Chapter 1

INTRODUCTION: CROPPING PATTERN AND CROP SCENARIO

The chapter outlines the purpose, motivation and the need to carry out a research work to develop a mathematical model for Rajasthan farm scenario. The background of the study and different physiographical attributes of the region are discussed. A holistic approach of the agriculture sector in country and in Rajasthan are illustrated followed by the challenges faced by the growers to get an overview of the cropping scenario. The literature reviewed, help to identify the research gaps on the basis of which research objectives are define. Further, the chapter concludes with scope, significance and limitations of the study.

1.1 Introduction

Agriculture along with its allied sector is the largest source of income in Indian scenario. Around 70% of the population in the country depends on agriculture and its related sector for their livelihood. India is the largest consumer, producer and importer of agricultural goods across a globe. Despite being the largest producer of agricultural products, the country still accounts for a quarter of the world's hungry people and around 190 million of undernourished people (Food and Agriculture Organization of United Nations, 2019).

Country accounts largest arable land area of 60.44% of an estimated 179.8 million hectares; experiencing a diverse and varying climatic condition that supports diversified cultivation. Being the largest producer of some of the agricultural products, still it accesses only 60% of produce due to lack of storage facilities which leads to an estimated loss of $13 billion annually. Many researchers contributed to optimize the post-harvest farm losses. Different mathematical tools were suggested by the economists and mathematicians to minimize these losses. An operational model is proposed by (Ahumada & Villalobos, 2011b) to generate a short-term planning decision. Thus, to get an optimized farm output judicious management of farm resources is required.

Management of farm involves short-term planning to optimize the farm activities on a regular basis. A mathematical approach helps the growers to maximize their revenues by making the distribution and production decisions during harvest season. The mathematical model is reliant on the fact that crop productivity and profitability is dependent on short-term planning decisions during the growing season. Some of the major factors that affect crop productivity in season include: management of labour cost, storage and transportation of perishable crops and operational activities involved for crop growth. All these farm parameters (Fig. 1.1) are analogous and thus, there is a need for rational management of farm resources for attaining optimal farm benefits.

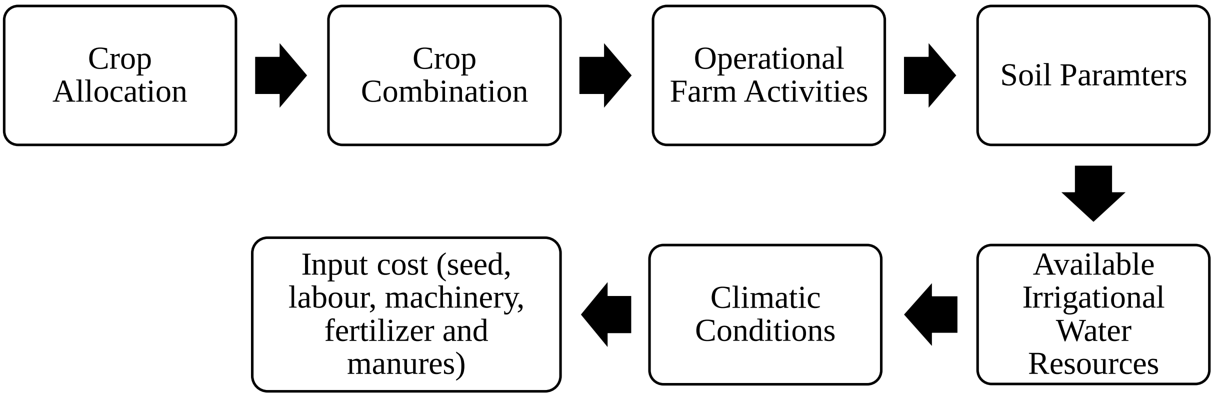

Fig. 1.1: Factors Affecting Crop Yield

Since we are discussing "optimal crop allocation" it becomes important to define some of the terms that we are dealing with.

Glossary:

- **Crop Allocation-** crop allocation deals with the area to be assigned under each crop. Traditionally, crop allocation depends on the previous season allocation or the farmers instincts.
- **Crop Combination-** crop combination is defined as a concept of cultivating multiple crops on a same piece of land.
- **Crop-Mix-** since we are dealing with the concept of "optimal crop combination" thus, there is a need to define a set of crops that will provide an optimal farm return. The set of decision variables that consider a multiple crop cultivated on a same piece of land together without following a particular pattern is termed as crop-mix.
- **Crop Pattern-** the way/manner in which crop is cultivated is defined as cropping pattern. Mono-cropping, multiple cropping and mixed cropping are some of the commonly practiced crop pattern adopted by the growers.

