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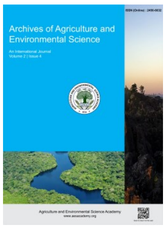

REVIEW ARTICLE

Future prospects of precision agriculture in Nepal

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ABSTRACT

Precision agriculture is a management system based on information and technology which analyses the spatial and temporal variability within the field and addresses them systematically for optimizing productivity, profitability, and environmental sustainability. It is an emerging concept of agriculture that implies a precise application of inputs at the right place, at the right time, and in the right amount to minimize the production cost, to boost profitability and reduce risks. The three main elements of precision agriculture are data and information, technology, and decision support systems. This system of management is known as 'Site-specific management' which makes use of technologies like global positioning system, global information system, remote sensors, yield monitors, guidance technology, variable-rate technology, hardware, and software. Agriculture is the mainstay of Nepal but still is not proficient enough to appease the daily consumption needs. The ongoing system of farming practices in Nepal is deemed insufficient to explore the available resources in its optimum potential. Many cultivable lands in the country are still a virgin, and many indigenous crop varieties have remained unexplored in their wilderness that is rich in biodiversity. These possibilities embark great room for increasing agricultural productivity through the precision farming system if adopted the technology on a large scale within the country. The national economy can be flustered and the environment can also be conserved using precision agriculture. It can address all agricultural and environmental issues. It is a technically sophisticated system and requires great technical knowledge for successful adoption and implementation. This study examines the history, global scenario, scope of precision agriculture, and its importance, opportunities, threats, and challenges in Nepal.

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INTRODUCTION

Nepal is predominantly an agrarian country that embroils 65.6 percent of denizens (Central Bureau of Statistics CBS, 2011) in farming and agriculture solely contributes 25.29% to the national GDP (Plecher, 2020). The farm sector contribution to the national GDP was 33 percent in the fiscal year 2014-15 and has been declining since then. This fall in the national GDP contribution is mainly accounted for a decline in cultivable land area and the labor force it demands, with these resources being diverted massively towards trade, tourism, health, and education sector. The horizontal expansion of land is limited to 0.14 hectares per capita due to urbanization and population growth. The traditional, subsistence farming system in Nepal is barely sufficient to fulfill the burgeoning domestic consumption needs. The rapid population growth, and the ongoing climate change crisis have further aggravated the problem of food deficit in the country. For the last two decades, the average annual growth rate of agriculture in Nepal has remained 3.2 percent without any sign of positive change. However, crop production and productivity have increased by 6.2 percent and 7.1 percent respectively in the last fiscal year which is still unsatisfactory (The Kathmandu Post, 2019). Despite boasting as an agrarian country, Nepal ranks 73rd out of 117 qualifying countries in the 2019 Global

Table 1. Conventional Agriculture Vs. Precision Agriculture.

Conventional Agriculture	Precision Agriculture
Choosing a location	
Manually	Using GPS, GIS and drones
Soil preparation	
Adding fertilizers and chemicals based on previous experience	Adding nutrients using sensors like temperature sensor, Humidity Sensor, Volatile matter sensor, etc. as per the soil requirement
Land preparation and leveling	
Bullocks and tractor operated scrappers and levelers	Laser-guided precision land leveler
Seeding and Planting	
Manually using hand tools	Precision drills, Seed drills, Broadcast seeders, Air seeders
Irrigation	
Flooding, Sub-surface irrigation, Bund irrigation, etc.	Drip irrigation using the internet of things
Fertilizer and pesticide application	
Hand spray and manually	Using drones, power tiller sprayer, electrostatic and air-assisted sprayer incorporating GPS, remote sensing
Weed removal	
Using hand tools	Using automated weeding machines
Harvesting	
Manual picking	Mechanical harvesting, limb shaker, robotic pick, and place arm, abscission chemical

Table 1. Conventional Agriculture Vs. Precision Agriculture

Data Collection Technologies	Data Process & Decision-Making Technologies	Application Technologies
Soil sampling and mapping Yield monitoring and mapping Global satellite positioning (GNSS) Remote sensing Field / crop scouting	Geographical info systems (GIS) Agricultural mapping software Geo-statistics Modelling Economic analysis	Variable rate application Agricultural robots Drones

