Chapter 2

LITERATURE REVIEW

The chapter provides an overview of literature pertaining to optimal crop allocation, crop combination, topographical & physiographical parameters, climate parameters and different mathematical & statistical tools adopted to determine the solution optimality. The literature discusses some of the typical hybrid Multi-Criteria Decision-Making (MCDM), optimization and statistical tools to evaluate the alternatives and constraints defined in decision space.

2.1 Introduction

To overcome the challenges faced by the agriculture sector mathematical model has been developed by the researchers that provide an insight about the parameters and factors that are needed to be focussed to get an optimal return. (Haouari & Azaiez, 1999; Rani & Rao, 2012) proposed a mathematical model to get an optimal farm returns under water-deficient conditions. In arid and semi-arid regions allocation of water resources are one the most crucial decision to be taken by the growers. An optimal cropping pattern is formulated to allocate the available water resources efficiently. A study is focussed to develop a linear programming model for a region with an inadequate availability of water resources. The irrigation requirement of different types of crops is different hence, the irrigation level of the crop to be cultivated is examined by researchers particularly, in region with arid topographical features.

Growers yearly allocate their fields with a different type of crops with an altered decision parameter depending on the previous season profit. To support the farmers, for the optimal allocation of resources (Dury et al., 2012a) decision support model is developed. The decision support model is formulated on two concepts first is crop planning and another one is crop rotation decisions. These decisions are mainly affected by crop cultivated, crop distribution (cropping pattern adopted for cultivation) and profit obtain from the previous season. Result of the study show that crop planning is incorporated as a static concept (i.e., only once a decision is taken for a year it will not change throughout the season); mathematical formulation of farm scenario is often considered as a single objective problem rather than a multi-objective; all the stochastic parameters under consideration is kept constant.

In farm planning crop yield forecasting plays a significant role. Many parameters impact crop production, such as land under cultivation, availability of irrigation system, climatic variations, quality and quantity of seeds, topographical attributes and soil composition. Cultivation of crop follows a seasonal pattern but some of these factors will not contribute to temporal factors. For instance, cultivated area, rainfall, fertilization impacted or results to improve irrigation pattern, soil quality and topographic attributes will remain the same for a long duration. Thus, to identify the relationship among these parameters (Guo & Xue, 2012; Hoogenboom, 2000) use a statistical approach and neural network to establish an interrelations between these parameters and crop yield. Thus, to get an in-depth knowledge of a literature related to the impact of crop combination, climate and other resources that impact the crop yield is studied. The literature reviewed is categorised under different sections as follows:

1. Topographic Attributes
2. Crop-combination, crop pattern
3. Impact of climate of crop yield

2.2 Topographic Attributes

(Warrick & Gardner, 1983) crop yield in a season depends on varying uniformities of available water for irrigation. This variation is a result of both crop choice and soil homogeneity. Thus, for a linear function, Monte Carlo Simulation is used to forecast the crop yield. In the case of scarce availability of water resources, the crop yield per unit of water applied is of utmost concern. Thus, the study is carried to analyse the effect of soil heterogeneity and irrigation on crop productivity. Crop productivity is defined as the fraction from the maximum quantity that can be achieved, in the presence of farm constraints such as operational farm activities, crop pattern, crop combination and application of water. The soil variability depends on fertilizers input by the growers. However, this varies in every season depending upon the crop cultivated in a period. Hence, it is concluded that both the soil and irrigation influence the crop yield but irrigation uniformity is likely, more important. The study provides a view to evaluate the contribution of each of the parameters with the mathematical approach.

(Rao et al., 1990) due to limited availability of water resources, judicious management of irrigations is essential to increase crop production. However, studies show that irrigation scheduling is extensively carried out for a single crop. But, in common practice field is allocated with multiple crops. Limited availability of water implies that the available resources are not efficient to produce the desirable potential yields. Thus, both the intraseasonal and seasonal system for a water allocation was considered. In case of the single crop, sequential irrigation decisions are significant enough to determine crop productivity. This further complicates the allocation of irrigation to multiple-crops. Thus, a Dynamic Programming approach is applied to determine the water allocation among different crops. For optimal intraseasonal distribution of water resources seasonal water production function:

$$y_k - y_{0k} = (a_k - y_{0k}) \exp [-b_k (x_{0k} - x_k)/x_k]$$

is considered where, n is the number of crops cultivated in a particular season; y_{0k} is the crop yield when no irrigation is given i.e., crop is rain-fed; a_k is the maximum attainable yield, imposing growth constraints; x_{0k} is the minimum irrigation required to obtain a relative yield a_k. Thus, a sequential irrigation pattern is obtained by the dynamic framework of a model.

(Berbel & Rodriguez-Ocaña, 1998) emphasizes the fact that the decisions in the agricultural sector should not only be made based on available material resources (such as land, water availability, soil composition) or economic resources since farms differ from each other in terms of socio-economic characters too. Thus, the paper aims to develop a methodology for the analysis of decision making and to evaluate its impact on crop productivity. The farm under study was characterized under two criteria: division of farms based on the decisions by using cluster analysis and another is to classify the farms based on the crop pattern. Cluster analysis support to classify the farmers with homogeneity in decisions. The result of the study shows that the decision made by the growers are mostly influenced by socio-economic parameters rather than other sources.

(C. Yang et al., 1998) argues that the arable land did not have homogeneous composition and attributes. These attributes vary in soil properties, topographic characteristics, infestations of weed and diseases across a field. The variations caused insignificant results differences in crop productivity and consequently the revenues. The region under study has distinctive topography and soil properties. Though the region owned a variability in the characteristic's, growers treats all the areas of the field in the same manner. This approach may result in lower potential yields. The paper aims to determine the field variability to allocate the crops, operational activities that support the cultivation and fertilizer input. Regression analysis is performed to determine the impact of yield due to topographic parameters such as slope and elevation. The geostatistical analysis indicates that spatial crop variability differed not only from field to field but also from one region to another within a field.

(Mallarino, 1999) used a multiple regression and factor analysis approaches to examine the relationship between the crop yield and soil parameters. Correlation and multiple regression show the homogeneity among the field parameters and these variables vary among different fields. Relation among spatially distributed variables is analysed by correlation. Correlation when integrated with multiple regression, makes it difficult to determine the measure of field variables. Factor Analysis provides a platform for including and model the correlated vectors in multiple regression equations, relating crop yield with site variable.