- **Crop Productivity**- crop productivity is defined as a quantity of crop grown, per unit area of arable land.

Crop productivity and crop allocation are the two most significant aspects of farm management that need to be optimized. Productivity index is calculated by Eyndei's method, which is as follows:

Productivity Index= $y/y_n * t_n /t *100$

Where, y: production of the respective crop in unit area

y_n : total crop production of the selected crop in unit area

t_n : per unit area under selected crop

t: total area under selected crop

Crop production depends on many factors such as weather conditions, topography, soil quality, variety of crops, quality of seeds, the irrigational requirement of a crop, the quantity of manure and fertilizers supplied and lastly the techniques adopted by growers for crop growth. Thus, to optimize all these parameters (Ahumada & Villalobos, 2011a, 2011b) at the farm level, decisions are classified into following tiers namely, strategic, tactical and operational. The decisions that have to be taken once in a year such as allocation of resources, sowing time is define under tactical planning. Strategic level deals with the farm location and other infrastructural related decisions. Lastly, the operational level deals with the short-term planning such as cultivation, harvesting and distribution of the crop. The main concern of researchers (Ahumada & Villalobos, 2011a) is to develop a mathematical model so as to maximize the farm revenues, especially those; cultivating perishable crops that highly depends on tactical planning. Fig. 1.2 represents different stages/ tiers of the decision-making process.

Fig. 1.2: Different Tiers of Decision Making

Another aspect i.e., crop allocation deals with the selection of crops and the area to be assigned under each crop. Traditionally, crop allocation depends on the previous season allocation, the market price of the yield and the operational planning involved for crop growth. By interviewing the farmers, it is observed that the thumb rule forecasting by farmers eventually lead to crop failure. Therefore, for optimizing land utilization arable land is classified into small, medium and large farms that make it easier for decision-makers to study the regional constraints to allocate the crop and resources. Since all these farm parameters are interrelated hence, there is a need to manage these resources to get an optimized output. Crop allocation and the problem of farm management become more complex if along with maximization of total profit, minimization of labour cost and other operational farm cost were taken under consideration.

By literature reviewed and survey conducted for analysis the most challenging constraints faced by farmers is the inadequate availability of irrigational water resources. Hence, the allocation of water resources became very important especially in arid and semi-arid regions. Moreover, in case of multiple crop scenario, crop combinations were considered based on availability of irrigational water resources.

The allocation of irrigational water resources depends on the cropping pattern adopted by the growers. Different optimal techniques were employed to secure crop diversification. Since 1970's, Linear Programming as a tool is assigned to determine the optimal selection. Due to the system complexity, interrelation among the sector variables and emergence of technology to improve the yield various multi-objective formulations were proposed (Tsakiris & Spiliotis, 2006; Xevi & Khan, 2005a; Zeng et al., 2010a). Furthermore, different statistical tools were employed to determine the interrelationship between the farm parameters. Determining the relationships among the parameters becomes a necessity to evaluate their impact on crop yield.

In every growing season, farmers have to allocate their field under different crops. These decisions depend on spatial crop distribution and farmers' strategy for field allocation. Thus, crop planning becomes a necessity to support the farmers in taking complex decisions. To get an insight about the challenges faced by the growers in the agriculture sector, the study is carried out in Rajasthan state of India situated at a western part of country.

A mathematical model for the Rajasthan farm scenario is developed with an aim to optimize the crop-mix by considering the constraints faced by the growers in every growing season to maximize the revenue, minimization of input cost and optimal allocation of resources. Different mathematical and statistical tools were applied for an analysis. Section 1.2 discuss the statement of the research problem studied.

1.2 Statement of the Problem

"Optimal Crop Allocation in Rajasthan Farming- Agriculture Skills Approach"

The research work conducted is an effort to reduce the gap exists in literature to overcome the issue and the challenges faced by growers in arid and semi-arid topographical regions by addressing a constraint and putting up a model that will provide a scientific basis to the decisions taken by the growers. However, it is argued that the agriculture is a skills approach, henceforth why there is a need to develop a mathematical model. Section 1.3 discuss the need to develop a mathematical model for farm scenario.

