Chapter 1

Introduction

1.1 Background

An agricultural production system is the outcome of a complex interaction of seed, water and agro-chemicals including fertilizers and pesticides. Therefore, careful management of all inputs is essential for the sustainability of such complex system. The focus on enhancing the productivity without considering the ecological impacts of the input resources has resulted into environmental degradation. The productivity can be increased without any adverse effect by maximizing the resource input efficiency. It is also certain that availability of labor for agricultural activity is going to be in short supply in future. The time has now arrived to bring information technology and agricultural science together for improved economic and environmentally sustainable crop production. This gives birth to Precision Farming.

1.2 Precision Farming and Tools of Precision Farming

1.2.1 Precision Farming

Precision Farming is generally defined as information and technology based farm management system to identify, analyze and manage variability within fields for optimum profitability, sustainability and protection of land resources. Precision Farming is helping many farmers worldwide to maximize the effectiveness of the crop inputs including seed quality, fertilizers, pesticides and irrigation water [1].

However, the conventional definition of Precision Farming is most suitable when the land holdings are large and enough variability exists between the fields. In India,
the average land holdings are very small, even with large and progressive farmers. The more suitable definition for Precision Farming in the context of Indian farming scenario could be: precise application of agricultural inputs based on soil, weather and crop requirement to maximize sustainable productivity, quality and profitability [2].

Today, because of increasing input costs and decreasing commodity prices, the farmers are looking for new ways to increase efficiency and reduce costs. In this regard, Precision Farming is an alternative to improve profitability and productivity.

1.2.2 Tools of Precession Farming

Precision Farming is a combination of application of different technologies. All these combinations are mutually inter related and responsible for developments. The same are discussed below:

1. **Global Positioning System (GPS):** It is a set of 24 satellites in the Earth orbit. It sends out radio signals that can be processed by a ground receiver to determine the geographic position on earth. It has a 95% probability that the given position on the earth will be within 10-15 meters of the actual position.

2. **Geographic Information System (GIS):** It is software that imports, exports and processes spatially and temporally geographically distributed data.

3. **Grid Sampling:** It is a method of breaking a field into grids of about 0.5-5 hectares. Sampling soil within the grids is useful to determine the appropriate rate of application of fertilizers. Several samples are taken from each grid, mixed and sent to the laboratory for analysis.

4. **Variable Rate Technology (VRT):** The existing field machinery with added Electronic Control Unit (ECU) and onboard GPS can fulfill the variable rate requirement of input. Spray booms, the Spinning disc applicator with ECU and GPS have been used effectively for patch spraying. During the creation of nutrient requirement map for VRT, profit maximizing fertilizer rate should be considered more rather than yield maximizing fertilizer rate.

5. **Yield Maps:** Yield maps are produced by processing data from adapted combine harvester that is equipped with a GPS, i.e. integrated with a yield recording system. Yield mapping involves the recording of the grain flow through the combine harvester, while recording the actual location in the field at the same time.
6. **Remote Sensors:** These are generally categories of aerial or satellite sensors. They can indicate variations in the colours of the field that corresponds to changes in soil type, crop development, field boundaries, roads, water, etc. Arial and satellite imagery can be processed to provide vegetative indices, which reflect the health of the plant.

7. **Proximate Sensors:** These sensors can be used to measure soil parameters (N and pH) and crop properties as the sensor attached tractor passes over the field.

8. **Computer Hardware and Software:** In order to analyze the data collected by other Precision Agriculture technology components and to make it available in usable formats such as maps, graphs, charts or reports, computer support is essential along with specific software support.

### 1.3 Scope and Limitation in Adoption of Precision Farming in India

Precision Farming concepts are applicable to all agricultural sectors like animal farming, fisheries and forestry. Precision Agriculture (PA) can be classified into two categories namely ‘Soft’ PA and ‘Hard’ PA. ‘Soft’ Precision Agriculture mainly depends on visual observation of crop and soil and management decision based on experience and intuition, rather than statistical and scientific analysis. Whereas, ‘Hard’ PA utilizes all modern technologies like GPS, GIS, VRT, etc.

