CHAPTER I
INTRODUCTION

1.1 Background

Agriculture, being the most primitive profession of the civilized man, draws much attention to its development, beginning with the shifting cultivation and progressing to advance precision farming. Population increase and advancement in the civilization made man to inhabit at one place and to cultivate the same land year after year. Now agriculture became a profession and is given the name commercial agriculture, and precision agriculture or sustainable agriculture as being the part of it. India being an agrarian country, agriculture is the major source of income for about three fourth of the population who lived in villages. India is characterised by small farms; nearly 80% land holdings owned by famers belong to marginal farmer group, with < 2 ha land holding. Majority of crops are still rain fed, with only about 45% of the land being irrigated. According to some estimates, around 55% of total population of India still fully depends on farming(Tupe , 2009; kaur, 1991). Agricultural production planning in India evolved around achieving self-sufficiency in food, fuel and fibre. Initially, production strategies started with resource-based extensive approach and this continued to the sixties of the last century. Agriculture is not only a major profession of the mass, but also a way of life, culture and custom of the whole population. Agriculture is one of the oldest economic activities of man. Agriculture has contributed nearly 18 percent of India's GDP (Arjun, 2013). Agriculture is the largest private enterprise in India, has been and will continue to be the lifeline of the Indian economy, at least in the foreseeable future. It provides livelihood of about two-thirds of the population, accounts for 52 percent of the national work force and forms the backbone of the agro-based industry. Besides, agriculture is a social sector where non-trading concerns like food and nutritional security, employment and income generation, poverty alleviation, gender equity, ecology and environment plays a significant role Kashyap (2010). Demand for food will further increase in the 21st century (Dyson, 1999; Johnson, 1999; Rose grant *et al.,* 2001 and FAO, 2003) which can only be met through increase in production area or in the amount of production per unit land area, henceforth ‘productivity’. The growth in food grain production is a result Green Revolution to increase all the inputs needed for maximizing the crop yield through, better quality seeds, right proportion fertilizer and pesticides, improved irrigation and skill development of farmers. Green Revolution supported in achieving sustainable development of high yielding varieties, modern irrigation facilities, crop inputs market facilities, availability of capital, transportation and education of advance technology changed the view about the cropping pattern in India.

Acute conditions of poverty available in India can be reduced with devising and implementing an appropriate scheme of agricultural development. Even though India has one of the world largest cropping areas, its agricultural production is low and inadequate to meet the food and other requirement of the country. Therefore the present agricultural patterns and future development plans must be understood and formulated in the light of prevailing natural and social conditions. A study of manner in which physical conditions influence the pattern of agricultural land use is therefore necessary. Rapid population growth, increased food demand, and urbanisation are the main causes that have created tremendous pressure on agricultural land, making it an increasingly scarce resource (Bhuiyan, 2001). In many developing countries with increasing population pressure, the scope for expansion of cultivable area is limited. Moreover, there is a growing competition for land from non-agricultural sectors like industrialization and rapid urbanization. Buringh (1982) estimated that approximately 25 million hectares of agricultural land worldwide is lost annually because of rapid increase of non agricultural uses. The per capita availability of land in India is 0.14 hectare at present which is likely to go down to 0.09 hectare by 2030. Thus, increase in agricultural production must be achieved through ensuring higher productivity from each hectare of land by increasing cropping intensity and inclusion of high yielding as well as high value cash crops. Important considerations for developing sustainable cropping systems depend upon several factors like soil, climate, available technologies, irrigation facilities, socio economic constraints of the farm community, infrastructure facility, food habit and market demand and thus, needs to be suitably manoeuvred.