However, most of the researchers carried out an analysis to maximize the farm output but so far, no literature is reviewed that give an imprint of an optimal crop allocation for Rajasthan scenario with mathematical and skills approach simultaneously.

1.3 Need to Develop a Mathematical Model

As we are dealing with the concept of "Agriculture Skills Approach" i.e., it is something in which farmers gain an expertise over a year by practicing it traditionally and by their thumb rule forecasting. Hence, the question arises why there is a need to develop a mathematical model? During the survey we interviewed some of the farmers that face crop losses due to sudden variation in climatic conditions or due to pest attack. However, there are many growers that make profits by their thumb rule forecasting. Thus, to illustrate the niche regions where the variations can be made to improve the optimal farm returns and to reduce the farm losses due to the change in weather conditions the need to develop a mathematical model for Rajasthan farm scenario emerges. Moreover, the decision made by the farmers to allocate the field does not provide any scientific basis. The model formulated along with optimal solution provide scientific basis to decision variables.

1.4 Purpose of Study

The mathematical farm model is formulated to investigate the challenges faced by the farmers in Rajasthan, situated at the northwest region of India. Rajasthan is positioned between 23° and 30' and 30° and 11' on the northern latitude and 69° and 29' and 78° and 17' on the east longitude.

Rajasthan is the largest state constituting 10.4% of the total geographical area and 5.67% of the total Indian population. The state experience 10 agro-climatic zones (Fig. 1.3) with varying topography. Around 65% of the state's population i.e., 56.5 million people are engaged in the agriculture sector and its related business. Most of the region in the state is arid and semi-arid with 13.27% of the region under cultivation. The majority of cultivation in a region is rain-fed. The diversity in the climatic conditions and topography supports the horticulture sector. The state receives an average of 25 cm of rainfall annually. The annual rainfall in western region of the state is erratic followed by frequent dry spells. Due to scarcity of water resources and harsh climatic conditions, the agriculture sector shows instability in crop production and productivity.

