Comprehensive sustainable cultivation development plans based on statistical/ mathematical models - A brief review of the literature

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Abstract- The development of agricultural sector directly influences the level of global development of economies and societies. Due to rapid increase of the population, demand for food has increased. The rehabilitation of extensive ancient agricultural network and massive new development in this sector is the viable solution for this pressing problem. Thus there should be a proper cultivation plan. This study presents a comprehensive review of the literature published between 1998 and 2018 on sustainable cultivation development plans based on statistical/ mathematical background which have considered major influential factors for cultivation. This study aims at reviewing the most appropriate sub sections: arable land selection, cultivating methodologies and climatic factors effect on cultivation which need to build a sustainable cultivation plan. A review was carried out using the following search terms: cultivation plan, optimal harvest, agricultural plans, development of agriculture, arable land selection, climatic factors effect on cultivation, cultivating methodologies and optimal cultivation plans. Articles published in English language were considered. Searching strategy was fails to identify a published article which considered the aforementioned three aspects together. Thus this study was done by using articles focus on sub sections separately and discussed with mathematical or statistical models.

Index Terms- Arable land, Optimal cultivation plan, Optimization techniques, Sustainability

I. Introduction

The agriculture is the back born of the economy of most of the Asian countries. Although the country is moving towards industrialization, the agricultural sector still continues to be an important sector in the economy. Due to rapid increase of population, demand for food is increasing. If the agricultural sector fails to supply and meet the rising demand of food, it will affect the economy of a country. Therefore, it is essential to find a viable solution, that is balanced supply demand food chain. For that, there should be an organized agricultural strategy. To fulfil subsistence food needs, it is important to have a proper cultivation plan in agricultural sector. This paper reviews the literature on statistical/ mathematical models which were used to develop a sustainable cultivation plan.

Lack of a proper cultivation plan is a threat for sustainability of the traditional farming in large rural areas. A proper cultivation plan will provide details of which crop should be cultivated in which area, the quantity that should be cultivated and the best time period for cultivation. On the other hand, consideration of environmental factors effect on cultivation will lead to achieve a best plan for sustainable cultivation. The present study is an attempt to review the various models, approaches and techniques specifically used for optimum cultivation planning. However, this study evaluates the statistical/ mathematical models which have been used various programming approaches for the development of agricultural sector.

Water management is an important part of agriculture. In general, researches have formulated various models for water management. Dai and Lia proposed that, developing a linear programming (LP) model for water resources planning and management to cultivation regions can be optimize the exploitation from surface water resources which helps decision makers to determine suitable cultivation pattern [1]. Further Dai and Lia mentioned that, support of the food chain in agriculture is one of the major part of rural development. A predominantly challenge for the agriculture is water management. Some researchers proposed a multistage irrigation water allocation (MIWA) model as a solution for water management by considering fluctuating water availabilities and demands. For many decades, in many countries the scarcity of water resources has become a serious problem due to the rapid population growth and shift in economic development. Agriculture requires the large amount of water, which places even more importance on agricultural water management. By developing a water resources planning model, the watering requirements for plants in arable lands can be fulfilled in full capacity.

To build a sustainable cultivation plan, some articles proposed an optimization model using “assignment algorithms” to recommend a crop type, suitable time period and land. The literature reveals the availability of statistical/ mathematical models for sustainable cultivation plan, but those studies have focused on only one or few factors. Thus this study summarizes the factors effect on cultivation and how to make the sustainable cultivation plan under mathematical background by reviewing many research articles.

Suitable land for particular cultivation can be selected by conducting a soil survey and based on results of the land quality checking and identification of land characteristics. Astee L.Y focused on viability of rooftop farming by considering several factors in his study. In that cultivation plan mainly he concerned about several design constraints for existing block typologies and rain water harvesting using an appropriate method (landscape opportunities) [2]. Based on soil survey results, suitability of the land and suitable crop type can be observed [3].

II. MATERIALS AND METHODS

The following search terms were used in this review: cultivation plan, optimal harvest, agricultural plans, development of agriculture, arable land selection, climatic factors effect on cultivation, cultivating methodologies and optimal cultivation plans. These terms were inserted in the fields "article title," "abstract," and "keyword." In the first search round, a large number of research articles were found related to the sustainable cultivation development plan. This first searching round based on the keywords which are located within the text instead of being matched to subject headings. Then move to the advanced searching, that is, chose to add boolean operators AND and NOT to exclude the headings "cultivation" and "rainfall". The final search strategy was: ["decision making" OR "Planning and management" AND "statistical techniques" AND "cultivation patterns" AND "agricultural development" AND "profit" NOT "lost"]. These strategies produced about 50 articles that were closer to the topic of interest published between 1998 and 2018. Out of the 50 references identified initially, 25 were excluded after review of the titles and abstracts or else non English publications and research which are not under mathematical background and the summary of final 25 articles is given in the Fig 01.