The cultivated land is found to be moderately suitable for agricultural crop cultivation due to a number of constraints (including low fertility, low crop inputs, lack of soil reclamation activities etc.) in most of the developing countries (Fischer et al., 2001). The intensification of agriculture including increasing number of crops per year and mixed cropping etc., are the most likely means to meet food demand of growing population. Land resource and available crop inputs need to be utilized to the fullest extent. Land suitability analysis can act as prerequisite for giving sustainability to agricultural production in developing countries. Agricultural crops generally best suited to the locations where the surrounding climatic conditions (including precipitation, temperature, relative humidity etc.) to fulfil their growth parameters. Soil type, slope, elevation, land cover and additional relevant factors that directly or indirectly affect suitability for crop growth. Land suitability assessment (LSA) for agriculture is to evaluate the ability of a land holding to fulfil the optimal ecological needs of a particular crop species or type. Hence, estimating the capability of a particular land is enabling optimum crop input application, growth and maximum productivity. Without including the economic condition consideration, a physical suitability evaluation shows the degree of suitability for a particular land use (Rossiter and Van Wambeke, 1997). The knowledge of land resources and crop practice records are some of the essential needs, especially in developing countries, where resources are often available in limited quantity. In order to identify an appropriate land use and to reduce the influence human activities on natural resources, it is essential to carry out physical land evaluations studies. With higher population density in India, it intensifies the pressure on available natural and agricultural resources. Optimum use of land and resource are required to fulfil the food demand of the ever growing population in India. Accurate and reliable LSA is necessary in formulating long term landuse policies for sustainable development and promising better return to farmers. Hence, land suitability classification is very much essential in grouping specific land areas means of their suitability for specific use keeping an eye on future demand. To provide the most desirable dimension for future development, the suitability for multiple land uses should be carefully studied by directing growth to the most appropriate sites. Establishing accurate and sustainable suitability factors is the major constraints of suitability analysis. Careful planning of the utilization of land resources is based on proper LSA, which is the process of estimating the suitability of the particular land for alternative land uses (Fresco et al., 1994). Information on land resources is a key to their careful and effective evaluation. The Food and Agriculture Organization (FAO) of United Nations' initiative to contribute to the wise use of land resources by man primarily focused on land evaluation systems. Many countries over time have developed their own systems of land evaluation and the need was felt for some form of standardization. This resulted in development of a framework for land evaluation (FAO, 1976; 1983) that can be applied to a wide variety of physical, economic and social environments, and to a broad range of planning and decision support purposes.

Land evaluation is the assessment of land potential for productive land use types, and then generally a comparison or match of requirements of each potential land use with the characteristics of each kind of land. The results are a measure of suitability of each kind of land use for each type of land. Identification of suitable crops for different regions will help development agencies in land use planning and suggest alternate land use for farmers for optimum utilization of soil resources. The planning of sustainable land management (SLM) is an urgent requirement during the 21st century. Smyth and Dumanski (1993) described SLM as a system integration of policies, technologies, and activities aimed at linking socio-economic principles with environmental concerns to, maintain or boost productions/services; minimize the risk in various level of production; protect the natural resources; prevent degradation and support restoration of soil and water resources; be economically profitable; and socially acceptable.

Though one of the biggest producers of agricultural products in the world, India and its farmers have been suffering from low farm productivity. Productivity needs to be enhanced, so that farmers can get better remuneration from their landholdings with less labour. LSA along with precision agriculture may provide a way to do it. GIS/RS based land suitability incorporated in precision agriculture (PA), as the name implies, refers to the application of precise and accurate amounts of crop inputs like water, fertilisers, pesticides etc. at the correct time to the crop for increasing its production and maximising its yields guided by GIS/RS technology. The goal of the farmers should be able to identify better crops and crop rotations, use the seed to reciprocate it further and hence in future become a breeder of sorts. Early adoptive farmers generally do that and with more time available to them due to PA technology, they can grow high yielding varieties and improve crop productivity and add new dimension in Indian agriculture.

1.2 Problem Statement

Agricultural growth has a significant impact on poverty reduction (Ravallion and Datt, 1996). Declining trend in the supply of institutional credit in the post-reform period in India has also been responsible for near stagnation in yield levels (Vyas, 2001). Adoption of HYVs technology without considering the soil and moisture conditions, inadequate rural infrastructure, weak network of agricultural marketing, sharply skewed land distribution and tenancy laws against the tenants in most part of the country, are the major impediments to agricultural growth in India (GOI, 2000). The improper use of chemical fertiliser and pesticides in technology-intensive production of rice and wheat largely account for environmental degradation and erosion of soil fertility. Against this backdrop, this chapter attempts to discuss some of the recent issues of agricultural development in Hooghly district, West Bengal.

In the selected study area, agriculture is the major profession of the people. The major crops in the study area includes rice, oilseeds, jute and potato. The prospect of changing cropping pattern towards fruits, vegetables as observed in Hooghly has also been examined in the context of openness of market for agricultural commodities. The major cropping patterns of the District are Jute/ Aus paddy/ Vegetables/Til; *Kharif* Paddy Vegetable/ Oilseeds/ Pulses/ Boro Paddy etc.