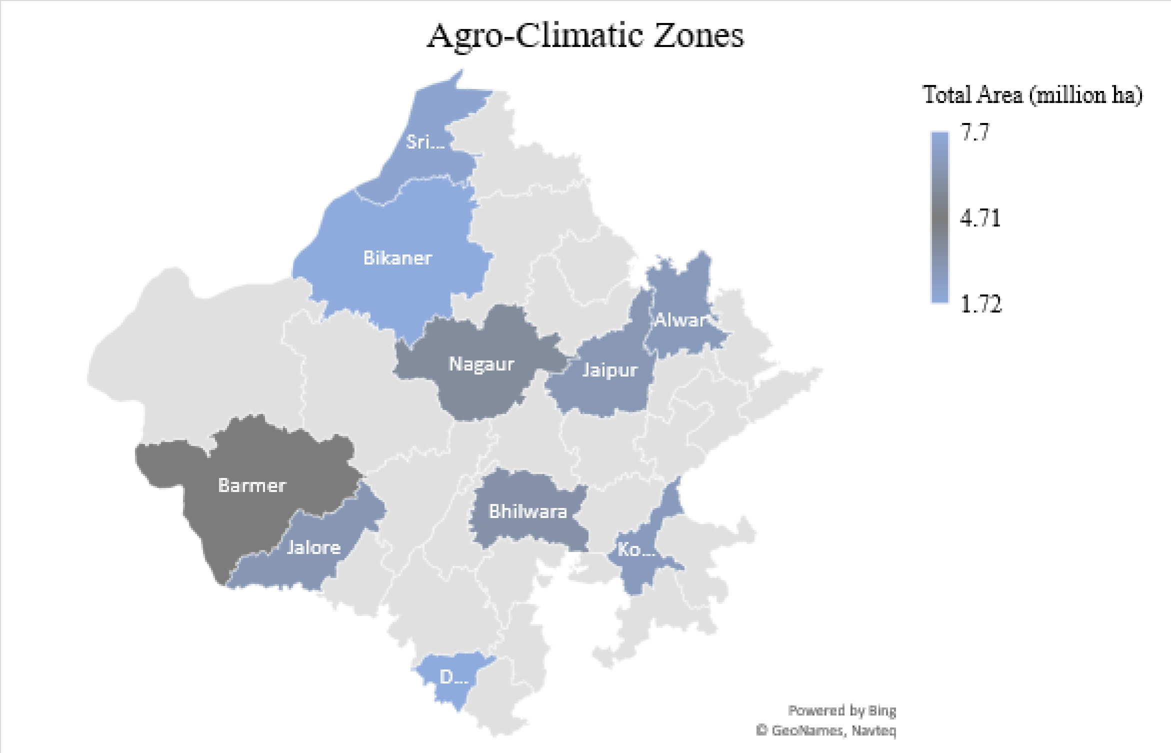

Fig. 1.3: Agro-Climatic Zones of Rajasthan

In 2017-18 the state's agricultural and allied sector contributed to 24.61% of total state's Gross State Domestic Product (GSDP) which is recorded more than that of the national average of 14.82%. Being richly endowed with diverse agro-climatic conditions, state supports a variety of crops and a husbandry sector (Table 1.1) too.

Table 1.1: Position of Rajasthan on Basis of Crop Production

Position	Crops
1st	Mustard, Guar, Carom seeds, Coriander, Fenugreek, Henna and Isabgol
2nd	Gram, Cumin seeds, Vegetables and Coarse Cereals
3rd	Soyabean, Pulses and Oilseeds
4th	Garlic
6th	Oranges
8th	Pomegranate

Fast-growing population laid immense pressure on resources, particularly on agriculture sector to produce more. Many researchers proposed a viable solution to-sustainable intensification, increasing production and improving productivity and its distribution. Availability and accessibility of water resources is always an issue of concern in the state. With the growing population the issue of water resource allocation become more serious. Therefore, management of water for irrigation become a concern for agricultural production in many parts of a state. About 70% of the world's fresh water is being used to irrigate the fields. In many regions' groundwater is being exploited to irrigate the arable land. Consequently, there is a substantial drop in groundwater table resulting in an imbalance of resources. Decision and policymakers are looking for alternatives for optimal allocation of water resources via cropping patterns and by raising irrigation productivity (Crespo et al., 2010; Sethi et al., 2002).

Harsh climate, erratic rainfall pattern, inadequate availability of water for irrigation, fragmented land holdings add challenges to the agriculture sector to choose an optimal crop combination and their allocation in a region. Thus, we formulate a mathematical model by undertaking the constraints and challenges faced by the growers with a view to overcome these issues by selecting an optimal crop combination within the feasible region of solution.

1.4.1 Physiographic Characteristic of State

Rajasthan experiences different topographical features as most of its region is dominated by parched and arid attributes. The state's topographical features include the Aravalli or Hilly regions, the Thar and other arid regions, the plateaus, fertile plains, the forest regions and water bodies including rivers and salt lakes.

Physiographically, the state is diversified with mountains, plains and plateaus. Aravalli hills are significantly responsible for climatic variations in Rajasthan. These mountains divide Rajasthan into two natural regions. The north-western part of the state is predominantly a desert and the north-eastern portion of the state is plain or plateau. The western part of Aravalli hills experiences low rainfall and varying weather conditions. Rainfall pattern has shown variations of 50-70% which is a wide range from the agriculture view.

Depending on the availability of water resources, soil composition and vegetation vary in a state. The majority of the region has sandy soil which has less water-retaining capacity. Being an arid region groundwater table is decreasing at an alarming rate. The region with less water availability has grasses and species like P. cineraria. However, food crops were cultivated in plains are drained by rivers and streamlines with deposits of alluvial and clay soil. The tract of Aravalli contains black, lava soil that supports the cultivation of cotton and sugarcane respectively. The soil variation found in Rajasthan include sandy, alkaline, calcareous, clay, loamy, black lava soil and nitrogenous soil. Table 1.2 indicates the district wise crop distribution in Rajasthan.