Hence, to overcome this issue Factor Analysis is applied to determine the covariance relationship among the variables. Factor analysis underlines the common parameters among the fields. However, unlike PCA; Factor Analysis identifies the correlated site-yield variables. The result of the analysis shows that site variables are very important to determine the crop yield as these parameters changes dynamically across the fields.

(Paul et al., 2000) presented a stochastic approach for optimal allocation of multi-crop and multilevel irrigation planning. Seasonal and intraseasonal crop and water allocation are considered by undertaking soil moisture and evapotranspiration parameters under study. Allocation of land and water depends on net profit per unit yield, potential yield of crops and minimum water requirement of the cultivated crop. The minimum depth of irrigation needed to obtain a potential yield is another parameter that affects crop production. Such parameters were controlled by stress sensitivity factors that record the irrigation applicability on a weekly basis.

(Reca et al., 2001) aims to develop a mathematical model for allocating irrigational water in farms. The model is divided into three sub-model. The first model deals with a water requirement timing of a single crop considering the impact of climatic conditions on crop yield. The optimum production function for each crop is studied. The second model deals with the optimal allocation of land and water resources simultaneously for a chosen cropping pattern. The last sub-model deals with the optimal allocation of water for irrigation under a complex distribution system.

The deterministic approach is used considering that the climatic inflow and other varying parameters are known. Based on the economic efficiency of a region a water allocation model is proposed thus, provides a direction for optimizing land and water resources for each crop.

(Makowski et al., 2001) Linear Programming, Multi-Criteria Decision Making, Dynamic Programming are some of the tools that provides an optimal solution. Once the solution is generated policy-makers and decision-makers have to overview an entire scenario, to make an optimal choice among all the alternative solutions available. Thus, the study aims to carry out the analysis by using Mixed-Integer Linear Programming for a decision support model in agriculture. The model is formulated to present a crop rotation as a function of economic and environmental objectives. By using two-stage Branch model, 10 optimal solutions were generated.

The model result indicates that variations or diversification in crop rotation will provide a nearly optimal value of a gross margin. There is a high degree of freedom in crop choice and rotations. The methodology adopted identifies the decision variables that shows variability in set of the optimal solution and the conservative decision variables.

(Prakash, 2003) for sustainable productivity, land suitability is a very important factor. With the growing population more stressed is laid on land. At present higher yield, with the limited arable land is a challenge for the decision-makers to deal with. Thus, farmers need to allocate the farm to get more sustainably. Consequently, much attention laid is on the crop combination selected for cultivation. This selection of crops is a function of soil and land characteristics. Besides this market fluctuations, socio-economic conditions influence the selection of crops too.

Hence, the need for land analysis emerges. Land suitability involves many parameters that are not deterministic in nature such as soil and climatic conditions. The study is carried out to determine the suitability of land for different crop combinations and compare the results with the existing practice. To determine the land suitability Analytic Hierarchy Process (AHP), Ideal Vector Approach (IVP) and Fuzzy (AHP) is formulated. The ability of the tools to evaluate the land-use type is investigated. The study reveals that the region under land analysis is suitable for rice cultivation. Such an approach supports the decision-makers to allocate their field optimally.

(Jiang & Thelen, 2004) evaluates that the variability of yield in the agricultural sector is a result of soil variability and different topographic features of the field. Crop yield though is a function of many other variables such as biological factors, agronomical conditions and climatic fluctuations too. Many soil factors such as bulk density, water-retaining capacity, pH of soil, acidity content, amount of organic matter and soil thickness have influenced the crop yield. Thus, a study is carried out to investigate the soil variables that impact crop productivity. A correlation is observed between soil properties and topographic features of a region and lastly, the impact of these parameters is analysed on crop yield. A multivariate statistical model is used to identify the soil components and their effect on crop growth. The output of the model indicates that soil and topographical characteristics vary every year and explained 28% to 85% of the observed yield variability.

(Koundouri et al., 2005) explains that ignorance of risk factors while estimating production function will produce inappropriate estimates. The production function introduced by Just-Pope is the sum of mean crop yield and variance. This specification enables the policy-makers to evaluate the impact of input on output and risk. In addition to this, it explains that the ignoring risk function will be misleading in result interpretations. The study focusses to demonstrate that an inconsistency may arise in the parameters of risk function if the selectivity of crop choice is not optimal i.e., specific characteristics of fixed and quasi-fixed inputs, observed and unobserved affects the choice of crop to be cultivated and production function simultaneously. The result indicates that the biased parameters of the risk function will produce if we fail to correct for sample selection.

(Xevi & Khan, 2005) the paper aims to develop a Multi-Criteria-Decision-Making (MCDM) model to analyse crop production under physical, biological, economic and environmental constraints. The approach is described by analysing the conflicts that may provide a trade-off between profit and variable production cost. The MCDM model proposed has three objectives: 1) maximizing net returns, 2) minimizing groundwater utilization and lastly to minimize the variable cost. To achieve this there is a need to opt for an optimized crop-mix alternative and allocation of water resources for irrigation. The result indicates that MCDM techniques provide better feasible solution than the Linear Programming model as this will integrate the impact of all the agricultural parameters simultaneously. Moreover, one of the advantages of using MCDM techniques over Linear Programming (LP) is that the LP restricts the model by imposing constraints on other hand MCDM tools provide an output based on evaluating all the decision criteria alternatives defined in decision space.

(Koomen & Stillwell, 2007) considered land as an economic asset. It explains the methodologies and the concept of land use. The concept is so introduced, as land is limited or is taken as a fixed resource. Every piece of land has some associated unique features such as soil quality, slope, moisture-retaining capacity and so on. However, the land utility depends on the need and total available alternatives for land use. The probability defines its intervals 0 to 1 but the value never meets the extremes. Particularly, when the concept is applied to land use it describes the use of certain land at a certain location depending on the availability of alternatives and resources. Thus, the usability of land can be determined by the utility of land and the availability of resources.

(Sharma et al., 2007) formulate a model to optimize crop yield, net revenues, labour and water requirement and reduction of machinery cost. Linear Programming as a technique is widely used for farm planning. Technique provides an optimal decision to allocate land under cultivation, maximizing crop yield, minimizing input cost and for optimal selection of crop combinations.