Agriculture contributes a significant proportion of district income. Almost one third of the district income comes from agriculture. As per 2011 census, the majority of the workers are occupied as Agricultural labourers (38.09 per cent), and Cultivators (19.55 per cent) in the study area. The average yield of rice (Aus- 2715 kg/ha, Aman 3193 kg/ha, Boro- 2661 kg/ha), potato- 31MT/ha and jute- 17 bales per hectare were found in the irrigated plots of the study area in the year 2013-2014 (B.A.E and Directorate of Agriculture W.B, 2012). The farmers grow rice, potato and jute as a cash crop in the study area, so the profit level should be enhanced to improve the economic condition of the farmers. As observed (B.A.E and Directorate of Agriculture W.B., 2012), the productivity of several principal crops viz., rice and potato are much higher compared to State and National average (Rice - WB: 2573 kg/ha and National: 2203 kg/ha;) but remained more or less stagnant. In fact, for potato crop, the productivity of about 22 MT/ha (Potato-National yield: 17 MT/ha) is the highest in the country (SREP Document, PAO, Hooghly District, 2011). Hooghly is an agriculturally prosperous district of West Bengal. The land use pattern of the district demonstrates a high proportion of net sown area as percentage of total reported area (about 70.01% in 2005-06) (District H. D. R: Hooghly, 2011; District Hand Book, Hooghly, 2006). Among major agricultural crops of this District, paddy covers 53 % of the gross cropped area at present. But the area, production and productivity of the crop remain almost stagnant. In case of Boro paddy negative growth in terms of productivity has been observed mostly due to poor soil health management practice, Pest management practice etc. Second major crop of the district is potato grown in 87,000ha area ranked first with respect to area and production in the State. Productivity also fluctuates due to natural calamity. Jute, another major crop, is cultivated in nearly 14000ha area of the district. Since pulse are considered not very remunerative, poor attention is being paid by the farmers, as a result the , productivity of pulse crop is low as compared to the potential yield of the crop (NABARD, 2012).

In irrigated areas there is very good opportunity for the application of the modern technology as most of the inputs (like irrigation level, quality seed, nutrients, pesticides and use of high yield varieties) can be regulated, to achieve the yield potential and sustainable agricultural crops.