Table 1.2: Soil and Vegetation Distribution in Rajasthan

Tropical Division	**Districts**	**Soil**	**Crops**	
			Rabi	**Kharif**
Western Desert	Jaisalmer, Bikaner, Barmer, Jalor, Jodhpur, Ganganagar, Sirohi, Jhunjhunu, Pali and Sikar	Alkaline and saline soils with a calcareous base	Wheat and Mustard	Kharif pulses and Bajra
Irrigated North western plain	Ganganagar	Alluvial and aeolian soil	Sesamum, wheat, mustard, gram, fruits	Maize, guar
Semi - Arid Eastern Plains	Dausa, Tonk, Jaipur and Ajmer	-	Barley, gram, wheat, mustard	-
Flood Prone Eastern Plains	Bharatpur, Alwar and Dhaulpur and the northern region of Sawai Madhopur	Alluvial, clay and loamy soil	-	-
Aravalli Hills & Sub-humid Southern Plains	Bhilwara district and the major parts of Udaipur district, Chittaurgarh district, Sirohi district and the tract of Aravalli Hills	Dark- lava soil	Cotton and sugarcane	-
Humid South-Eastern Plains	Baran, Bundi, Jhalawar and Kota	Black soil	Cotton, sugarcane and opium	-

	Dungarpur, Banswara, Udaipur, Bhilwara and Chittaurgarh have	Red and yellowish soils.	-	-

Source: Rajasthan Soil and Vegetation, (2020)

From the total available area in the state around 50% of the land is uncultivated and among the available cultivated land, soil fertility varies across the districts. Fig. 1.4 indicates the land distribution in the state. More than half of the total land area (Fig. 1.4) is under cultivation indicating that majority of the population is involved in the agriculture sector. Swain, Kalamkar, & Ojha, (2012) argues that the variation in crop production and productivity indicates the variation in the soil type and resource availability.

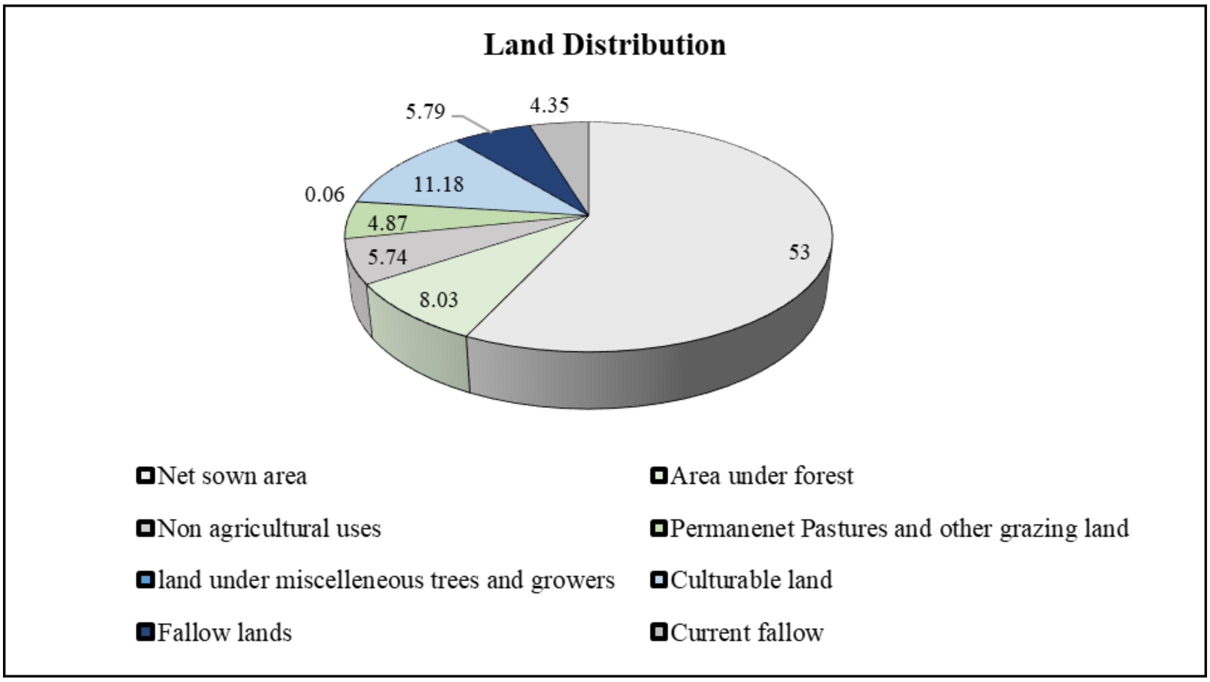

Fig. 1.4: Land Distribution pattern in Rajasthan 2018-19 (in %)
Source:(RajRas, 2019)