Hunger Index (GHI). According to the report of Nepal Demographic and Health Survey (2016), 4.6 million people of Nepal are food-insecure (20 percent of household's mildly food-insecure, 22 percent moderately food-insecure, and 10 percent severely food-insecure). Similarly, 40 percent of children under 5 years of age are stunted and 10 percent of children are suffering from acute malnutrition. The country heavily relies on neighboring borders to meet the growing demands of food for its increasing population. Nepal imported agricultural products worth Rs. 220 billion in the last fiscal year alone (The Kathmandu Post, 2019). Agriculture, being the socio-economic backbone of the nation, still heavily relies on farmer's experience, physical labor, and mercy of nature for production. There is a staggering need for improving agricultural productivity to ensure food security.

The time has now arrived to fathom the crop and soil variability within the field and appose information technology and agriculture science to develop and disseminate systematic and efficient production techniques for sustainable crop production. This calls for a switch from conventional farming methods that operates at the high environmental cost to eco-friendly modern methods of farming for revolutionizing agricultural productivity. This can be achieved by adopting a Geographic positioning system based site-specific agriculture: precision agriculture which is a feasible approach that turns the extensive traditional production system into intensive production as per space variable data. Precision agriculture is comparably more propitious than conventional agriculture and offers good profits as compared to conventional agriculture (Table 1). Precision agriculture includes soil and spatial variation based on modern technologies and uses precise land leveling, seeding, fertilizer application, and irrigation to optimize crop production, ameliorate profitability, and reduce environmental risk. Improving traditional agricultural practices by integration with modern technologies is only possible using precision agriculture (Maohua, 2001). Nepal is a developing country and accomplishing a precision farming system is a way too far within a short period, but still, we can forward our journey towards revolutionizing agriculture and making the country self-sufficient in terms of food using the techniques of precision agriculture. The objective of this study is to explore the scope of precision agriculture, the need to introduce in Nepal together with its importance, advantages, challenges, and threats.

CONCEPTUAL FRAMEWORK OF PRECISION AGRICULTURE

The more relevant definition of Precision Agriculture in the Nepali ambiance could be the precise application of the agricultural inputs as per the intrinsic spatial variability, soil and weather conditions, and crop requirements for boosting the crop yield, profitability, sustainability, environmental conservation, and quality of the product (Figure 1). It is the management of field variability using ICT (Information, Computer, and Technology) (Gemtos *et al.*, 2013). Precision agriculture is a site-specific farming system of doing the right thing at the right place, at the right time, in the right amount, and in the right way