1.3 Rationale

The land-use suitability evaluation with GIS approach is leading to higher cropping intensities and yield goals in agricultural production. Some of the new technologies and approaches used in PA seem to be appropriate for eradicating the prevailing inefficiencies in crop production practices in the developing countries. The study developed a methodology and guidelines for land-use suitability evaluation using multi-criteria analysis, which could systematically evaluate the significance and could imitate the potential of the system for higher gains. A land suitability evaluation criterion was developed using geographic information system (GIS) and Remote sensing (RS) for the selection of lands for PA technology adoption. The application of GIS techniques in PA is multipurpose, such as conservation of important plant species in land-use planning, land-use suitability evaluations, crop selections and rotations, irrigation and mechanisation planning etc. (Setojima et al., 1988; Yanamoto,1988; Cruz, 1992; Gouvenian, 1995; Swain, 2001; Runquist et al., 2001). In developed countries large land areas are divided into square grids for analysing the special variability of management properties. The average farm size in the developed countries like USA is 182 hectares (Statistics on USA, 2002) and that of Europe is 20 hectares (Hennessy, 2003). The smaller average farm-size in the developing countries restricts its further sub-division into smaller grids, which cannot be economically justifiable in any means. However, in GIS, an individual small farm plot could be considered as a single grid unit (Aronoff, 1989). Land suitability analysis for Precision Agriculture (PA) helps properly in managing crop production inputs in an environmentally friendly way while increasing profits (Jin and Jiang, 2002). It is a strong possibility that appropriate adoption of PA could be helpful in addressing the poverty alleviation, food security, improved livelihood as well as sustainability in agricultural production under developing country context (Maohua, 2001). In the developed countries, Agricultural land use suitability PA with cutting-edge technology has been practised for past decade with tremendous success (Srivastava, 2001). The access to the affordable technology and sincere government support assisted with intensive research work has created a healthy environment for Agriculture land use suitability PA technology adoption in developed countries. The meaningful adoption of PA technology could be promising in enhancing the productivity as it has already been proved in some applications in developing countries (Cook et al., 2003; Zhang et al., 2002). Therefore, in this study, the current standard of the PA technology was slightly modified to suit the conditions of developing countries. PA is a better usage of resources and control mechanisms to improve production efficiency, reduce input costs, and reduce environmental impact. PA focuses on a level of detail smaller than the size of an individual field. It can be described as a new concept for sustainable utilization of agricultural resources, and this can be achieved by managing agricultural systems based on information and knowledge. The term "precision agriculture" can be used in more general terms such as the application of information technology across all aspects of agriculture, in which case Site specific Management (SSM) forms one component, of it defined as the management of agricultural crops at a spatial scale as small parcel of the whole field. In PA, land suitability analysis research so far has been involved in a lot of work on yield monitoring (e.g. Colvin and Arslan, 2000) and some work on quantifying soil variation (e.g. Godwin and Miller, 2003; Adamchuck et al., 2004) for variable-rate application (VRA) of inputs. Today the major focus is to be on some form of zone management (Whelan and McBratney, 2003), but there are not many formal Decision Support Systems (DSS) and no well-designed strategies that are flexible enough to incorporate these practices and concepts into the range of management processes that operate in the practical world. The true practical applicability of PA technology really remains linked to high-tech agriculture. Vehicle guidance (and auto-steer) systems are being adopted widely because, from a user's point of view, economic benefits are readily achievable without the need for much, or any, added decision support or system component integration. The essence of PA is to obtain more data on production processes and to convert that data into information that can be used to manage and control those processes. Information can be characterized by various attributes, including timeliness, accuracy, objectivity, completeness, clarity, and convenience. These attributes can be applied to the crop information used in, and information about, PA techniques. The greatest technology push has been in precision agriculture SSM- where sensing, information technologies, and mechanical systems enable sub-field crop management. Despite this push, acceptance by the agricultural community has been hesitant and weak, although most producers admit they will have to adopt SSM technology eventually. The general perception is that Agricultural land suitability approach cannot be applied for small-scale farms of developing countries. If only 'hard PF' is considered, this concept is true. Searching for 'appropriate PA technology' for small farms is a real challenge faced by scientists and engineers. A number of options for the application of the PF philosophy in these countries have been discussed (Cook et al., 2003). PF can be implemented through improved agronomic decision making on the same spatial scale by increasing the number of decisions per unit time and by using some Decision Support System (DSS) tool (Alex, 2005). Agriculture land use suitability paradigm in PA is facilitating the prospects and scope for switching over to modern agriculture leaving the traditional one by utilizing right resources in right time and management, which results an environment friendly sustainable agriculture. The precision farming developments of today can provide the technology for the environment friendly agriculture of tomorrow. Especially in the case of small farmers in developing countries, precision farming holds the promise of substantial yield improvement with minimal external input use (Fountas et al., 2004). So, Rapid socio-economic changes in some developing countries, including India, are creating new scopes for application of precision agriculture (PA) based land suitability approach.

1.4 Scope and Limitations

In this study the relative efficiency of GIS land use suitability map based soil nutrient parameters as compared to the conventional soil testing for prediction of native fertility level in farmers' fields for PA adaptation technology. Exploring the use of such maps as an aid for effective nutrient management of rice-potato-jut-lentil cropping system in the study area and given the best suggestion to use the proper nutrient practice for their crop field. It has been hoped that the results of the study will be useful for developing an understanding about the efficiency of GIS land suitability mapping with relation to conventional soil testing method with special reference to alluvial soil zones. The information generated through this study is also expected to help in optimizing the grid sizes for such mapping and, at the same time, assessing the possibility of using GIS land suitability maps through plot-to-plot soil testing in an efficient manner.