Agricultural planning involves a multiple aim to deal with all the goals simultaneously. These goals include: maximizing crop production, maximization of farm revenues, minimization of labour and other farm input cost. All these goals are contradictory. This provides a trade-off to achieve the goals. Thus, a Goal Programming approach is employed to obtain the conflicting objectives. The technique is appropriate to determine the solution feasibility in case of multiple conflicts within a linear framework. To validate the model solution LINGO10.0 is used for computation. The study concludes that Goal Programming is more appropriate than Linear Programming when multiple objectives is involved.

(Santé-Riveira et al., 2008) focusses to develop a land-use allocation planning system in the rural areas. The study focusses on three main concepts: evaluating land suitability, optimizing land-use area and spatial allocation of land use. According to, FAO (1976) land evaluation is defined as “ the land assessment or the degree to which land can be utilised for a specific purpose.”

The framework developed by the Food and Agriculture sector is applied for land evaluation using multicriteria evaluation methods. Thus, for optimizing land allocation a Multi-objective Linear Programming model is been formulated. The first step to determine the optimized region for each land use is to set the constraints for the Linear Programming model. A Hierarchical Optimization process is applied for spatial allocation of land use. RULES (Rural Land-use Exploration System) aim to plan land-use for supporting the operations that ease the working of decision makers. An optimal land use scenario created by the system based on the conditions specified by the user. Thus, an alternative for the land-use is provided by the system and provide a support throughout the planning process. Under a static condition, system can be applied to access land usability. One of the limitations of the system that it will not support the decision-makers in case of a dynamic environmental scenario. In other words, the approach is applicable in deterministic scenario only.

(Georgiou & Papamichail, 2008) proposed a non-linear programming approach with an integrated soil water balance to determine the optimal policies with the aim to allocate the water among multiple crops. An integrated methodology of simulation annealing and stochastic optimization is applied to determine solution feasibility. A probabilistic parameter such as rainfall, evapotranspiration and water inflow were considered to describe the stochastic farm scenario. The water requirement at each plant stage is considered that provides an optimal spatial distribution of land. The deterministic and stochastic approaches were compared. Further, the results of the study reveal that a significant increase in cropped area and farm income is possible only if the deficient water irrigation regime is followed particularly in the regions with inadequate supply of irrigational water.

(Hajkowicz & Higgins, 2008) a Multi-Criteria Decision-Making approach is employed, to allocate the available water resources among multiple crops with the aim to deal with multiple objectives. Hence, decision makers are looking for analysis beyond a conventional methodology that can deal with a multi-objective decision environment. The study proposed an MCA technique to six water management decision problems. A Multi-Criteria Analysis (MCA) model aims to rank the available alternatives in decision space based on the available set of criteria. The MCA tools used for analysis include the weighted sum method, PROMTHEE II and Compromise Programming. The study formulated that MCA methods were in strong agreement within high correlation with rankings of the preference allotted to the available alternatives in decision space. The result of the model suggests that before opting for the available MCA techniques there is a need for proper formulation for decision alternatives and criteria.

(Elaalem et al., 2010) available land resources gradually became scarce, as population growth lay a pressure on natural resources. In arid-regions, the pressure is compounded by agricultural lands. Thus, to support sustainable development there is a need for proper land evaluation. The study proposed presents a comparative analysis for barley by using Fuzzy AHP (Analytical Hierarchy Process) and TOPSIS (Technique of Order Preference Similarity to the Ideal

Solution) methods. The criteria considered include the soil texture, calcium carbonate content, rootable depth, water-retaining capacity of soil, organic content, soil salinity, soil PH and soil alkalinity. The model result indicates that the evaluation of land by using hybrid MCDM techniques provides a way to crop preference which is an important and significant effect particularly, for arid and semi-arid regions.

(Manos et al., 2010) due to population increase and depletion of natural resources, to feed the growing population researchers focus on issues such as sustainable development. Economic growth and sustainable development can occur simultaneously if decision-makers develop and use robust tools and techniques. The paper aims to develop a multicriteria mathematical model that optimizes the agricultural resources substantially. An optimized output is achieved by combining different criteria to a utility function under a set of defined constraints. The model result indicates that the technique adopted to maximize the farm revenues and minimize the labour cost provides an optimal result than the existing practice through better allocation of available resources. A simulation can be used to further implement the model to different agricultural regions.

(Alabdulkader et al., 2012) the mathematical model developed for optimal crop planning in Saudi Arabia showed that there is a need to restructure the cropping pattern of the country on the grounds of the available water resources. The objective of the study is to determine a one-year optimal crop plan in comparison with the existing crop pattern. To get the optimized solution LINGO is used. The solution is obtained by restricting some of the farm parameters. The optimized model comes with the proposal to reduce the area under arable land to about 48% that will cut down the water needs by 53%. The model can be further extended by considering weather as a function for determining crop yield.

(Biro et al., 2013) emphasizes the land use/land cover changes mainly due to agricultural expansion and other natural calamities. Thus, a multi-temporal Landsat data is analysed from the year 1979,1989 and 1999 to monitor the land-use change. Moreover, the study also focusses on the land use due to soil properties. To analyse the soil properties three types of land use: cultivated land, fallow land and woodland are considered were investigated. Results indicate that the change in land use is due to the change in soil properties over a decade. Hence, soil composition is one of the significant parameters for determining crop growth and yield.

(Feizizadeh & Blaschke, 2013) study the optimal allocation and utilisation of land resources for maximizing agricultural production. Several factors such as soil, climatic conditions, availability and accessibility of water resources were investigated to determine the impact of these attributes on crop yield. To rank the sustainability factors Analytical Hierarchical Process is used. The result of the system indicates the land-use intensity for the agricultural purposes should increase, decrease or remains unchanged. GIS-based Multi-Criteria Decision-Making tool will help the decision-makers to plan their strategy based on the attributes discussed.

(Rendel et al., 2013) provides a need to identify how an individual farm system alters when changes regarding strategic decisions were considered. These decisions become more crucial when the parameter of varying and diverse landscapes on which the farm output depends were taken under consideration. Some of these parameters include irrigation planning, operational activities for crop growth and so on. Thus, a farm resource allocation model is developed to allocate capital, feed budget and stock reconciliation. A Linear Programming approach is applied to optimize the resources whilst maximizing the profits. The study aims to allocate the capital optimally among all the farm segments. The model is studied only for a one-year time horizon. The objective function also includes the cost of animal stock allocation, labour, feed cost and stock maintenance cost. Thus, a model will support the policy makers operating mixed enterprises to allocate crops and husbandry simultaneously.