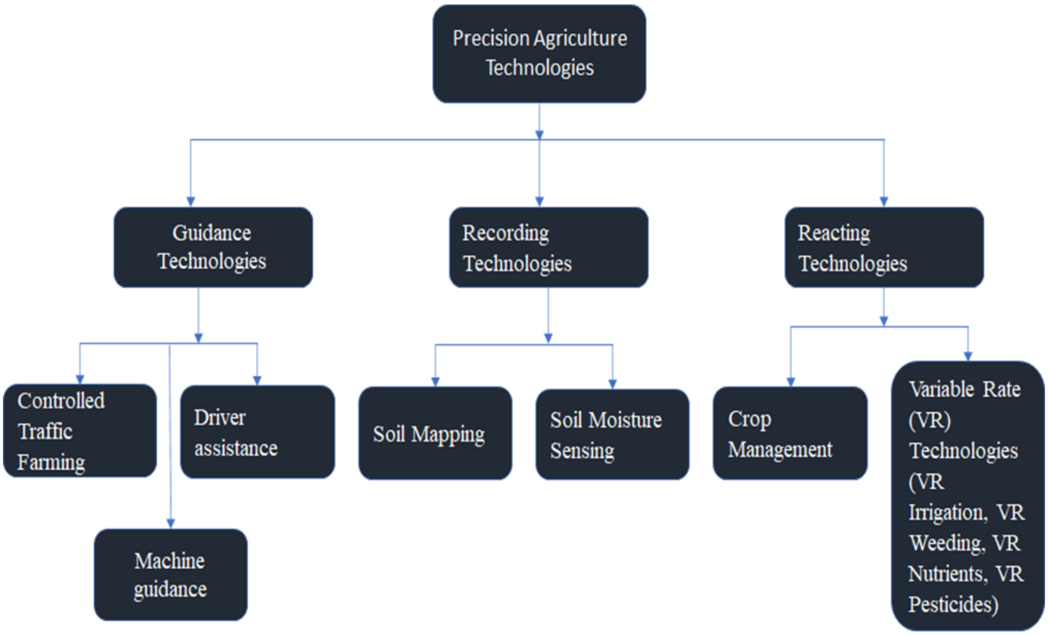

Figure 1. *Conceptual framework of precision agriculture.*

(Alemaw and Agegnehu, 2019). According to The International Society of Precision Agriculture, "Precision agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and amalgamates it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production". Precision Agriculture (PA) is a judicious crop management system that emphasizes at the micro-level and is "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 the environment" (Alemaw and Agegnehu, 2019). Precision farming brings farmers, crops, and agriculture scientists together regardless of their geographical difference and facilitates agricultural information collection, evaluation, and spontaneous as well as instantaneous decision making. It is a holistic approach that helps the farmer to manage the spatial and temporal variability within the field for agriculture revolutionization by increasing the profitability, optimizing yield and quality, and reducing cost (Paustian and Theuvsen, 2017) and is regarded as a paradigm shift in the management of spatial and temporal variability of soil and crop within the agricultural sector (Whelan and Mcbratney, 2000). Precision farming is an appealing concept (Hakkim *et al.*, 2016) which identifies the controllable yield-limiting factors and determines variability by using modern technologies such as geographical information system (GPS), remote sensing (RS) and geographical positioning system (GPS) (Tripathi *et al.*, 2013) (Table 2). The ability to locate the precision position in the farm helps to create the map of spatial and temporal variability of the variables such as crop yield, soil moisture level, organic matter content, nitrogen level, pH, topography, etc. (Mcbratney *et al.*, 2005) and implies site-specific management practices that economically optimize the yield while maintaining the soil, water, plant, and natural resources. Data and information, technology, and decision support are the backbones of precision agriculture (Abobatta, 2020). It is a direction of research rather than a destination (Biswas and Rao, 2000).

NEED OF PRECISION AGRICULTURE IN NEPAL

The population of Nepal is proliferating at an alarming rate so is the demand for food whereas the food productivity is at menace due to climate change, population pressure, uneconomic landholdings, decreasing agricultural lands, etc. The food production system faces formidable changes today which is genuine to increase in the upcoming days. Future agriculture will be severely knowledge-intensive, competitive, and market-driven. The horizontal expansion of the land is not possible due to the increasing population. This scenario demands an increase in food production within the existing agricultural land using modern methods of farming such as precision agriculture (Figure 1). The economic and environmental benefits of farming could be boosted through the precise application of inputs. Entire fields can be managed as per site-specific differences rather than hypothetical average which may not exist everywhere. With Precision Agriculture, farming can be automated and the collection and analysis of field information are simplified (Tripathi *et al.*, 2013) as well as soil and environment quality can be conserved. It allows site-specific management decisions on small areas within larger fields and succors to optimize production efficiency and quality.

HISTORY OF GLOBAL EVOLUTION PRECISION AGRICULTURE

Precision Agriculture is widely perceived as the third wave of the modern agricultural revolution. The first agricultural revolution; the machine revolution (1900-1930) led farmers to be apt to produce enough food to feed 26 people at that time with the introduction and implementation of mechanization. The second agricultural revolution (1990-2005) with new methods of genetic modification made farmers capable enough to feed 155 people. With the agricultural revolution of precision farming each farmer must be able to feed 265 people by 2050 (EY, 2017). The term "Precision Agriculture" was first used as a title of the workshop sponsored by Montana State University held in Great Falls, Montana. Before this, the term "site-specific agriculture" was used (Adl, 2014). Precision Agriculture was initiated with the introduction of GPS guidance for tractors in the early 1990s. John Deere introduced this technology using GPS location data from satellites (Schmaltz, 2017). Al Myers invented the on-the-go crop yield monitor in 1993 which led to the creation of detailed yield maps by linking the yield monitor data to the GPS plotted locations. In 1996, John Deere invented a GPS receiver nicknamed 'green eggs and ham' and launched the Green Star Precision Farming System. The first substantial workshop in Precision Agriculture was held in Minneapolis in 1992. The United States of America formally recognized Precision Agriculture by the drafting of a bill on PA by the US Congress in 1997 (Taylor and Whelan, 2005). Precision agriculture developed at a varying pace around the globe. United Nations, Canada, and Australia were the precursor nations (Dwivedi *et al*., 2017).