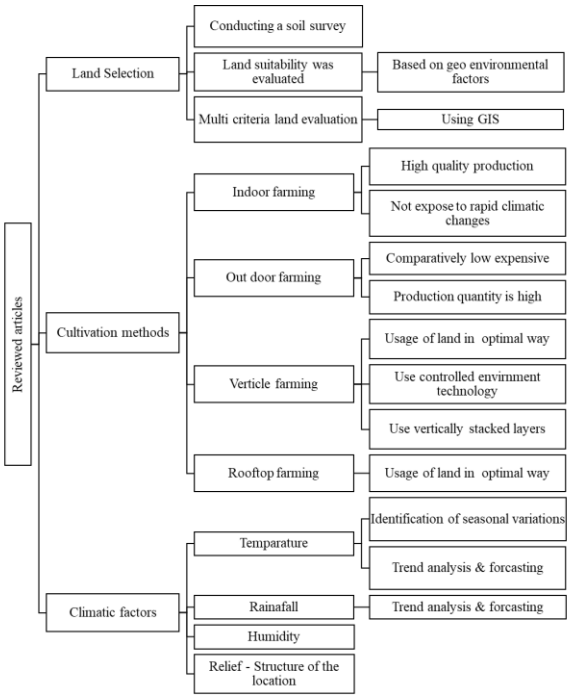

Figure 1: Summary of searched strategy for the period 1998 to 2018

III. RESULTS AND DISCUSSION

Most of the earlier studies deals with a particular specific area in agriculture. Because of that this research was conducted by reviewing different approaches separately.

A. Arable land selection

The main step of a cultivation plan is selecting a suitable land for cultivation which is done by a land evaluation as one of the systematic method. Numerical analysis was conducted by Elsheikh to identify the suitability of land for cultivation by considering the requirements like water, nutrients, avoidance of erosion and etc. [6] By conducting a soil survey and based on land qualities and land characteristics the best land for particular cultivation can be selected. Mathematical models were used to identify the patterns and the variations of the identical factors related to soil selection. Astee L.Y discussed viability of rooftop farming by considering several factors in his study. Mainly he concerned several design constraints for existing block typologies and rain water harvesting in appropriate method in his study [2]. Arable land can be identified by conducting a soil survey. Allocation of arable land for perennial crops, annual crops and seasonal fruit crops were accompanied according to the seasonal variations of the soil conditions [3]. Elsheikh proposed an intelligent system for assessing arable land for cultivation of different kinds of crops. Geo environmental factors were considered in that study and further he proposed agricultural land suitability evaluation which was helped to determine the quality of land for cultivation. Further this study was intended to support decision makers to plan and make decisions related to cultivation [4]. Using geographic information system (GIS) Ceballos proposed a multi criteria evaluation approach to identify arable lands for cultivation. Further, numerical analysis was conducted in that study to evaluate the land suitability [5]. As literature implies further about the sustainable cultivation, selection of suitable land for cultivation is a must. Specifications of the numerical models used in articles are summarized in Table I.

Table I: Description of the specifications of the numerical models used in referred articles.

Study category	Number of articles	Summary	Country where study was carried out	Reference number
Arable land Selection	4	Optimization of land resource - Rooftop farming	Singapore	1
		A dynamic program for calculation of eigenvalues and eigenvectors of a weighting matrix is provided. Expertise and	Malaysia	3

		knowledge help ensure that ALSE databases represent realistic, practicable and functional systems. Optimization of land resource – Vertical farming	USA	7
Cultivation method	7	Optimization of land resource – Vertical farming	New York	7, 8
Climatic factors	11	Climate change will have a significant impact on smallholder profitability economic impact of climate change on agriculture The effect of rainfall intensity on soil erosion and particulate phosphorus transfer from arable soils Prediction of temperature	Sri Lanka USA UK India	12 13 14 19

B. Cultivation Methodologies

In order to obtain high quality vegetable product, Gruda proposed that indoor production is more profitable than outdoor production for vegetables based on quality of the product [6]. The reason that the researcher mentioned in his study is: indoor productions are not exposed directly to the rapid climatic changes. Further, conditions created with in the cultivated environment will effect on quality of the production. On the other hand, there are considerable environmental harms like soil degradation, pollution of ground water and surface water. Although indoor production is popular and effective cultivation method, it may course huge environmental disasters like greenhouse effect.

C. Climatic factors effect on cultivation

Geographical changes like availability of slopes, mountains and urbanization are challenging the horizontal farming in most agrarian countries. To avoid or minimize this challenge, many researchers proposed a most appropriate solution to overcome problems as use of controlled environment technology vertically stacked layers commonly integrated into other structures like a skyscraper, shipping container or repurposed warehouse and produce food in it. This is known to be vertical farming which practice the cultivation on vertically inclined surfaces [8]. Aforementioned innovative method, commonly referred to as vertical farming has emerged in recent years and has become an increasingly relevant part of the movement toward sustainable urban agriculture [9 - 12].