(Sarkar et al., 2014) proposed a study to analyse the land suitability by applying Geographical Information System (GIS) in conjunction with multi-criteria decision making for assessing wheat cultivation in Purulia, India. Land attributes that affect crop growth was identified. An integrated approach is applied to support crop sustainability in a region. A Multi-Criteria Decision-Making technique was developed to characterize the land suitability for agricultural crops. Land suitability is evaluated on certain factors: soil composition; soil PH; topographic factor (slope); climatic fluctuations; land cover/usability.

(Juhos et al., 2015) aims to examine the impact of soil properties on crop productivity. In land-use planning the land variability influences the crop yield. Several statistical methods have been developed by mathematicians to forecast the crop yield. Such an analysis is particularly based on the exhaustiveness and size of the dataset with its own restrictions. Thus, a stepwise multivariate analysis is applied to predict the relationship between agronomical factors and crop production. The agronomical parameters are analysed by using Principal Component Analysis (PCA) with Varimax rotation. Though PCA is not able to explain the variance of the defined set but could predict the yield better than the latter. The Multivariate analysis predicts the correlation among the topographical and climatic conditions. Hence make it easier to estimate the yield of the crop cultivated in a region. However, linear functions are not able to predict the results, due to the absence of a trade-off or correlation among the parameters.

(Das et al., 2015) proposed a mathematical model for optimal allocation of land and water resources. To determine the feasibility of decision variables the Linear Programming approach is used. The results indicate that there is a deviation in crop yield of approximately 20%, 40% & 60% from the existing cropping pattern. The optimized results of the model show that there is variation in the revenues obtained by existing farm practice and the proposed optimized model. The growth in farm revenues is due to the increase in the land under crops with more economic values. To further evaluate the impact of water allocation on crop yield Dai & Li, (2013) formulated Multistage Irrigation Water Allocation (MIWA) model with an objective to optimize land and water allocation for the crops under consideration. MIWA model developed incorporates an interval parameter within a Multistage Stochastic Programming (MSP) framework. The outcome of the model shows that water allocation pattern, for irrigation, varies because of the spatial and temporal distribution changes depending on the water inflows and different stages of crop growth. Thus, there is a trade-off among the different crops allocated to meet the water requirements.

(Bozdağ et al., 2016) to improve the agricultural practices in Cihanbeyli, an integrated approach of agricultural land suitability analysis by using AHP and GIS is proposed. The applied methodology identifies the region suitable for irrigated and dry farming. The integrated approach of the MCDM technique in GIS provides a spatial decision support system that offers the space to efficiently plan land suitability. The result indicates that 7.18% of the land is suitable for irrigation and 56.77% of the total land is fit for dry-farm practice. An integrated approach is useful to get an optimized agricultural returns land evaluation, promotion of non-agricultural practices in a region that is unsuitable for cultivation and lastly to avoid ant construction at arable farmlands.

(Kendra, 2016) identifies the constraints faced by the farmers in the Tonk district of Rajasthan for crop production. The major challenges faced by the in a region is a dependency on monsoon, erratic rainfall, low soil fertility and small & fragmented land-holdings. The constraints in the agriculture sector are identified via participatory research approach. The result shows that the farmers in a district are vulnerable to inefficient knowledge about production management.

(Banihabib & Shabestari, 2017) in agricultural sector with the increase in population and expansion of arable land, the scarcity of water resources becomes a challenge for the growers to allocate multiple crops particularly, in arid regions. Low precipitation leads to the more water requirement in these regions thus, the management of water resources in these regions is a challenging issue. Therefore, an MCDM techniques is proposed to prioritize the agricultural water demand strategy in arid areas. The paper compares, Fuzzy MCDM (Multi-Criterion Decision Making) models MTAHP (MTOPSIS-AHP) and FMTAHP (Fuzzy MTOPSIS-AHP) and access the performance of the model. AWDM (Agricultural Water Demand Management) technique is used to assign a weight to different criteria. The results indicate that AHP, TAHP and, MTAHP performed quite well. But the (Coefficient of Variation) CV index of the models shows that MTAHP is introduced non-fuzzy MCDM model. The formulated MCDM model can be used for ranking, agricultural water management strategies with several sustainable decision criteria in decision space.

(Buzuzi & Buzuzi, 2018) formulate an operations research model**,** in particular the Linear Programming approach is used to optimize farm revenue constrained by the limited availability of resources. A model is developed based on the farm practice adopted by farmers based on his intuitions and experience. The mathematical model formulated indicates that the resources were not allocated optimally. EXCEL Solver is used to obtain the optimal values of decision variables. The result shows an increase in farm revenues by 76% by adopting optimal planning.

(Ren, 2018) optimizing land and water allocation is a challenging issue for the growers. However, the weight or the cost coefficient of each objective function is a varying parameter. Further, uncertainties are always associated with the optimal allocation of resources particularly, land and water. Thus, to overcome these complexities and the challenges faced by growers a Multi-Objective Stochastic Fuzzy Programming Model is developed. To validate the results of the model a case study of China is discussed. The goal is to maximize the net farm benefit, minimization of water utility and maximization of crop yield. The demand for such a mathematical model emerges because the growing population leads to a reduction in available water resources for irrigation. The introduction of the fuzzy set theory provides a spectrum to deal with the system uncertainty.

(Ikudayisi et al., 2018) to optimize crop distribution and allocating water resources among the multiple crop a new evolutionary algorithm technique known as combined Pareto multi-objective differential evolution (CPMDE) is applied. An algorithm presents an integrated approach of Pareto ranking and Pareto dominance selection. The aim of the paper is to maximize the farm profit and minimization of irrigation water cost. To investigate the most appropriate solution compromise programming is employed. The model results show that the crop planting within an optimal area minimizes the usage of water and increases farm profit.

(Lone et al., 2019) to attain the efficiency of crop production planning a mathematical modelling technique is used. With the limited availability of resources, there is a need to optimize resource allocation to feed the growing population. Thus, to get an optimized crop combination the Fractional Programming Problem is formulated. LINGO Programming is used to get the feasibility of decision variables. Illustrated results indicate that the crop combination considered by the growers effects a farm profit.