ECONOMIC PRECISION AGRICULTURE IN THE WORLD

Most of the farmers in the developed parts of the world are combining information technology with agricultural science and are exploiting all the modern farming tools and techniques however precision agriculture is still in infancy in the developing countries. The United States is the leading country in the adoption of Precision Agriculture. About 90% of the yield monitors in the world were operated in the US before 2005 (Fountas *et* al., 2005). (Norwood and Fulton, 2009) reported that 54% of farmers in the US adopted one or more precision farming technologies where 32% used yield monitoring and 32% used yield steering. In the US 85% of the agricultural dealers (Whipker and Akridge, 2009) and one-third of the cotton farmers (34%) (Paudel *et al*., 2011) used PA technology. (Erickson and Widmar, 2015) reported that the most popular PA technology in the US was GPS guidance with auto control (83%), GPS enabled sprayer (74%) and GPS control with manual control (63%) and 66% of the surveyed farmer used automated guidance and 42% used automated section control (Miller *et al*., 2017). In the 2000 harvest year, about 800 yield monitors were used in Australia (Mondal and Basu, 2009) and 80% of the grain growers used automatic guidance technology (Leonard, 2014). About 70% of the fertilizing and spraying machines in Europe are equipped with PA technologies (Armagan, 2016) and only about 25% of the European farmers use PA technologies (Cornelia *et al*., 2016). About 150000 hectares of land in France is managed using PA technology (Invivo, 2016). Developing countries like Argentina, Brazil, Turkey, India are also practicing PA technologies to some extent. Argentina is the second country with the highest number of yield monitors i.e. 1200 and the fifth country (after US, Denmark, Sweden, and Great Britain) with yield monitor density of 51 yield monitors per million hectares of land (Bongiovanni and Lowenberg-DeBoer, 2005). Soil sampling and GPS guidance is the most adopted technology in Brazil (Albuquerque, 2017). (Keskin and Sekerli, 2016) reported that about 500 combined harvesters in Turkey are equipped with a yield monitoring system. Leaf color chart-based Nitrogen management and laser-based land leveling is used in rice farming in India (Mondal and Basu, 2009). The adoption of PA technologies is in increasing trend around the globe and GPS guidance and yield monitoring system are more dominant. The precision farming market is approximated to grow from USD 7.0 billion in 2020 to USD 12.8 billion by 2025, at a CAGR of 12.7% (Farming Market, 2020).

THE SCENARIO OF PRECISION AGRICULTURE IN NEPAL

Nepal is still in infancy regarding the adoption of Precision Agriculture technology. However, Nepal has made some effort to blend ICT with agriculture. Project for Agriculture Commercialization (PACT) and Agriculture Management Information System (AMIS) under MOAD and several other organizations are working to increase the access of farmers to ICT. The Government of Province 5 has proposed the 'Smart Agriculture Village Program' with a budget amount of 360 million rupees which aims at increasing farmers' income through commercialization of agriculture (Kaini, 2019). Few agricultural applications like Smart Krishi, IFA Krishi, ICT for agriculture (Award winner app of Ncell App Camp, 2014) Krishi Ghar, Yuba Krishi, Farm Nepal, Hamro Krishi are available in the play store (Naharki, 2017) which provides reliable information regarding the agricultural sector. Also, a television show "Sajha Sawal" by BBC media group shows some successful farmers' stories to lure the youths towards agriculture. Various NGO's are working to increase market access to the farmers; for example, SMILES-Nepal is working in Sindhuli district to provide information to the farmers about the disease and pest control and market price through mobile SMS. Special management practices such as drip irrigation, sprinkler irrigation, Integrated Pest Management (IPM), leaf color chart-based Nitrogen management, judicious use of fertilizers and pesticides are being taken into consideration these days. Precision farming development requires huge technological advancement in Nepal.

TOOLS OF PRECISION AGRICULTURE

Precision Agriculture is a technically sophisticated farming system based on a vast array of tools including software, hardware, and the best management practices, and requires know-how of how to use these tools. These tools are described briefly in the following paragraph.