Understanding soil variability and topographical components of a region are important to determine its impact on crop yield. Though yield is a function of some other parameters (such as biological factor, climatic condition, soil components including pH of soil, bulk density, texture, clay content, thickness and soil acidity too) have found to affect the crop productivity. But for the formulation of mathematical model these parameters are assumed to be constant. Previously some of the studies were carried to determine the impact of slope, elevation and surface curvature (C. Yang et al., 1998a; Ciha, 1984; Daniels et al., 1985; Simmons et al., 1989; Stone et al., 1985). Topographical features directly influence crop growth. Thus, there is a need to determine the correlation between these parameters such that the spatial distribution of crops will improve the crop yield. (Kravchenko & Bullock, 2000) described a correlation between crop yield and topography. Higher yields were obtained in a region with lower slope elevation and vice-versa. The correlation among the two parameters indicates that the elevation of a region is a significant factor impacting the crop productivity.

1.4.2 Rajasthan: Cropping Scenario

Rajasthan experiences three cropping seasons: Kharif, Rabi and Zaid. Crops cultivated in October and November and harvested in months of March and April are known as Rabi crops. These crops include wheat, barley, oilseeds, gram and pulses. Majorly cultivated oilseeds in a region are rapeseed & mustard. Kharif are the crops cultivated in June and July and harvested in September and October. Crops cultivated in season include maize, pearl millets, kharif pulses, sorghum (jowar) and millets. The state owned a first position in production of pearl millets. Between these two seasons there is a short cultivation season known as Zaid, that supports the cultivation of some pulses and groundnut. Most of the farmers owning small farm leave their land fallow in Kharif season due to inadequate availability of water resources.

In year 2010-11, the total gross sown area and net sown area in a region are 26 million hectares and 18.34 million hectares respectively. This indicates that 7.65 million hectares (3.7 %) of the total net sown area is cultivated more than once. In Kharif season about 63% of the total arable land in a state is under cultivation. Major food grain crops include cereals and pulses. Pearl millet and wheat are dominated crops in Kharif and Rabi season respectively. In 2018-19 food grain production has reached 22.80 million tonnes (IBEF, 2020). The state produces 5.49 % of the nation's food grain and 21.31 % of its oilseeds. Thus, holding a 1st and 3rd position in mustard and soyabean & oilseeds respectively. Out of the total irrigated area, 35.79% is under wheat, 23.65% under rapeseed & mustard and 5.8% under grams (Hooda, 2013).

In Rajasthan, the legume-wheat cropping system is commonly practiced. Such a crop pattern enables the soil to retain the nutrients, contributing to optimize the yield. The southern region (Kota, Bundi, Baran, Jhalawar, Chittorgarh, Banswara) of the state is cultivated with soyabean and wheat as a dominant crop. However, in districts of Tonk and Banswara and eastern Rajasthan pearl millet-wheat; pearl millet-mustard and maize-wheat are the prominent crop combinations. Different crop pattern is being adopted by farmers to improve the crop yield. Some of the commonly practise cropping pattern in state includes: mono-cropping, multiple cropping and mix-cropping (Table 1.3). Mono-cropping is predominated in most of the districts of Rajasthan. Most of the small farmers often practice mixed crop systems to support the family. Mix farm practice represents a scenario of integrated farm management witnessing the management of crop, livestock and resources simultaneously.

Table 1.3: Different Cropping Techniques

Cropping Techniques	
Mix-Cropping	Cropping two or more crops simultaneously on same piece of land
Multiple-Cropping	Growing two or more crops on a same piece of land in a defined pattern
Mono-Cropping	Cultivating single crop on a piece of land

Being a region owned with arid topography with inadequate irrigational water resources, the allocation of crop poses a challenge to decision-makers. According to World Bank, only 20% of the total cultivated land contributing 40% of the total food produced is irrigated and remaining 80% of cultivation depends on rain. With urbanization, the demand for water resources is expected to increase impacting crop productivity significantly. Thus, for the management of farms with limited availability of water resources the allocation of water efficiently is a major objective to maximize the output.

