AGRICULTURE 5.0
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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADC</td>
<td>Analog to Digital Converter</td>
</tr>
<tr>
<td>ADSS</td>
<td>Agricultural Decision Support System</td>
</tr>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>ANN</td>
<td>Artificial Neural Networks</td>
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<tr>
<td>ANT</td>
<td>Adaptive Network Topology</td>
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<tr>
<td>APIs</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>BLE</td>
<td>Bluetooth Low Energy</td>
</tr>
<tr>
<td>CAGR</td>
<td>Compound Annual Growth Rate</td>
</tr>
<tr>
<td>CDAC</td>
<td>Center for Development of Advanced Computing</td>
</tr>
<tr>
<td>CGIAR</td>
<td>Consultative Group on International Agricultural Research</td>
</tr>
<tr>
<td>CIAE</td>
<td>Central Institute of Agricultural Engineering</td>
</tr>
<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor</td>
</tr>
<tr>
<td>CPS</td>
<td>Cyber-Physical System</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>DARE</td>
<td>Department of Agricultural Research and Education</td>
</tr>
<tr>
<td>DARPA</td>
<td>Defence Advanced Research Projects Agency</td>
</tr>
<tr>
<td>DPM</td>
<td>Dynamic Power Management</td>
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<tr>
<td>DSN</td>
<td>Distributed Sensor Networks</td>
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<tr>
<td>DSS</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>DVS</td>
<td>Dynamic Voltage Scaling</td>
</tr>
<tr>
<td>EEPROM</td>
<td>Electrically Erasable Programmable Read-Only Memory</td>
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<tr>
<td>ENS</td>
<td>Embedded Networked Systems</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>GMO</td>
<td>Genetically Modified Organism</td>
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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite Services</td>
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<tr>
<td>GODAN</td>
<td>Global Open Data for Agriculture and Nutrition</td>
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<tr>
<td>GPRS</td>
<td>General Packet Radio Services</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<td>GSM</td>
<td>Global System for Mobile</td>
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<tr>
<td>GSN</td>
<td>Global Sensor Networks</td>
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<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>HSPA</td>
<td>Evolved High-Speed Packet Access</td>
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<td>IBM</td>
<td>International Business Machines Corporation</td>
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<td>ICAR</td>
<td>Indian Council of Agricultural Research</td>
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<td>ICT</td>
<td>Information and Communication Technology</td>
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<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
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<tr>
<td>IDSS</td>
<td>Intelligent Decision Support System</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<tr>
<td>IERC</td>
<td>International Energy Research Centre</td>
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<tr>
<td>IETF</td>
<td>Internet Engineering Task Force</td>
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<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>IoE</td>
<td>Internet of Everything</td>
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<td>IoT</td>
<td>Internet of Things</td>
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<tr>
<td>IoTWF</td>
<td>IoT World Forum</td>
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<tr>
<td>IP</td>
<td>Internet Protocol</td>
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<td>IPFT</td>
<td>Intelligent Precision Farming Technology</td>
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<td>IR</td>
<td>Infrared</td>
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<tr>
<td>IR</td>
<td>Infrared</td>
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<tr>
<td>ISM</td>
<td>Industrial, Scientific, and Medical</td>
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<td>ISO</td>
<td>International organization of Standardization</td>
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<td>ISPA</td>
<td>The International Society of Precision Agriculture</td>
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<td>ISRO</td>
<td>Indian Space Research Organisation</td>
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<tr>
<td>IT</td>
<td>Information Technology</td>
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<tr>
<td>ITC</td>
<td>Indian Tobacco Company</td>
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<td>ITU</td>
<td>The International Telecommunication Union</td>
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<td>LAN</td>
<td>Local Area Network</td>