The major expected output of this research is to provide farmers upto date knowledge of quality and fertility level of their agriculture land. Without knowledge of the soil quality, they are using fertilizers, chemicals etc. blindly, which is mostly over used affecting soil quality in long run. Soil testing is very important and through testing of soil, farmers will discover and get to know the nitrogen, potash, phosphorus and organic carbon contents of the soil. Consequently, soil quality information, farmers will have the advantage of fixing the right fertilizers type, rate and timing for a particular crop. The final outcome of this research is that it helps us to identify with capacity and limitation, in accordance with suitability of the agricultural land. Due to time constrain, interlinking land suitability to field may not achieved; but further research is required to tackle all this issues. Research may be under taken to study the long term effect of integrated nutrient management practices on soil fertility dynamics and productivity. Studies are needed on quality parameters of the produce with application of higher amount of organic sources of nutrition, crop rotation approach and climatic, topographic, irrigation facilities, market infrastructure and socio economic factor are also needed for land suitability evaluation for agricultural planning in the study area. It is important to create the soil database and land information system, including soil types, soil fertility, terrain, current land use pattern, climate, slope, vegetation cover, soil erosion, land unit map. This will give much room for development and also improve the land suitability evaluation standard. This land suitability analysis gives an idea where should farmers produce rice, so that they can be benefited from that land. In addition to this, proper set of guidelines is mandatory for the management of nutrients being contributed by all stakeholders, which will enhance crop yield.

This exploration is a biophysical evaluation that provides information at a local level that could be used by local farmers to select their cropping pattern. Additionally, the results of this study could be useful for other investigators who could use these results for diverse studies. For further study, we propose to include more number of factors such as, topography, climate, irrigation facilities and socio-economic factors etc. which influence the sustainable use of the large scale land. Consequently, the results obtained from this study indicate that the use of GIS-RS and application of MCA using AHP could provide a superior database and guide map for decision makers. The study has further explored the importance of GIS as a useful supporting tool in integrating social-economic and soil data for community development.

It is important to produce soil databases and land information system along with soil types, with GIS software, allowing users to use, edit, update, overlay and analysis to create a map which fulfil the requirements of the study problem. Application of other information tools such as: remote sensing (RS) images, Global Positioning System (GPS), etc. should be persuaded, as it will helpful in bringing near real time variation in land use and management strategy. Low pH soil, being not suitable for crop production should be enhanced upon through liming to raise the pH to suitable levels. further validation exercise should be done with real production figures in future, this would further strength the results presented in the study.

In the present study, separate GIS maps were prepared for different soil properties with AHP. For making the technology more easily adoptable, all these maps may be integrate together in a single map and specific management zones be identified for undertaking soil fertility based fertilizer application practice. Main scope of this research study indicate the integration of

RS-GIS, Fuzzy-logic-Quantifier and application of Multi- Criteria Evaluation using AHP could provide a superior database and guide map for decision makers considering crop land substitution in order to achieve better agricultural production in PA Land use suitability adaptation technology.

Limitations

Present investigation showed that GIS land suitability map based soil nutrient parameters may be considered as an effective tool for predicting agricultural land suitability status of agricultural soils leading to partial substitution of plot to plot soil analysis. However there is a few limitations in the study. Such as:

- Though the positive results of this initial study has indicated that this technology may open a new dimension to facilitate soil fertility based fertilization, more studies need to be carried out to develop effective packages for successful utilization of GIS mapping for this purpose.
- For further validation of the results of the study, it is felt that multi location trials may be carried out covering different soil classification zones with GPS coordinate integrated soil sampling point of the state or country for agricultural land suitability evaluation.
- Similar kind of studies need to be taken up with different kinds of soil series also.
- It is a continuous process and needed for long term assessment approach for the land suitability analysis for the agricultural planning. The laboratory facilities available in the department are insufficient and overcrowded. For these reasons we could not study some important aspects of soil, (eg. Presence of micro nutrients, trace elements in the soil etc.) which could provide further insight into the nature of problems of agricultural land utilization in the study area.
- As mentioned earlier, this is a new field of study and limited work on use of GIS-land suitability assessment have so far been carried out in India. Good amount of studies are to be carried out for further development of this technology as a simple but effective strategy for land suitability based nutrient management.
- It is necessary for taking determined efforts in this regard. Continuous effects are needed to integrate the latest science and technology developments into the methodological arena of land evaluation. Big data generated by various Earth

observation satellites, for example, is one of the many directions that deserve more attention.

- Land fragmentation is measured to be the main difficulty for large-scale agricultural mechanization in the study area. But these fragmented lands are cultivated in a family accountability system, and all small farmers have been following consciously or unconsciously 'soft' land use suitability PA technology for centuries.