(Peltonen-Sainio et al., 2019) a land-use optimization tool is applied based on prior methods, that are affected by farmers decisions. Such an approach becomes significant because of a large number of complex and interrelated factors. Thus, a tool is developed to investigate the change in land use patterns in Finland. The tool enables the land-use change dynamically over a period of time. Thus, the study is conducted with the aim to develop a land use tool that considers:

1. The physical feature of land for crop allocation.
2. The integrated approach evaluates the differences within the fields.

One-way ANOVA is applied to determine the impact of physical farm characteristics on decision making. The outcomes indicate that the farm size decides crop allocation. When the result of the optimized land tool is compared with the field categorizations carried by the farmers, it is observed that the farmers are misled when considers multiple characteristics of land simultaneously.

(O. Ye, 2019) discuss an issue of optimal allocation of irrigation water under a scenario of scarce availability of irrigation technologies, to obtain high and qualitative yield. Several decision support tools were (Lalehzari et al., 2016; M. Li & Guo, 2014) developed in this direction, to regulate the allocation of water and other resources per unit of crop production. AquaCrop software is applied for result analysis. The results obtain will predict the difference between biologically optimal and water-saving irrigation schemes. The mathematical modelling of the scenario provides an evaluated and observed data set points for the crops. The analysis makes it easier to schedule an irrigation regime, by considering the model constraints.

Simulation modelling for irrigation schedules with varying parameters and factors allows the optimization of water, soil nutrient content to prevent the water loss and optimize the crop yield in a short rotation practiced by growers in short period due to inadequate water resources. Since the climatic variations need water changes alternatively. Hence, an analysis makes it easier to determine the optimality conditions thus, allocate the resources accordingly and efficiently.

(Varas et al., 2020) to support the wine grape harvesting a multi-objective mixed-integer linear programming is proposed. The objective of the formulation is minimization of operational cost and maximization of product quality. Since grapes are perishable in nature thus, the model is constrained with routing decisions, product decay and time lags. To assign a weight to attributes Tchebycheff method is used to compute the first optimal Pareto solution. A solution is validated by two decision makers if no conclusion is made than iteration is carried out to find the Pareto solution in a neighbourhood of an ideal solution by augmented constraint method.

2.3 Crop Distribution/ Crop Pattern

(Green et al., 2007) focuses his study to investigate the land-surface topographical attributes to investigate the spatial crop pattern that is affected by variability in soil and water availability. Thus, study is carried out to determine the grain productivity, affected due to topographic attributes. Topographic attributes considered to determine the productivity include: elevation, slope, aspect, curvature and soil wetness index. For predicting the crop yield Spatial Analysis Neural Network (SANN) was used. The approach applied to investigate spatial crop distribution by determining topographic attributes SANN is a supportive spatial interpolator.

(Castellazzi et al., 2008) proposed a crop rotation technique to optimize the farm revenues. Crop rotation is one of the traditional farm practices adopted by the growers to increase the yield and balance the composition of soil nutrients. In crop rotation, the duration of the length of the crop being rotated impacted the yield. Rotation controls temporal crop patterns. The paper proposed four groups of rotations.

These groups consider crop choices to be cultivated in rotation which can tolerate the fluctuating climatic variations and market conditions. To manage the crop rotations the transition matrix technique is proposed. The crop rotation practice is illustrated as the probability of the crop preference over the other in rotation. The model assumed that the crop to be cultivated is based only on the previously cultivated crop. The long-term crop productivity of any rotation can be determined by applying transition matrices. By evaluating the crop production of each rotation, the land allocation under each crop can be optimised. Thus, matrices provide an opportunity to alter land-use due to variations in crops because of changes in climatic and economic conditions.

(Abdelaziz et al., 2010) proposed a Linear Programming approach to determine the farm revenue by evaluating the constraints faced by the farmers in the Dar Elslam district. The study shows that in region labour and the operating capita is the major constraint faced by growers. The result of the model shows that the farm revenues will be increased by adopting optimal cropping pattern. The variations in the area allocated under each crop affect the farm revenue. The objective function shows more feasibility of decision variables when optimal cropping pattern is adopted.

(Boustani & Mohammadi, 2010) emphasize to determine an optimal crop pattern especially for arid and semi-arid regions. For reduction in water utility and its proper allocation Multi-Objective Programming is approached to provide a trade-off among the reduction in water usage and maximization of gross farm margin with the reduction in risk was proposed. The study also provides an in-sight on the impact of prevailing market conditions and government policies on crop choice. The optimal model shows an expansion of the cultivated region under maize and vegetables as compared to the exiting cropping scenario.

(Zeng et al., 2010) planning of crop to be cultivated, plays a significant role in agricultural water resources. The planning done helps to estimate the water to be allocated to different crops to achieve a goal such as maximized returns constrained by available land and water resources. Due to sector complexities, multi-objective involved in a system generally conflicts with each other. Some researchers adopted the Multi-Objective Linear Programming approach due to the presence of multiple objectives in a system. Thus, a Fuzzy Multi-Objective Linear Programming approach is applied to determine the different cropping patterns under different water-saving levels. The fuzziness of a model made a problem more stochastic and real. The result indicates that the formulated model provides a better alternative solution for better decision support when applied in the cropping areas.

(Chen & Önal, 2012) for simulating the decision making at farm level mathematical programming models has been widely used at the regional level. Linear Programming as a tool will be applied if production costs are assumed to be constant. Linear programming technique, due to its technical efficiency is widely used in numerous studies conducted at a farm level. Assuming that the solution obtained from the simulation model must lie within the convex hull of cropping decisions, the model identifies the best combination of those solutions that optimizes the objective conditions under prevailing market conditions. This will be achieved by considering the constraints that limit the model solutions within the convex region and then determine the optimal value of the weights assigned to each decision variable. The model assigns a positive weighted variable to each decision variable of crop-mix that can be estimated endogenously. Since the convex combination of two optimal solutions is also optimal thus, the crop-mix can be considered as a corner point in decision space and the optimum solution would be the convex combination of these extreme points.

(Sarttra et al., 2013) the allocation of land under dynamic market conditions and operating cost is a complex issue. By literature it is analysed that the farmers decision of crop choice depends either on the previous year crop production or the market price of the crop. Thus, a study is carried out to propose a mathematical model for optimizing land, by allocating it under different crops in a season. Linear Programming is used to determine the optimal solution. Linear Programming supports to allocate the land under different crops. Under the dynamic scenario, Dynamic Programming is the most appropriate tool to determine the feasibility of decision variables. A shift in product price, operational farm cost, harvest period, yield per unit area and other farm constraints were considered for modelling. Result found that the solution obtains by Dynamic Programming is more appropriate.