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<tr>
<td>LCC</td>
<td>Leaf Colour Chart</td>
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<td>LED</td>
<td>Light Emitting Diode</td>
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<td>LoRa</td>
<td>Low Range</td>
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<tr>
<td>LoWPAN</td>
<td>Low-Power Wireless Personal Area Network</td>
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<td>LTE</td>
<td>Long-Term Evaluation</td>
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<td>M2M</td>
<td>Machine to Machine</td>
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<td>MEMS</td>
<td>Micro Electro Mechanical Systems</td>
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<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
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<td>MiWi</td>
<td>Microchip Wireless</td>
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<td>ML</td>
<td>Machine Learning</td>
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<tr>
<td>NABARD</td>
<td>National Bank for Agriculture and Rural Development</td>
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<td>NAIP</td>
<td>National Agricultural Innovation Project</td>
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<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<tr>
<td>NBSSLUP</td>
<td>National Bureau of Soil Survey and Land Use Planning</td>
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<td>NiCd</td>
<td>Nickel Cadmium</td>
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<td>NIMS</td>
<td>Networked Info Mechanical Systems</td>
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<td>NIST</td>
<td>National Institute of Standards and Technology</td>
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<td>NNI</td>
<td>National Nanotechnology Initiative</td>
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<td>NOAA</td>
<td>National Oceanographic and Atmospheric Administration</td>
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<td>ODLT</td>
<td>Open Distributed Ledger Technology</td>
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<td>OSI</td>
<td>Open System Interconnection</td>
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<td>PA</td>
<td>Precision Agriculture</td>
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<td>PDCSR</td>
<td>Project Directorate for Cropping Systems Research</td>
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<td>PF</td>
<td>Precision Farming</td>
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<td>PFDCs</td>
<td>Precision Farming Development Centres</td>
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<tr>
<td>RF</td>
<td>Radio Frequency</td>
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<td>RFID</td>
<td>Radio-Frequency IDentification</td>
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<td>ROM</td>
<td>Read Only Memory</td>
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<td>RS</td>
<td>Remote Sensing</td>
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<td>R&amp;D</td>
<td>Research and Development</td>
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<td>Abbreviation</td>
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<tr>
<td>SHF</td>
<td>Super High Frequency</td>
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<td>SMS</td>
<td>Short Messaging Service</td>
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<td>SOSUS</td>
<td>Sound SURveillance System</td>
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<td>SPAD</td>
<td>Soil Plant Analysis Development</td>
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<td>SSCM</td>
<td>Site-Specific crop management</td>
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<tr>
<td>UAV</td>
<td>Unmanned Aerial Vehicle</td>
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<tr>
<td>UHF</td>
<td>Ultra-High Frequency</td>
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<td>UN</td>
<td>United Nations</td>
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<td>USD</td>
<td>United States Dollar</td>
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<tr>
<td>USN</td>
<td>Ubiquitous Sensor Network</td>
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<tr>
<td>VRA</td>
<td>Variable Rate Application</td>
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<tr>
<td>VRT</td>
<td>Variable Rate Technology</td>
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<tr>
<td>W3C</td>
<td>World Wide Web Consortium</td>
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<tr>
<td>WiFi</td>
<td>Wireless Fidelity</td>
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<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access</td>
</tr>
<tr>
<td>Wireless HART</td>
<td>Wireless Highway Addressable Remote Transducer Protocol</td>
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<tr>
<td>WSN</td>
<td>Wireless Sensor Networks</td>
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1 Introduction to Precision Agriculture

