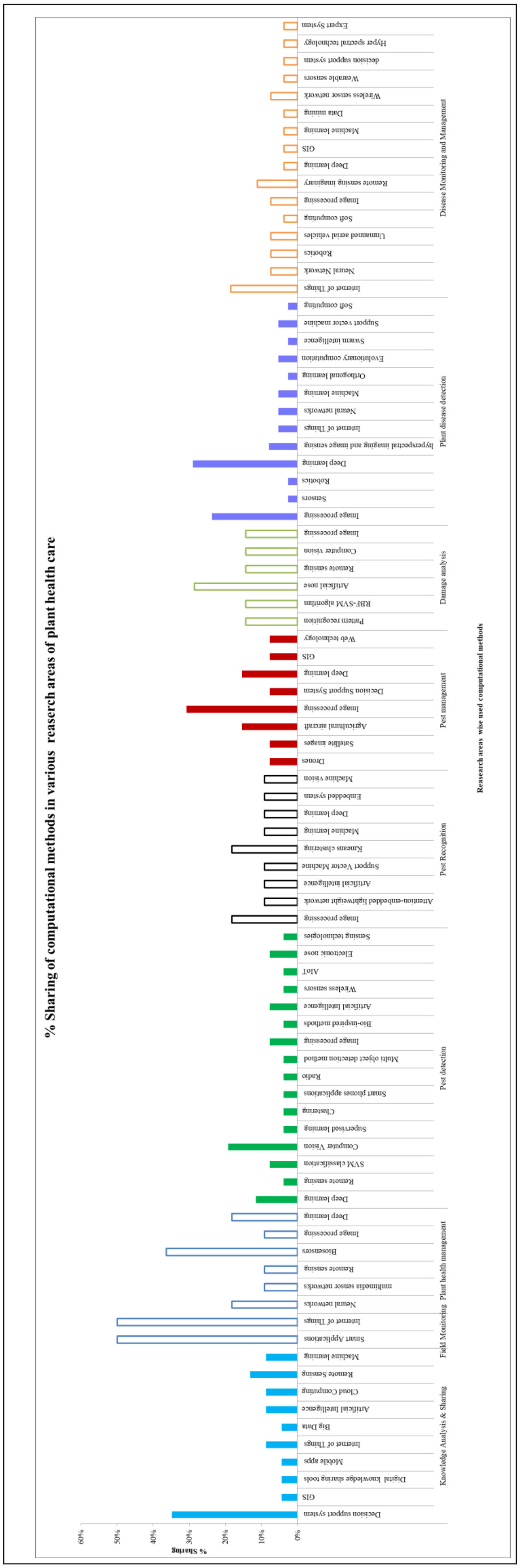

Fig. 4: A Graph Showing Research Area Wise % Sharing of Used Computational Method in Development of Plant Health Care Related Tools and Applications

tools used by researchers for various research areas related to plant health care. Among nine identified research areas, plant disease detection and disease monitoring is most frequently researched. For each observed nine research areas in the literature, the most used computational method identified. The area most used tool duo for each of the observed research area are: (i) Knowledge Analysis & Sharing – DSS (35%), (ii) Field Monitoring – IoT (50%), (iii) Plant Health Management – Biosensors (36%), (iv) Pest Detection – Computer Vision (19%), (v) Pest Recognition – Image Processing (18%), (vi) Pest Management – Image Processing (31%), (vii) Damage Analysis – Artificial Nose (29%), (viii) Plant Disease Detection – Deep Learning (29%) and (ix) Disease Monitoring and Management – IoT (19%). The present research can be used to identify research gaps in terms of plant health issues and used computational methods.

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