In India 96 million farms out of a total 105.3 million farms have less than 4 hectares (ha) area [3]. Though only fragmented lands are cultivated, the present food grain production in India is nearly 200 Million Tone, which has made India self-sufficient in food production. To compete with the world production, the crop yield per hectare must be economic and without environment degradation. In India, overall fertilizer consumption rate is 84.3 Kg/ha, which must be reduced by systematic soil testing and creating nutrient maps along with fertilizer recommendations [3].

Along with nutrient zones pest control, disease and weed management also plays an important role in high yield of crop. Using advance technology, it is possible to monitor and control the pest and disease at lower costs. Some states like Punjab, Haryana use high doses of fertilizer and pesticides. For example, the state of Punjab has 1.5% of total geographical area of India, but uses 1.38 million tones (nearly 10% of all India fertilizer consumption) of NPK fertilizer along with 60% of weedicides used in India.
Overall exploitation of land as well as excessive use of agriculture input are typical problems of these areas [3].

Stress management is another area where Precision Framing can help Indian farmers in scheduling irrigation more profitably by varying the timing, quantity and placement of water. Mechanization of farming helps the farmers to reduce the labor cost and to improve the accuracy of farming including quality seed selection, weed removing, pesticide and fertilizer application, harvesting and sorting of the crop as per the quality.

There are many limitations to adoption of Precision Farming in developing countries in general and India in particular. Some of these limitations are common to those in other regions; however, following are specific to Indian conditions:

1. The culture and perceptions of the users,
2. Small farm size,
3. Lack of success stories,
4. Heterogeneity of cropping systems and market imperfections,
5. Land ownership, infrastructure and institutional constraints,
6. Lack of local technical expertise,
7. Availability, quality and cost of data.

1.4 Need of Precision Farming in Sugarcane Agriculture

India is world’s second largest producer of sugar and sugarcane [4]. Sugarcane is cultivated in about 4.09 million hectares, producing about 283 million tones of cane with an average productivity 69.19 MT/ha. Of the several agriculture crops, sugarcane is the most remunerative, its requirements for water and fertilizer are also equally very high. About 60% of cane in India is in the Subtropical Zone and 40% in the Tropical Zone. The productivity is 89 MT/ha in sub tropical zone and 58 MT/ha in tropical zone. The productivity in Madhya Pradesh is lowest, 39.3 Mt/ha and that of Tamilnadu is highest, 134.2 MT/ha in the country [4]. The productivity of sugarcane is declining due to following reasons:

1. Non availability of high yielding varieties,
2. Dearth of good quality seed,
3. Improper water management,
4. Use of imbalanced doses of fertilizers,
5. Negligence in plant protection,
6. Low awareness among the farmers to use improved cultivation practices,
7. Poor attention to Raton crops.

1.5 Literature Review

A brief literature review of major research work carried out in the field of Precision Farming is given below:

RGV Bramley and RP Quabba [2] Explain the opportunities for improving the management of sugarcane production through the adoption of Precision Agriculture. This paper reports some preliminary research into sugarcane yield mapping that has demonstrated how other industries are making use of the technologies embodied in Precision Agriculture.

U. K. Shanwad et.al [3] described the dreams and realities related to Precision Farming for Indian agriculture. They highlighted the different issues, need, basic components and basic steps of Precision Farming. The explanation ends with comments on the present scenario, prospects, obstacles and opportunities of Precision Farming in India.

Pinaki Mondal et.al [4] carried out the critical review on Precision Agriculture technologies and its scope of adoption in India. Precision Agriculture concept was initiated for site specific crop management as a combination of position system technology, variable rate technology, remote sensing and yield mapping, etc. to optimize the profitability, sustainability, with a reduced environmental impact. They noted that the challenges of free globalized market as well as ever-increasing population with huge food grain demand created the need of adoption of hard Precision Agricultural technology in Indian farms. Remotely sensed data has been identified as an important tool for precision crop management.
E.M. Barnes et.al [5] detected concurrently the crop water stress, nitrogen status and canopy density using ground-based multispectral data.