(Prisenk & Turk, 2015) proposed a combination of linear and weighted goal programming for optimizing crop rotation farm practice. The main purpose of the model is to allocate an organic farm. Crop rotation practices prefer production of mono-crop. Most of the farmers try to allocate maximum acreage of their farm under cultivation. Such an approach often leads to depletion in soil quality, risk of pest attack and crop failure too.

Crop rotation in case of an organic crop is often complex as it integrates some more parameters such as maintaining the nutrient content of the crop cultivated and soil simultaneously. For this purpose, growers need to cultivate the legume plants to maintain the nitrogen content of the soil. Such a crop practice reduces the need of manure and hence results in the reduction of fertilizer cost. However, it has been observed that the productivity of organic crops is less than the crop cultivated under normal conditions. Such an approach results in increased crop yield year after year because of improved soil properties naturally.

(Li et al., 2017) due to food security management of farm under climate change and population growth is a challenge for decision-makers. Thus, leading analytics emphasizes food security as a challenge to feed millions of people across the globe. Thus, to increase farm productivity; crop rotation, land use pattern, crop combination and sustainable agriculture is reviewed. As the demand for agricultural products increases the need to optimize land and water becomes more significant. Thus, a farm management mathematical model is proposed based on Mixed-Integer Programming. The varying parameters such as temperature, rainfall, evaporation and moisture were not considered. Varying irrigation pattern is adopted consequently, resulting in increased farm revenues. The proposed model will also associate the risk factor tools for the farmers seasonal irrigation constraint. The result indicates that crop production depends on water allocation and seed selection.

(Filippi et al., 2017) the concept of optimization is quite a complex issue in the agricultural sector as it has to consider numerous factors such as crop allocation, crop choice, crop-mix and input parameters simultaneously. Thus, a mathematical model is developed to support the farmers in decision-making regarding crop selection and their allocations. Finding a way to face these agricultural challenges affect both productivity and farm revenues. Thus, a case study of a farm cultivating multiple crops is discussed. Each crop has its own requirement needed for growth. Hence, for crop selection based on the returns generated by them a Mixed-Integer Linear Programming model is proposed. The two parameters play a significant role in crop selection decision-making first one is the crop yield price and variability and another is the contribution of the crop in overall revenue. Thus, study concludes that the model proposed is capable of determining the impact of resources on the crop yield and the model has adaptability for incorporating the decisions regarding scarce resources.

(Seyedmohammadi et al., 2018) employed MCDM techniques to determine the suitable arable land for the cultivation of maize, rapeseed and soyabean, respectively. To evaluate the crop preferences there is a need to define/restrict the model. Thus, different criteria: soil depth, slope, climate, soil pH, electrical conductivity, the portion of sodium, calcium carbonate and gypsum were defined in a decision space. The criteria defined supports the crops growth defined for cultivation. Hence, to determine the cultivation priority, Simple Additive Weighting (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Fuzzy TOPSIS method is applied. The model result indicates that the maize-rapeseed-soyabean is a preferred optimal crop combination. Hybrid MCDM technique; Fuzzy-TOPSIS provides more appropriate results than traditional MCDM tools.

(Boyabatlı et al., 2019) aims to determine crop planning decisions in a sustainable environment i.e., how to allocate the land to each crop among multiple crops in each growing season such that crops will have the rotation benefits. Thus, a farmer cultivating two crops with low cost of production when cultivated in the rotation is taken under consideration. A key feature of the farm taken is crop rotation benefits across each growing season. The simple heuristic policy, based on the principle of sustainable development is formulated. The profit from the crop cultivated in rotation where some other crop is cultivated in the previous season is stochastically more than the one when it is cultivated as a nonrotated crop. The result computed indicates that the crops when cultivated in the rotation is capable of generating more revenues than cultivated otherwise.

(Balezentis et al., 2020) the agriculture sector is vulnerable to fluctuations and variations caused due to weather parameters, crop allocation, market demand, and crop policies. Thus, an integrated approach is developed for an analysis of different crop-mixes. Multi-Criteria Decision-Making analysis is employed to study the agriculture scenario. The SAW, TOPSIS, and EDAS tools were applied for analysis. Total farm output, water availability, coefficient of yield variables was taken as a decision criterion. The model result indicates that the changes have been observed in cropping scenario in a region due to the variation in arable land and structural crop change. Hence, the crop yield has shown an increase. Change in crop structure induces economic and environmental effects too.

(Tirth et al., 2020) agricultural practices depend on economic and social conditions. Rajasthan has an arid climatic condition. Exprom2, the technique for order of preference by similarity to ideal solution (TOPSIS), and the VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) were employed to select an appropriate crop. Four criteria and five alternatives were selected to rank a crop cultivated in Kharif season. Entropy method is used to assign a weight to an attribute. The study concludes that the chosen alternatives were in order: jowar> bajra> maize> black gram> green gram. The study outcomes will help the policy-makers to increase the crop yield by adopting sustainable agriculture practices.

2.4 Impact of Climate on Crop Yield

(Semenov & Porter, 1995) to evaluate the impact of climate on crop yield crop simulation model is applied. The uncertainty involved in crop growth is taken as an input parameter for formulation. Most of the interactions between the crop yield and climatic parameters are non-linear. These interactions will simultaneously evaluate the impact of all the climatic parameters on crop yield. Thus, to investigate the impact of climate on crop productivity there is a need to stabilize the weather sequences. An increase in mean temperature shows a positive impact on the rate of crop development. The results show that the variations in temperature and precipitation had a larger impact on yield than average.

(Riha et al., 1996) in crop simulation models air temperature and precipitation are the major driving variables. The proposed model predicts that temperature variability reduces the crop yield. The simulation approach is used to determine the crop growth for two different locations and three types of soil. The simulation of environmental conditions will determine the impact of climatic variables on crop yields. The variation in standard deviation in crop yield due to temperature variance is quite small, indicating that the coefficient of variance increases with the increase in temperature variance. Thus, a series of simulations is implemented concluding that the temperature and precipitation variability impact the crop yield.