Global Positioning System (GPS)

Site specificity is the main concept of Precision Agriculture. Global Positioning System is a satellite-based radio navigation system that provides 3dimensional location data (latitude, longitude, and elevation) with accuracy between 100 to 0.01m at any time, in any weather and freely available (Sahu *et al.*, 2019). It comprises a complete set of 24 satellites orbiting around the earth in a designed pattern maintained by the US Department of Defence (DoD). GPS allows farmers to monitor crop conditions, macro- and micro-scale spatial variability of the soil (Brejda *et al.*, 2000) and locate the exact position of field features such as field boundaries, acreage for field crops, soil type, pest occurrence, disease-affected areas, weed invasion, water holes and obstructions (Dwivedi *et al.*, 2017) which allows the application of inputs(seed, fertilizers, pesticides, herbicides, water, etc.) based on performance criteria and previous input application (Batte and Van Buren, 1999).

Geographic Information System (GIS)

Geographic Information System is the brain of Precision Agriculture (Kumar *et al.*, 2017). This software is designed for the analysis of GPS-referenced data. It imports, exports and processes spatially and temporally geographically distributed data and stores them. GIS data sets can be converted to maps to illustrate spatial and temporal variability within the field. GIS data accumulated over time can be used to predict crop responses to the input, identify interactions affecting yield, and for record-keeping (Dwivedi *et al.*, 2017).

Variable-rate Technologies (VRT)

Adaptation of the parameters in the machine to apply the precise and variable amount of inputs in the right place, at the right time (Batte and Van Buren, 1999) according to the exact variation in the plant growth, soil type, and nutrient status is the practice of variable rate technology in precision farming (Chen *et al.*, 2013). VRT requires a multi-year analysis of one or more factors affecting the crop yield. Management zones with well-defined features can be created for management recommendations by the study of the yield values of crops of our interest (Sahu *et al.*, 2019).

Remote sensing

Remote sensing is a precision farming tool that uses sensors mounted on the spacecraft or satellites to monitor the changes in the wavelength of light from the growing crops and fields. It helps to monitor the spatial and spectral changes over time at high resolution (Moran *et al.*, 1997). The spatial-temporal changes help to understand the field variability over time and help to differentiate crop species, locate diseased and pest attacked plants, monitor stress, soil, plant, and drought condition. Remote sensing data helps to evaluate two components of crop production: yield (Edlinger *et al.*, 2012) and acreage (Zhang *et al.*, 2013).

Mapping

Mapping of the crop and soil properties is the first and most important step in precision agriculture. It is the graphical representation of geo-referenced data on crop yield of a defined area. It includes procurement, analysis, and summation of crop yield data within a field (Alemaw and Agegnehu, 2019). It aids in measuring the spatial variability and helps and forms the basis for controlling spatial variability. Data for mapping are collected through yield monitor, sensor, a group of sensors (Alemaw and Agegnehu, 2019), or sensing instruments such as soil probes, electrical conductivity, and soil nutrient status (Tripathi *et al.*, 2013). Mapping can be done manually during field operations using remote sensors and GIS.

Crop management

Data from satellites, GPS, GIS, remote sensors provide a better understanding of the spatial and temporal variability within the field to the farmers. Farmers can, therefore, precisely manage inputs and production factors such as seed, water, fertilizers, labor, pesticides for increasing yield and efficiency (Hakkim *et al.*, 2016).

Grid sampling

Grid sampling is the method of breaking the field into smaller blocks or grids of about 0.5-5 hectares for increasing the intensity of sampling. Samples collected from grids have location information which helps in mapping. Samples taken from the grids are analyzed in the laboratory and the nutrient requirement of each grid is determined. The goal of grid sampling is to form a map of nutrient needs also known as application map (Hakkim *et al.*, 2016).

Yield monitors

Yield monitors are the device installed on harvesting machines for measuring the crop yield. Yield monitors include a combination of different sensors, user interface (display and keypad), storage device, and a computer that controls the interaction and integration of these components (Hakkim *et al.*, 2016). It records and a store yield data at regular intervals along with the positional information from the GPS unit and creates a yield map.

Proximate sensors

Proximate sensors measure crop properties and soil parameters such as Nitrogen content and pH as the sensor attached tractor passes over the field. The soil sample is scooped, pressed against an electrode for the stabilization period of about 10-15 seconds and the reading is taken.