S. Erasmi and M. Kappas [7] determined the crop stress using spectral transformation of hyperspectral data. The major outcome of the investigation was that the quality of a spectral normalization to produce an input variable for the prediction of concentrations depends on a variety of critical factors. In general, simple spectral ratios can be used to describe the heterogeneity of crop physiology but the red edge inflection point seems to be sensitive for changes becomes of plant stress compared to the NDVI.

Sandor Lenk et.al [8] used multispectral fluorescence and reflectance imaging at leaf level to characterize plants and their health status. In contrast to conventional point measurements, imaging detects the distribution and quality of signals. This improves the interpretation of fluorescence and reflectance signature.

E. Raymond Hunt et.al [9] proved that remote sensing with unmanned airborne vehicles has more potential for within-season crop management than conventional satellite imagery. Inspection of the colour-infrared photograph revealed large spatial variation in biomass and leaf area index within each treatment strip. As with most aerial photograph, there are problems in the imagery with lens vignette and vegetation anisotropy. The green normalized difference vegetation index reduced the effect of this image problem and was linearly correlated with leaf area index and biomass.

Eguchi H. et.al [10] used digital image processing for the images of plant in two wave bands of Red and Infrared for evaluation of growth. The attempt was to extract clear pattern of plant image from the background. Two wave bands of red (670 nm) and infrared (900nm) regions were selected on the basis of spectral characteristics of leaf reflectance. Used for taking R and I images in phytotron glass room by a TV camera. These images were digitized for computation and denoted as respective matrices of Red (MR) and Infrared (MI), where each matrix element was expressed as reflectance. From MR and MI, difference in reflectance between R and I bands was given as MS. In MS, the plant image was clearly separated from the background. So, a sum of the elements of MS was used as a parameter for evaluation of the growth.
Cheryl McCarthy et.al [11] developed a real-time and automatic machine vision sensor for measuring structural parameters such as length of plant in growing cotton crop. Plant geometry is a significant factor for irrigation in cotton because the distance between main stem nodes indicates water stress in a growing cotton plant.

M. R. Mobasher et.al [12] used broad band digital camera for sugarcane phonological date estimation. While doing this, it was noticed that the effect of a layer of soil dust on the leaves can limit the capability of the procedure. A comparison of histogram of RGB bands in each leaf photos before and after the dust removal showed that the effect of the dust on Difference Normalization (DN) values in each of three RGB bands can be estimated. This was done by calculating the difference between mean DN values in each band before and after dust removal.

LIU Yaju and CAI Zhenjiang [13] developed computer vision system for monitoring plant growth. They concluded that the individual plant could be distinguished from the images by computer image processing. This was done by collecting the growing images of the young plant leaves, measuring biophysical and biochemical indices and counting each colour eigenvalue. The developed measuring models could be used to measure the relation of full nitrogen content, which was essential for plant growing with chlorophyll.

Mikko Hautala and Mikko Hakojarvi [14] designed the plant growth models for Precision Agriculture. In order to make the simulation feasible, crop growth and water transport models were kept as simple as possible taking into account the objective of the simulation. Therefore, the number of parameters was also held low and each had a clear physico-chemico-physiological meaning.

Hiroya Kondou et.al [15] designed experiment for getting the information on the tree growth using digital camera instead of the human eye. They studied nutrient conditions of grape leaves to find out change in shape and colour of leaf. The outline data of the leaf was analyzed in the polar co-ordinate so that the character of the shape was quantitatively classified. This experiment helps the farmer to cultivate the agricultural products of high quality.

Enrique Rico-Garcia et.al [16] investigated two new methods to measure leaf area of the plant, using digital photographic processing in MATLAB and Computer Aided Design (CAD) software. They compared the result of these two methods with standard method (LICOR) and found coefficient of correlation of above 99%.
Chaohuri Lu et.al [17] measured leaf area based on image processing. Hough transformation was used to acquire the coordinates of quadrangle corner points in the distorted image. Then, image segmentation was performed using threshold method. The contour extraction was used to eliminate the influence of the holes in the leaf and finally leaf area was measured by pixel number statistics.