(Jones et al., 2000) study how climatic variability influences the agriculture sector. The vulnerability of the sector due to climatic fluctuation is often devastating, as what to cultivate in next season. Thus, growers were unprepared for the weather fluctuations and make decisions based on the general climatic pattern. If climatic variability can be determined than crop combinations were altered, thus minimizing the risk. Simulation as a tool is used to get a range of weather conditions and to determine the relationship between crop variability and climate.

(Hoogenboom, 2000) weather has a significant impact on crop yield and development. Some of the agrometeorological variables associated with agricultural production include precipitation, temperature and solar radiation. Temperature is one of the major parameters that impact plant growth.

The alterations in climate parameters are the major issue of concerns for researchers. Thus, a need to formulate a mathematical model that will determine the impact of climatic variability on crop yield is emerged. Many of the crop models were based on the strategic and tactical decision-making. The paper overview development and application of crop models. The variability in crop yield is because of the fluctuations in climatic and weather conditions over a period of time. The results obtained by simulation provide support to growers to carry out the changes in the farming techniques.

(Boken, 2000) explain six different statistical techniques to predict the wheat yield without using weather data. Linear and quadratic trends, simple exponential smoothing, double exponential smoothing, simple moving average and double moving average were applied for series formulation and their corresponding second-differences. The forecasted variable is defined as a function of time. The series defined for prediction can be stationary or non-stationary hence, depending on the nature of series different statistical tests were employed. The result reveals that the deterministic approach favours the quadratic trend and stochastic approach considered simple moving average technique is the best to describe the yield forecast. The attributes assigned to different statistical tools employed for yield prediction considered quadric trend as an optimal technique for forecasting yield.

(Goyal, 2004) temporal and spatial changes in weather cycle is a matter of concern for the environmentalist and policy-makers. Climate change impact the hydrological parameters. Among this parameter evapotranspiration is one of the significant factors that impact the crop water requirement. Thus, the study is carried out to understand the impact of climatic changes due to evapotranspiration in arid regions of Rajasthan. Evapotranspiration by plants depends on temperature, wind speed, vapour pressure and net radiation. The result shows that a marginal change in evapotranspiration influences the crop yield. Moreover, change in soil moisture due to climate change, alters the water requirement of plants. Thus, there is a need to focus on the crop variety with limited water requirements particularly, for arid regions.

(Chen et al., 2004) influence of varying climatic conditions is always an issue of concern for the agriculture sector. Many researchers carry out an analysis to determine the impact on the mean crop but only few addressed the effect on variance. The study is carried out to evaluate the impact of climate change on crop variance. The Maximum Likelihood Panel Data technique is used for the calculation of crop variance. The result of the model indicates that the change in climate improves the crop yield level and variances in a crop-specific fashion. An increase in rainfall and temperature improves crop yield and variability. This effect varies from crop to crop. The estimated model outputs reveal how future variations in climatic conditions influence yield variability.

(Kim & Pang, 2009) the crop yield depends on soil properties, topographical conditions, operational activities and certainly the climatic shifts. (Hazell, 1984a) suggested that operational farm activities, high-yielding variety of seeds and planting techniques make crops more sensitive to weather conditions. Fluctuations in crop yield results in instability of crop price, and market risks. It is important to learn how much crop yield and variability changes over climate change to alter the farm practices for more production. Just and Pope stochastic production function is applied to show that temperature has a positive impact on rice yield and precipitation has a negative impact. Estimation of the influence of climate on yield indicates that the rice productivity can increase up to 10%-20% respectively.

(Fore & B, 2010) to predict the variations in crop yield there is a need to model how crops respond to the climatic changes. There is a need to develop a robust mathematical model such as the yield variations can be evaluated. A most commonly used approach used by researchers is the statistical model approach that will estimate the variations by using temperature, precipitation and rainfall as a parameter. Thus, the study proposed reflects the ability of statistical tools to predict the crop yield with respect to change in mean temperature and precipitation respectively.

The advantage of using a statistical model are their limited reliance on field data and their assessment of model uncertainty. For instance, if a model estimates the low value of Coefficient of Determination (R^2) indicating that the model calibrated do not able to represent the impact of climate on crop yield. The study concludes that the statistical model appears to be more reliable for the uncertain data set than a deterministic approach.

(Holzkämper et al., 2012) the change in climatic conditions may affects the crop yield and yield variability. In particular, the crop respond to the changing climatic pattern is non-linear. Thus, statistical models are often used to measure such variations. Thus, the study was carried out to test the ability of statistical too to predict the effect of change in temperature and precipitation on maize yield. 'Perfect model' approach is used to examine the predictive capabilities of statistical model. The analysis revealed that effect of change in mean and variability of temperature and precipitation can be quantified by using statistical models. Thus, the study will provide a minimum data to formulate a statistical crop model.

(Poudel et al., 2014) the weather fluctuations have impacted the grain productivity in Nepal. Thus, the study is carried out to investigate the impact of precipitation, maximum and minimum temperature ranges and extreme climatic conditions on mean yield and variability of rice, maize and wheat yields. (Yang et al., 2011) evaluated the impact of temperature, precipitation and solar radiation on crop yield and variability. The result shows that solar radiation and temperature have a positive correlation.

Since temperature is the major factor that causes a fluctuation in crop yield variability thus, both minimum and maximum temperatures were taken under consideration. Thus, to determine the impact of the discussed parameters on crop yield Just-Pope stochastic production function is applied. Panel Data result shows that climate trends had significantly influenced the crop yield and variance. The increase in precipitation levels in a region negatively influences maize and has positive impact on wheat mean yield. In addition, minimum temperature supports the crop yield and the maximum temperature lowers the yield. However, low precipitation and high temperature is responsible for low crop production. The Maximum Likelihood Model result shows that the change in average weather conditions results in change in yield levels and variance, however, the impact of these variations vary from crop to crop.

(Amin et al., 2015) for sustainable growth of the agriculture sector, the impact of the climatic conditions on crop growth is an issue of concern. A varying climatic condition may have both positive and negative effects on crop yield. Focussing on the issue, a study is carried out to examine the impact of climate particularly, maximum and minimum temperature, rainfall and humidity on the productivity of four major crops namely; Aus rice, Aman rice, Boro rice and wheat. Time-series analysis determines the interrelation among climate and crop yield.