1.1 HISTORY OF PRECISION AGRICULTURE AND ITS GLOBAL ADOPTION

Precision farming was adopted by US agriculture in the 1980s at a sluggish rate of 10 to 15 years due to doubt in profitability at that time, as no legitimate pieces of evidence were present and the adoption of this innovation was uneconomical. Some specific reasons include the lack of genuine information at that time, farmer attitude, economic constraints in acquiring technology, and the technology itself. Later, it was discovered that the two major reasons were:

I. Willingness:
   Willingness is directly proportional to the availability of information about PA, precision in information, and the probability of positive results.

II. Ability to Adopt:

Early in the year 2000, it was identified that the adoption of precision farming was related to:

a. The degree of relevance between the existing problem and the technology
b. Ease of handling the technology
c. Most importantly, the profit related to the aforementioned adoption

During the early stages of implementing precision farming, improving efficiency was the only motivating factor and, of course, this was not sufficient. Batte and Arnholt investigated that profit that was related to PA was the biggest contributing factor [1]. During the first ten years, the 21st-century exponential rate for acceptance of PA was observed among producers as well as commercial businesses.

The reason for this rapid growth in adoption during the last 15 years is related to certain factors:

1. In terms of efficiency, productivity, and profitability executed in an eco-friendly manner, nutrient management research has enabled development.
2. The affordable pricing of commodities led to high net profits and large investments in advanced technologies.
3. Auto-guidance systems not only improved the farming efficiencies but also reduced the manual efforts of farmers.
4. There was an increase in the number of skilled people who had knowledge about both agricultural and technological domains.

The abovementioned factors only constitute a few of the reasons for the adoption of PA in the past 15 years. However, there was a gap that needs to be bridged among different sectors. The acceptance of PA has boosted due to the collaborative and synchronized efforts of industries, researchers, institutions, and the media. Global extensive research is proving beneficial and is significantly changing the agricultural domain [2].

1.2 PRECISION AGRICULTURE – INTRODUCTION

This book is aimed to provide a deeper insight into precision agriculture by discussing almost all of the techniques and tools that are currently used all over the world.

India is a vast land with a diverse climate and has an edge in producing a multitude of vegetables and crops throughout the year. According to the Ministry of Agriculture, India has achieved the second position in terms of the production of fruits and vegetables worldwide, following China (Reported by Horticulture at a Glance 2015). The Indian population is completely dependent on the production of cereal crops, fruits, vegetables, and milk, thus turning the country into a farming powerhouse globally. Nonetheless, we are still lacking in terms of productivity, focus, competition, and zoned agricultural sector. The requirement to remove these limits is quite simple: we need to adopt and promote the use of new technology and sciences that will be achieved by rigorous research in the field of agriculture [3]. The dearth of awareness as well as inadequate utilization of technology and traditional mechanisms for handling agricultural practices and constraints have negatively affected production all over the country.

The introduction of the latest and most innovative techniques, concepts, methodologies, and technology to replace conventional agricultural ways, thus making it sustainable is called Precision Agriculture (PA). It is focused on maximizing production while using the least amount of resources while causing minimum impact on the environment by judicious irrigation and an adequate quantity of pesticides and fertilizers. PA critically depends upon factors such as information, technology, and management which have equal importance and accords numerous benefits on crops [4]. Nowadays, we become increasingly familiar with the term, and there has been a progressing trend toward this field. When agricultural practices are executed rather efficiently, such as when the proper amount of materials required (e.g. fertilizers, pesticides, nutrients, water, etc.) are supplied at the proper location and at the correct time to boost production, to grow profits, to directly promote soil health, and to indirectly increase water quality and farmer health while reducing environmental wastes is termed as precision agriculture [5]. In India, PA is still in its infancy, and significant work is currently proceeding in this field.
1.2.1 Foreign Perspective

The first definition of PA was given by the US House of Representatives (US House of Representatives, 1997) [6].

*Precision agriculture is an integrated information- and production-based farming system that is designed to increase long-term, site-specific, and whole farm production efficiency, productivity, and profitability while minimizing unintended impacts on wildlife and the environment.*

According to Gandonou [7]:

*PA can be defined as a set of technologies that have helped propel agriculture into the computerized information-based world and is designed to help farmers get greater control over the management of farm operations.*

As reported by the Second International Conference on Site-Specific Management for Agricultural Systems that was held in Minneapolis, Minnesota, in March 1994 [6]:

*The precision farming system within a field is also referred to as site-specific crop management (SSCM).*