Marlon Marcon et.al [18] built a model based on indirect measures to estimate the leaf area in coffee plants using image analysis. They evaluated two models, one based on the height and width of the canopies and other based on the area of the digital image of a tree. The accuracy of the result was 82 %.

Shigeto Kawasima and Makato Nakatani [19] estimated chlorophyll content of leaves using a portable colour video camera and a personal camera. They have shown that the red-blue and green-blue wavelengths have the highest correlation with chlorophyll content under limited range of metrological condition. They had also shown that the accuracy of measurement of chlorophyll could improve by correcting solar radiation data.

J. K. Sainis [20] developed software to measure the intensity of colour for each leaf disk in an arbitrary unit of intensity called inverse integrated gray value per pixel which is proportional to the actual concentration of chlorophyll per pixel.

Pablo J. et.al [21] estimated chlorophyll under natural illumination from hyperspectral data and demonstrated that the effects of natural chlorophyll fluorescence are observable in the reflectance red edge spectral region.

Xingmei Suo et.al [22] developed artificial neural network based prediction system for extraction of leaf population chlorophyll content from the cotton plant images. This system need of training with leaf green pixels, extracted from a set of cotton plant images following a two-step procedure. In the first step, a global thresholding and pixel-labeling algorithm is applied to the image to help to identify green leaf pixels and all the identified green pixels were labeled as red. In the second step, background noise was suppressed by using an omnidirectional scan noise filtering, coupled with the hue histogram statistic method. They found the average prediction error for chlorophyll density is within 62%.

Mark Steele et.al [23] developed a precise, efficient, non-destructive technique to estimate total chlorophyll index, based on reflectance in the red-edge (710-720 nm)
and near infra-red (755-765 nm) spectral range.

Parviz Ahmad et.al [24] estimated single leaf chlorophyll content in sugar beet using machine vision. To estimate chlorophyll status, a neural-network model was developed based on the RGB (red, green, and blue) components of the colour image captured with a conventional digital camera. The results of the experiment were compared with the results of the SPAD (Soil Position Analysis Development) meter values and estimated Mean Square Error (MSE) was 0.06.

Hao Hu et.al [25] have developed relationships between chlorophyll content and leaf image colour indices in the RGB and L*a*b space in comparison with SPAD meter. They have also shown that the RGB colour indices of R, G and R+G+B, R-B, R+B, R+G and the L*a*b space parameter had a significant relation with chlorophyll content. Excessive use of pesticides for plant disease treatment increases the danger of toxic residue level on agricultural product and is among the highest components in the production cost so their use must be minimized. This can be achieved by assessing severity of disease and target the diseases places with the appropriate quantity and concentration of pesticides.

J. K. Sainis [26] developed the software to quantify the extent of infection on different parts of the plant. They used the image enhancement technique, adaptive histogram equalization, median filtering, thresholding and morphological operation for the measurement of final count of insects on the leaf.

A. Apan et.al [27] used discriminant function analysis to select an optimum set of indices based on their correlations with the discriminant function. The predictive ability of each index was also assessed based on the accuracy of classification. Results demonstrated that Hyperion imagery can be used to detect orange rust disease in sugarcane crops.

Dimitrios Moshou et.al [28] detected yellow rust in wheat using reflectance measurements and neural networks. Yellow rust infection on winter wheat can be detected in the field by means of a visual spectrograph in ambient lighting conditions. High spatial resolution spectra must be normalized with irradiating spectra.

M. Mirik et.al [29] used digital image analysis and spectral reflectance data to quantify damage by greenbug in winter wheat.
Rajesh Pydipati [30] investigated the use of computer vision and image processing techniques in agricultural applications for citrus leaf disease classifications. Algorithm was based on feature extraction and classification of colour co-occurrence method. The manual feeding of the data sets in the form of digitized RGB colour photographs was implemented for feature extraction and training the SAS statistical classifier. They found 95% overall classification accuracy.

Sungkur Roopesh K. et.al [31] designed and implemented a reliable and efficient automated system to recognize fungi caused disease spots on sugarcane leaves. They used algorithms such as the chain code technique, bounding box method and moment analysis and tested for suitability in the recognition of sugarcane diseases. The recognition precision of the implemented system was found to be 95.3%.