Real-Time Kinematic (RTK) System

Real-Time Kinematic system is a GPS based navigation system that enhances the precision of location data from satellites (Wikipedia Contributors, 2020). This high accuracy guidance system helps to avoid costly skips and overlaps and saves cost on inputs and also reduces operator stress. This system uses a fixed base station that transmits location to the GPS receiver in the rover to correct its position concerning the known position of the fixed base station within 1-2 cm accuracy (Dwivedi *et al.*, 2017). It enables accurate row-to-row positioning.

Automated steering system

An automated steering system is an autopilot solution for agricultural machinery. It is an integration of a high precision navigation system and software which enables agricultural machinery to move along a pre-set path. It helps to manage rows accurately, reduces farmer fatigue, and reduces fuel cost, input cost, and over-application of chemicals.

Robots

Robots navigate the field and carry out assigned tasks effectively. It reduces farmers' drudgery. Sensors in robotic systems can monitor soil and plant nutrient levels and supply nutrients accordingly.

Drones

While precision agriculture is the brain of farmers, drones can be regarded as the body of farmers (Smith, 2018). Drones are used to observe soil and crop, their growth, texture, condition of diseases, and pests. They can also be used for spraying chemicals. Drones take high-quality images so they can be used to create contour maps, determine variable seeding rate, and create yield maps (Dwivedi *et al.*, 2017).

Internet of Things (IoT)

Internet of Things is an internet-based system that enables physical objects to be sensed and controlled remotely (Agriculture Victoria, 2019). Physical devices that communicate with each other using sensors can operate using IoT. It creates direct integration between the physical world and the computer-based system.

IMPORTANCE OF PRECISION AGRICULTURE

It makes a significant contribution to maintain food security.
Improves the farm operation system.
Provide solutions to ensure food safety and sustainability.
Provides social security to farm at risk.
It allows a more precise application of inputs and results in higher yield at a low cost.
It allows easy supervision of the farm.

STRATEGIES FOR DEVELOPMENT OF PRECISION AGRICULTURE IN NEPAL

Nepal, being endowed with biodiversity has huge potential for boosting agricultural production and the economy of the country as a whole. So, there is a great need for the adoption of precision farming strategies for the upliftment of productivity. Successful adoption is comprised of three stages: exploration, analysis, and execution (Shanwad *et al.*, 2004). In the exploration stage, data on crop yield, soil, and weather characteristics are collected and mapped which serves to increase awareness among the farmers. The yield-limiting factors and their interrelationship with each other are determined using GPS based modeling system in the analysis stage and the controllable factors and management actions are prioritized. Lastly, the variable rate application of inputs and cultural operations are carried out in the execution phase. The precise application of inputs is adopted. Precision farming can lead the country towards food sufficiency. That is why effective plans and policies for the adoption of precision agriculture are important. Following are the strategies to be implemented:

Strategy 1: Changes in agricultural policies

Changes in agricultural policies are essential for the adoption of precision farming. The National Agricultural Policy 2061 aims to uplift the living standard of farmers through sustainable agriculture by transforming subsistence agriculture into commercial and competitive agriculture. The policies should be so changed that it aims for sustainable as well as eco-friendly agriculture. The penalty should be called for pollutant generators to reduce the unwanted use of inputs and the who opt for an eco-friendly system of farming should be rewarded.

Strategy 2: Intensifying research, development and commercialization

The focus should be driven to develop quality seeds, fertilizers, integrated disease, and pest management, and the package of practices as per the area.
Research to develop climate-resilient crops needs to be conducted.
New technologies and research must be spread to the farmers in collaboration with the Nepal Agricultural Research Council (NARC), District Agriculture Development Office (DADO), Directorate of Agricultural Extension (DAE), colleges, and universities.

Strategy 3: Promoting skill development

Agricultural and entrepreneurship skills of the farmers should be enhanced.
The current skill sets of farmers should be upskilled using modern technology and good agricultural practices.
Start-up grants and soft loans should be made available.

Strategy 4: Improving market access

Agricultural product marketing must be improved by linking consumers with commercial outlets and more markets must be established.
Agricultural products must be promoted in relevant international markets through trade and food exhibitions.