As stated by the National Research Council, Italy 1997 [6]:

*SSCM refers to a developing agricultural management system that promotes variable management practices within a field according to site or soil conditions.*

The genetic improvement, agrochemical practices, irrigation, and farm machinery have been successful in improving productivity, but this is not significant enough to meet the continuously growing demand due to population expansion. Increased demand poses a threat to the environment as well as food security all over the world. Numerous innovative attempts have been pursued to enable sustainable crop production. Precision farming system (PFS) was one of the efforts that were undertaken during the early 1990s. This made its appearance in various forms, depending on the knowledge and technology that were available during its time. PFS was the combination of the latest technology and the
mechanization of the agro-sector. PFS made a sharp turn with the introduction of electronic information technology which enabled the collection, processing, and analysis of the data from different sources streamlined for decision-making. PFS has gained the platform due to a decline in the rates of agricultural products and increased production. Even the National Aeronautics and Space Administration (NASA) has shown interest in PA, hence proving the importance of its enactment [6]. Furthermore, precision farming technology (PFT) acts as a reliable base for making site-specific management (SSM) decisions. There has been an enormous demand for information about technologies that are used to manage agricultural production systems with the introduction of:

1. Yield monitors
2. Global positioning systems
3. Improvements in computing power and data management [8].

This emphasizes the use of technologically sophisticated equipment and promotes research and development in agronomy and crop and soil science in providing vital information and supporting decision-making for variable application of inputs at the local levels too [9].

1.2.2 Indian Perspective

Below is a definition of PA that is accepted in India:

*Precision agriculture, satellite farming, or site-specific crop management is farming based on observing, measuring, and responding to inter-and intra-field variability in crops.*

*Another interpretation is the following:*

*PA is an information- and technology-based farm management system to identify, analyze, and manage variability within fields for optimum profitability, sustainability, and protection of land resources.*

*The succeeding meaning also defines PA:*

*PA is the precision application of technologies and input based on soil, crop weather, and market demands to maximize sustainable productivity and profitability.*
Finally, another acceptable definition is in the next paragraph:

Precision forming is generally defined as an information and technology best for the management system to identify, analyze, and manage variability within fields for optimum profitability, sustainability, and production of land resources.

PA in India is different from the traditional models because the input, in this case, is of optimum quantity and has increased yield comparatively. The main components of PA are namely: information, technology, and management from a comprehensive system that improves the efficiency of production, its quality, crop efficiency, reduces energy utilization, and safeguards the environment. PA proves naturally beneficial for small farmers in developing countries due to more yield with minimum input.

Furthermore, the masses should be environmentally conscious while adopting PA. Hence, there is a demand to alter conventional agricultural management so as to make sustainable conservation of natural resources (i.e. water, air, and soil quality). The concept of five “Rs” in the PA explain further [10], [11]:

a. Right input (of fertilizers and pesticides)
b. Right time
c. Right place
d. Right amount
e. Right manner

This is called site-specific management. Market-based global competition in agricultural products is the main challenge of the traditional agricultural systems, so the scope of PA lies in this aspect [12]. In PA, we need to accumulate huge data that comes from a myriad of sources while mapping the factors of soil, crop, and environment of the field. Therefore, PA is said to be “information intense”. Figure 1.1 shows the information flow below.

The data is acquired from the internal factors (e.g. soil, crop, environment) and is then compounded by expert knowledge (e.g. the site data manager) as well as data from the existing market and the metrological department. The development of data integration tools, expert systems, and decision support systems makes the administration of this huge data more convenient (Sigirimis et al., 1999). There should be provisions in PA for the standardization of data formats [9].

Some basic steps involved in PA are illustrated through the succeeding flow chart [13]:

[Diagram reference]
1.3 NEED AND SCOPE OF PRECISION AGRICULTURE

The population of India is growing rapidly, and unless affordable technologies and solutions are developed for farmers and applied to minimize crop deficiency, food