Kridsakron A. et.al [32] collected and analyzed reflectance characteristics of sugarcane leaves infected by white leaf diseases using field spectroradiometer and chlorophyll meter. The results were then applied to gain spectral index of infected sugarcane plot which were similar to those with spectral value from satellite imagery.

Di Cui et.al [33] explored feasible method for detecting soybean rust and quantifying severity. In this study, images of soybean leaves with different rust severity were collected using both a portable spectroradiometer and a multispectral CCD (Charged Coupled Device) camera. Different forms of vegetation indices were used to investigate the possibility of detecting rust infection. Results indicate that at the leaf development stage and rust infection stage both were changing the surface reflectance, within a wide band of spectrum.

K. Moshashi et.al [34] designed algorithm for mechanizing sugarcane planting by machine vision system and image processing method. This algorithm used convolution, thresholding and look-up table operation for identification of sugarcane nodes and sent the cut-point position of two consecutive nodes to microcontroller.

1.6 Motivation and Problem Definition

India is an agriculture based country, wherein seventy percent of the population depends on agriculture. Diverse nature of India, uncertainty in rainfall, effect of pests, diseases and stress on the crop can cause decrease in crop production. Sugarcane Industry remains one of the main pillars of the Indian economy, though it is facing many problems. The area of land under sugarcane cultivation is still significant in many
states of India.

To increase the crop productivity, farmers approach experts to seek their advice for quality seeds selection, to know the growth conditions, to control different stresses and diseases. Sometimes they have to travel long distances to contact experts. Even after travelling such long distances, the expert may not be available at that time or they may be not able to advise the farmer. In such cases seeking the expert advice is very expensive and time consuming.

To increase the average sugarcane yield per hectare with minimum cost, an alternative solution is to adapt the ‘Hard’ Precision Agricultural concept. This concept uses advanced technologies to maximize the effectiveness of the crop inputs including Seed selection, Growth and Disease monitoring, Weed controlling, Fertilizers, Pesticides and Irrigation. The Precision Agriculture (PA) uses data from GPS, GIS, and Remotely Sensed Images for monitoring, analyzing and controlling the stress, diseases and other issues.

In rural areas it is difficult to access these types of data and in India 91% farmers are marginal farmers so the cost of these tools is not affordable to those farmers for farm management. Now trends are going towards group farming, in this case the alternative solution is to use the CCD images as a data for crop management. The advantages of this technique over others are as follow:

1. Images have very high resolution,
2. Cloud cover those not prevent acquisition of images,
3. Quick delivery of information to the user is possible and
4. Low cost of technology.

The following are the objectives of presented research work: To design efficient algorithms using CCD images for:

1. Seed selection and to locate the cut point in between nodes of the sugarcane stalk,

2. Crop status management:
   - Measurement of growth of sugarcane,
   - Measurement of chlorophyll content of sugarcane leaf,
- Measurement of disease severity of sugarcane leaf, upto two growth stages of the sugarcane.

1.7 Research Methodology

The research was initiated with the writing of a project plan, which includes the objectives, and the time plan. The next stage was a bibliographic study of related work and relevant theory so as to get acquainted with the topics. After this, images were captured and ideas were transferred into algorithms. The performances of the algorithms were tested on the captured images. The results were evaluated and discussed, leading to new ideas or changes of parameters in the algorithm and ways to capture the images to improve the results. The final stage was the summary of research and some proposals for future applications. The report writing was partially carried out during the work but formed the dominant activity during the final weeks of the research.

1.8 Outcome of the Research

As an outcome, the following results are confirmed in this research work using image processing method.

1.8.1 Seed Selection

Sugarcane planting with traditional methods is costly, time consuming, it needs great human force, more numbers of sugarcane stalk per hectares. Also, because of the unskilled labor, stressed or diseased buds may get planted that result into low yield. Recently, sugarcane planters used to avoid labor work and time saving but these machines have no control over the cutting position of the stalk and identification of the diseases. This causes loss of the seed and plantation of the diseased buds.