Strategy 5: Scaling up agricultural financing

Subsidized credit programs should be enabled to promote research and development on precision agriculture.
Fixed terms, as well as flexible loans, should be made available.

SWOT (STRENGTHS, WEAKNESS, OPPORTUNITIES, THREAT) ANALYSIS OF PRECISION AGRICULTURE

SWOT-analysis helps to analyze lists of important factors regarding precision agriculture. Towards strength, it plays an important role in increasing crop productivity and enhancing production quality (Györg, 2009) and promotes food security and sustainability. PA allows more precise application of inputs such as seed, fertilizers, labor, water, pesticides, and enhances the crop production at low cost (Balafoutis *et al.*, 2017). It assists farmers in different farm operations from land preparation to harvesting, and reduces input, increases profitability, and protects the environment (Maheswari *et al.*, 2008) and enables them to identify various stages of crop growth, make judicious use of natural resources (soil, water), and protect the environment from various hazards (Abdulwaheed, 2019). PA provides accurate information regarding soil fertility, crop productivity, water supply, disease, and pest outbreak which help the farmers in decision making to make the right policies (Grisso *et al.*, 2011). It offers proper information to the farmers to help them make the right decision at the right time (Ess DR, 2002). The use of precision agriculture increases water resources use efficiency and reduces the excessive use of chemicals in soil consequently leading to environmental protection. PA influences work practices and living conditions of farmers and help to increase new agribusiness models.

Precision Agriculture possesses many weaknesses too. The initial capital cost is very high which may discourage the rate of adoption among the farmers (Demirbas, 2018). It requires several years of data collection to implement this system in developing countries (Yigra and Hassan, 2010) and the collection and analysis of data is an extremely difficult task (Wiseman and Sanderson, 2018). Precision agriculture is technically sophisticated and requires expert advice. Such creative technical manpower who can analyze the data and make smart decisions are usually limited in developing countries (Mcbratney *et al.*, 2005). Farm size in the developing countries is small which necessitates the formation of large entities for the implementation of PA (Katke, 2019).

Some opportunities enable the implementation of Precision agriculture in Nepal. Growing usage of smartphones and ICT in agriculture paves a path towards PA. A study suggested that about 42% of farmers are eager to reap benefits from emerging ICT technologies and ICT contributes about 5% in improvement in the agriculture sector (The Kathmandu Post, 2016). With the network coverage over 90% of the country and smartphones getting cheaper the use of ICT among farmers is increasing. The diversified geographical pattern of Nepal with diversified topography, temperature ranging from 4-40°C, and rainfall ranging from 250mm to 6000mm create enough potential for crop production which can be intensified by using precision agriculture.

Despite several strengths and opportunities, PA encompasses some threats that attack the agricultural sector (Chae and Cho, 2018) as PA is connected online permanently and is a mechanical intensive industry. PA technology may not be fully accepted among the farmers. Lack of standardization may lead to ineffective technology development. Information theft is one of the major threats in PA. Relying on various embedded and connected technologies, PA is always exposed to malicious cyber threats. PA is exposed to natural disasters, terrorist attacks, equipment breakdown too. Intentional data theft, publishing, and sale of confidential information may lead to a loss of reputation. The introduction of rouge data to damage the crop, disruption of navigation, communication networks, and positioning is also a major threat.

Conclusion

Agriculture being the socio-economic backbone of the nation necessitates the implementation of Precision Agriculture to accelerate food productivity at a reduced cost, achieve food security, safety, and sustainability, and conserve the environment. It is still only a concept in Nepal and requires strategic assistance from both public as well as private sectors for successful adoption. Precision agriculture a way of research for revolutionizing agriculture and is a systematic implementation of the best management practices into a site-specific system. The concept of 'doing the right thing, at the right time and the right place' is an intuitive appeal. It is a technically sophisticated system of farming and requires technical manpower with the know-how of modern-day machines. PA can offer solutions to the agricultural and environmental issues of today. The major issues of conventional farming such as scarce input, change of weather patterns can be addressed using precision agriculture. However, farmers are most likely to adopt this system of farming only if it provides more or at least the same returns compared to the conventional methods of farming. The successful adoption depends on how well and how quickly the knowledge needed to guide the new technologies develops in Nepal. Assistance from the government and private sectors and training regarding the use of modern technological devices is a must for the development of precision farming in Nepal.

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