The result shows that climatic fluctuations have a significant contribution to crop productivity. Rise in temperature effects the productivity of all the chosen crops except Aus rice. However, minimum temperature impacts the productivity of Aman rice but supports the growth of all other three crops. Moreover, rainfall supports the Aus rice whereas it has a negative impact on the cropping area under Aus rice. Hence, climatic variations impact the crop yield in one way or other. Thus, it can be concluded that crop management is done in such a combination of crops that compete with each other in a phase of fluctuating climatic conditions. This, will thus contribute to minimize the risk of crop failure.

(Asseng et al., 2015) crop models are essential tools to investigate the impact of climate change on food production. Thus, the study is carried out to predict the wheat grain yield in response to climate change. Most of the models formulated simulate the yield but do not give approximate results at the higher temperatures. The rise in temperature shows a low crop productivity at most of the wheat growing regions. Global wheat production is reduced by 6% with a unit increase in temperature and becomes more variable over space and time. Estimating how different climatic parameters impact food production is essential to evaluate how to adapt climatic alterations. To do so the contribution of different climate factors on crop yield need to be identified and quantified. Change in temperature reported to have a negative impact on crop yield. Thus, crop simulation model is useful to study the impact of climate on crop productivity.

(Arshad et al., 2017) Just and Pope production function is applied to access the impact of climatic parameters on crop yield and variance. The advantage of using the J-P production function is that it provides flexibility to the model in case of the absence of cross-sectional or time-series data. Thus, a production function is employed to examine the impact of climate on crop variability. The variance function for both temperature and threshold variables showed a positive and significant correlation with yield variability. The result indicates that wheat is more temperature-sensitive.

(Wineman & Crawford, 2017) the mathematical model for decision-making at a farm-level is formulated that includes labour, financial resources allocated to each crop and crop management techniques. A Linear Programming as a tool is applied to get feasibility of the formulated model. All the farm-level decisions are needed to be taken at the beginning of each growing season. It is assumed that the economic factors are fixed and climate is the only driven variable that influences the production process. The paper aims to determine the impact of climate change on crop productivity. Firstly, the crop to be included in the model is identified then the most commonly practiced crop combination and patterns are observed.

The paper has sought to elucidate the most common practice crop choices that farmers will make in future in response to the climatic variations. The result of the model reveals that when the farmers face low productivity due to altered climate they shift towards a different set of crops. In such a case they have to offset the expected losses for most of the crop regimes.

(Vaitkeviciute, 2017) adopted a Ricardian Model to examine four different panel data model to measure the impact of climate on agriculture in Europe. A comparative analysis between pooled OLS model estimation that does not consider time variant with the three-panel set that estimates the time-variant is compared. An empirical analysis indicates that climatic variations greatly influence the farms in Europe. The relevance to employ a panel data is discussed.

However, panel models offer different outputs. The pooled model and temporal random effect model show a similar result however, individual random effect model offers a poor result, further the analysis show a stable but less significant results.

(Zachariah et al., 2020) in agriculture driven economy, crop failure and agronomical crises are an issue of concern. Researchers identify increasing temperature as one of the major factors for crop loss. Thus, a study is carried out to analyse the impact of rainfall and temperature in the drought-prone Marathwada region in Maharashtra. Mixed-effect regression and simulation are used for estimating the impact of rainfall, temperature and precipitation on crop loss. The study shows that the reason for crop failure is the sudden shift of crop patterns from water-deficient crops (pearl-millet, sorghum) to water-intensive crops (sugarcane). However, the temperature variations influenced the crop less than that of rainfall. Thus, it can be stated that the irregular rainfall pattern is one of the significant parameters for crop loss. The operational planning strategies proposed in the study is to promote the drought-resilient food crops, that will not only overcome the challenge of agrarian crises but also provide an insight for food security in the region under sudden climatic variations.

(Choudhary, 2020) the impact of various climatic parameters on crop productivity depends on air temperature, the concentration of CO_2 , humidity, rate of evaporation and so on. (D. B. Lobell & Burke, 2008) evaluated that both temperature and CO_2 have a positive and negative impact on crop growth. Researchers carry out simulation modelling to predict the crop response to climate change. Thus, the study is carried out to examine the impact of climatic variations on farms' income. Panel Data model is used for analysis. The approach makes it possible to overview the time variables and determine the effects of adaptations on crop production. By pooling the time-series and cross-section data Panel Data estimation has been carried out. The interaction term in data helps to avoid variable biasness. The study concludes that the adaptation of technology by the growers is striking evident of the crop response model. Farmers must provide financial aid to keep pace with the technological enhancement in the sector and thus, capable to respond to climate change.

(Şmuleac et al., 2020) focusses to determine the impact of fluctuating climate parameters; rainfall and temperature on water regime. The complex impact of fluctuating climatic conditions on agriculture directs a need to evaluate a decision-making process, to reduce the crop loss and improve the crop standards. Thus, a correlation between precipitation and potential evapotranspiration is analysed. The study reveals that the increase in temperature particularly, during vegetative growth and the years in which evapotranspiration exceeds the precipitation; there is a need to balance the plant water requirement.

2.5 Summary of Literature

Thus, the literature reviewed overviews different mathematical and statistical tools to evaluate the impact of climate, crop combination and topographical characteristics of a region on crop yield and productivity. Though agriculture is a skills approach but the formulation of mathematical model laid a scientific basis to make a decision and support the farmers to make the changes when and where required. The research gaps were identified that laid a foundation to formulate a research objective. Some of the gaps identified in literature:

1. An extensive study to illustrate an optimal crop allocation, optimal crop-mix and optimal resource allocation for Rajasthan farm scenario is not carried out using mathematical tools.
2. A holistic study of problem is not taken up so far by using skills and mathematical approach together.
3. No study so far, employed a Multi-Criteria Decision-Making Technique to determine a feasible crop set based on defined criteria in a decision space for Rajasthan farm scenario.
4. No study has been conducted for Rajasthan scenario that considers both the climatic parameters and optimization of farm revenues simultaneously.

As per the researcher knowledge no study has been conducted so far that will focus on mix-crop scenario, allocation of water and other resources, predict the impact of climatic variations on crop yield in Rajasthan. The state being owned with arid topographical features, face challenges for allocating farm resources optimally. Thus, to overcome this issue a mathematical mode will determine the optimized crop-mix that fits best for the region. Different operational and statistical tools is proposed for analysis. Hence, the study will elaborate the literature by evaluating the results by mathematical and skills approach.