To solve this problem, algorithm is designed for automation of sugarcane planting machine using image processing. It detects the normal nodes efficiently and locates the cut point for stalk cutting. It rejects cutting of stressed and diseased sugarcane stalk.

The success rate of normal node identification of sugarcane stalk by designed algorithm is 95%, for the defective node identification is 86% and for stressed node identification it is 100%. This type of research has been conducted for the first time for sugarcane planters.
1.8.2 Crop Status Management

Measurement of Growth of Sugarcane Plant

Traditionally, the plant geometrical parameters are measured using tape and protector. The tools are the simple, while the procedure is hard and results are not accurate. Accurate measurement of growth is carried out by designing efficient image processing algorithm. Algorithm is tested on different conditions of the +1 dewlap of the sugarcane plant. The results of the experiment are compared to the growth measured by meter scale. The accuracy of measurement of the growth by algorithm is found to be greater than 96% with Root Mean Square Error (RMSE) 0.2872.

Measurement of Leaf Chlorophyll

Disadvantages of the traditional methods of measurement of chlorophyll is high cost of SPAD meter, difficult to use remote sensing systems in rural area and chemical analysis work is more time consuming.

In the work presented here, the chlorophyll meter (CM1000) readings are considered as standard reference. Experiments are successfully conducted to measure the chlorophyll content of sugarcane leaf with RMSE 1.9334 only between actual and predicted chlorophyll.

This methodology is also useful to measure the chlorophyll content of the leaf of other plants by simply changing model parameters.

Measurement of Leaf Disease Severity

The naked eye observation method and Grid counting methods are generally used to measure the disease severity in the production practice of sugarcane agricultural, but results are subjective and it is not possible to measure the disease extent precisely.

In this research, severity of brown spot disease is measured with the help of image processing technique. The accuracy of the experiment is 98.60%. The calculated diseased severity percentage and disease severity scale developed by agricultural scientist Horsfall and Heuberger is helpful to farmers to decide the specific quantity and concentration of pesticide to control the disease which would ultimately reduce the production cost and help to maintain the ecosystem.
1.9 Organization of Thesis

A brief overview of the thesis is as follows:

Chapter 1- Introduction discusses briefly about Precision Farming and scope of and limitation of adapting Precision Farming in India. After discussing the need of Precision Farming in sugarcane agriculture, this chapter presents extensive overview of literature survey of Precision Farming and existing techniques in agriculture. In next step chapter presents the motivation, problem definition, research methodology, outcome of the research and outline of the research work presented in the thesis.

Chapter 2-The Sugarcane: An Agricultural aspect is devoted to sugarcane botany, requirement of soil and climate, varieties, planting season and methods, sugarcane management. Precision Farming practices in sugarcane are also discussed in brief.

Chapter 3- Image Processing: An overview reviews basic image processing and image analysis system.

Chapter 4- Image Processing Method for Seed Selection explains the constraints of quality seed selection for sugarcane crop. The chapter also describes in detail the implementation right from acquiring image till classification of image including preprocessing, feature extraction and certain segmentation techniques. The results are also discussed.

Chapter 5- Image Processing Method for Crop Status Management describes in detail, the implementation of image processing algorithms for sugarcane crop management and result e.g. growth measurement, chlorophyll measurement and disease severity measurement.

Chapter 6- Conclusion and Future scope the conclusions derived from the results together with brief description of research work are presented. The future scope of this work is highlighted.

Appendix A Agricultural Terminology gives the meaning of various agricultural terms used in the thesis.

Appendix B Readings of seed selection includes image numbers, condition of nodes tested by proposed algorithm in normal, stressed and diseased condition.
Appendix C Readings of growth measurement gives image number, growth measured by meter scale and proposed algorithm, Deviation Factor and Accuracy of measurement.

Appendix D Readings of chlorophyll measurement gives image number, chlorophyll measured by chlorophyll meter and proposed algorithm.

Appendix E Readings of disease severity measurement gives image number, and disease severity measured by proposed algorithm.

Appendix F Authentication letter for node detection.

Appendix G Authentication letter for growth measurement.

Appendix H Authentication letter for chlorophyll measurement.

Appendix I Authentication letter for disease severity measurement.