Climatic changes have a significant impact on smallholder and farmers profitability in Sri Lanka [13]. Further, global warming causes the huge harm to agriculture in developing countries as many arable lands in the low latitudes already endure climates that are too hot [14]. By forecasting rainfall data with in the study area, a proper cultivation plan can be developed by including the major factor affecting cultivation [15]. By developing an inter-annual, inter-decadal and long-term trends of extreme rainfall, farmers can get rid of disasters occur due to rainfall [16]. Figure 2 illustrate the environmental factors effect on cultivation. By improving sustainable production by investigating all influential factors like water resources, temperature, humidity, rainfall, soil type, fertilizers, pest insects, crop rotation and etc. will lead to improve the yield.

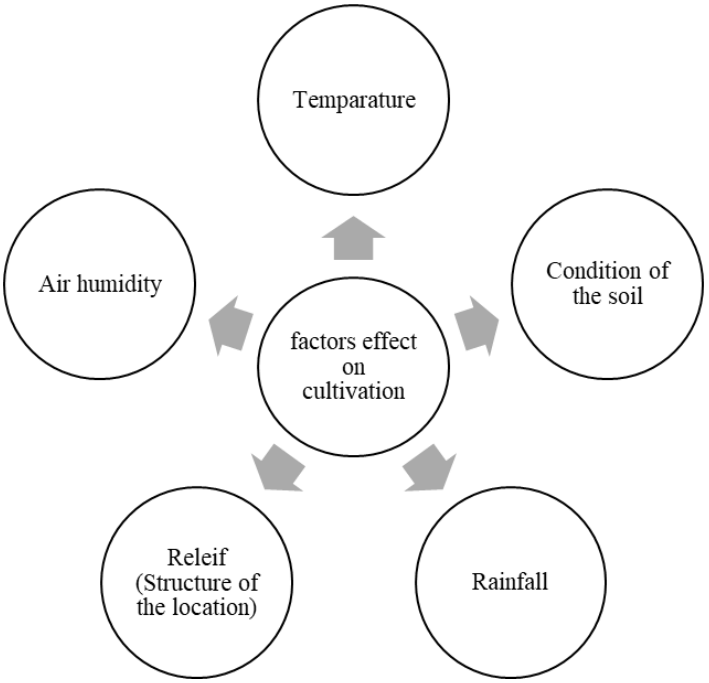

Figure 2: Environmental factors affecting cultivation

Evaporation and transpiration together called evapotranspiration. The combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration is referred to as evapotranspiration (ET). By considering the relationship between saturation vapor pressure and temperature, evapotranspiration was calculated [17]. This is one of the most important considerable factor on cultivation. Rainfall is obviously key factor which influence on cultivation. It is very important to decision makers to have a proper model to forecast rainfall for particular cultivation areas. Using Mann-Kendall statistical analysis, Nikhil, was able to identify the characteristic of seasonal and monthly rainfall. To find out the trend of rainfall researcher used Kendal's rank correlation statistics and wavelet analysis [18]. Seasonal variation is important as different crops require water at different times. Due

to soil moisture deficit sustainable plant growth cannot be expected. Reasons for soil moisture deficit are high temperature, high rates of evapotranspiration and very dry soil.

Similarly, conducting a trend analysis on temperature, erratic pattern can be identified. Further, based on a proper predictive model, the temperature for future period of time can be forecasted [19]. Farmers adapted to the climatic changes and they have confidence in dealing with climatic changes. Because of engaging in extensive agriculture those communities can decide climatic changes which can be affect to their cultivation. Bryant discussed adaptation of agricultural communities in his study area to climatic variability and change [21]. The effects of climate change on rice production was investigated by Mukand using the CERES-rice crop growth model [22-25]. In that study, the CO_2 concentration, temperature and rainfall data were simulated, seasonal patterns were identified and forecast them under the objective of identification of effect of climatic factors on rice production.

Based on most important factors effect on cultivation and resources available in the region many researches have faced limitations and delimitations. Several factors have been identified as agents for improving agricultural production such as consideration of technical changes in agriculture, contribution of land productivity to total output of crops, estimation the growth rate of productivity of crops and etc.

IV. Conclusion

This study sought to present and discuss the comprehensive sustainable cultivation plans under statistical/ mathematical background through a review of the literature. A worldwide trend toward standardization of the agricultural process with optimal cultivation strategy was observed, especially concerning the influential factors of the cultivation. Mathematical models developed for selecting arable lands for selected crop's cultivation. By developing an optimization problem for water resource management system for farmlands have increased 8% of the net profit. Further, this can be implement for all other factors which are basic needs of cultivation. Due to availability of small number of published articles about the development of sustainable cultivation plan under mathematical/ statistical background there is still a tremendous scope for improvement in model for sustainable cultivation plan. Finally, one limitation of the present study is the absence of published articles which have considered all influential factors together on cultivation.

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