Along with the allocation of irrigational water at fields, another important parameter is the irrigation scheduling. It includes the application of the right amount of water at right time depending on the different stages of crop growth. Vedula & Mujumdar,(1992) discuss the water requirement at different stages of plant growth. The amount of water supplied to the crop has impacted crop production and growth simultaneously. Each crop has an optimal water requirement that results in maximum growth and productivity. An empirical formula is derived by (Steduto et al., 2012) that defines a relationship between evapotranspiration and crop yield respectively is represented as:

$$1-\frac{Y_a}{Y_x}=K_y\left(1-\frac{ET_a}{ET_x}\right) \tag{1.1}$$

Where, Y_x and Y_a represents maximum and actual crop yield, ET_x and ET_a is the maximum and actual evapotranspiration. K_y is the yield response factor respectively. Equation (1.1) represents the water production function. The large value of the yield factor $\left(K_y\right)$ indicates that crop growth and yield are adversely affected by water inadequacy and vice-versa. (Azaiez, 2008) proposed a dynamic model to allocate water resources over different growth stages of a given crop, considering water shortage. The main purpose is to choose the crops that can compete in terms of water and maximize the yield. To evaluate the yield response, equation (1.1) has been used by many researchers.

Water requirement of different crops is calculated by Ali, (2010):

$$CWR_j = ET_j = \sum_{t=0}^{n} (ET_{0t} * KC_t) \qquad (1.2)$$

Where, CWR_j indicates water requirement of the cultivated crop (in mm), ET_j is the crop evapotranspiration (in mm), t is the time duration in which crop is planted (in days), n is the phenological stage of a plant ET_{0t} is the average transpiration by plants in a region in t days (in mm), KC_t crop coefficient in t^{th} day. Fig. 1.5 represents the water requirement of crops cultivated in the state. To allocate water resources among multiple crops in multi periods a multistage irrigation water allocation model is developed by (Dai & Li, 2013).

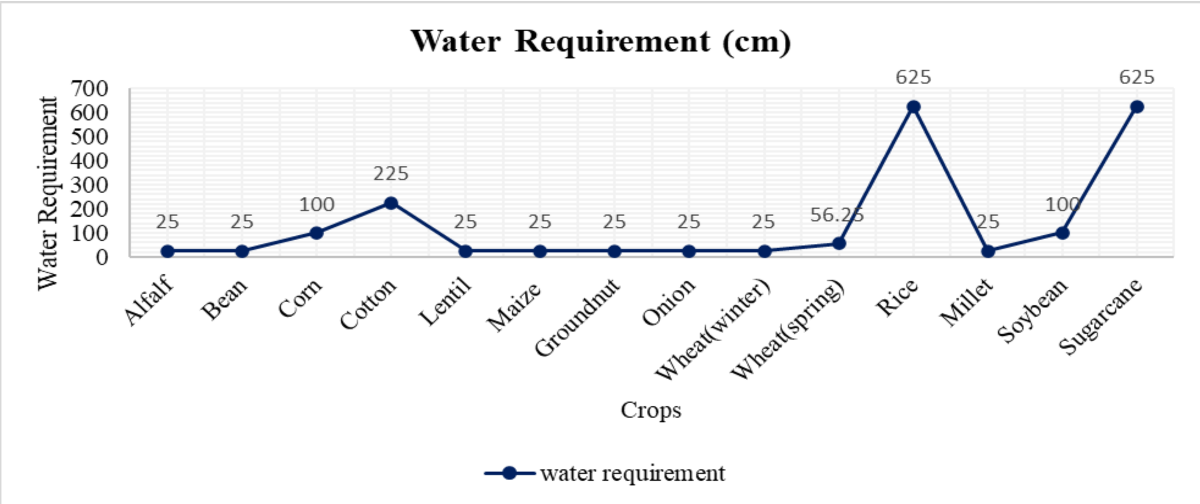

Fig. 1.5: Average Crop Water Requirement (in cm) of Different Crops

Water is one of the critical inputs that determine the crop combinations, crop allocation, variety and number of crops to be cultivated in a season. Seeds and fertilizers were not able to provide their optimum outputs if it does not get adequate and efficient water resources. Not only crops, but the management of water resources is also essential. 75% of agriculture in Rajasthan is rain-fed whereas, only 25% of the land is irrigated. Moreover, this 25% of a region undertakes more than 50% of agriculture output. Sources that contribute to provide irrigational facilities in the state are illustrated in fig. 1.6.

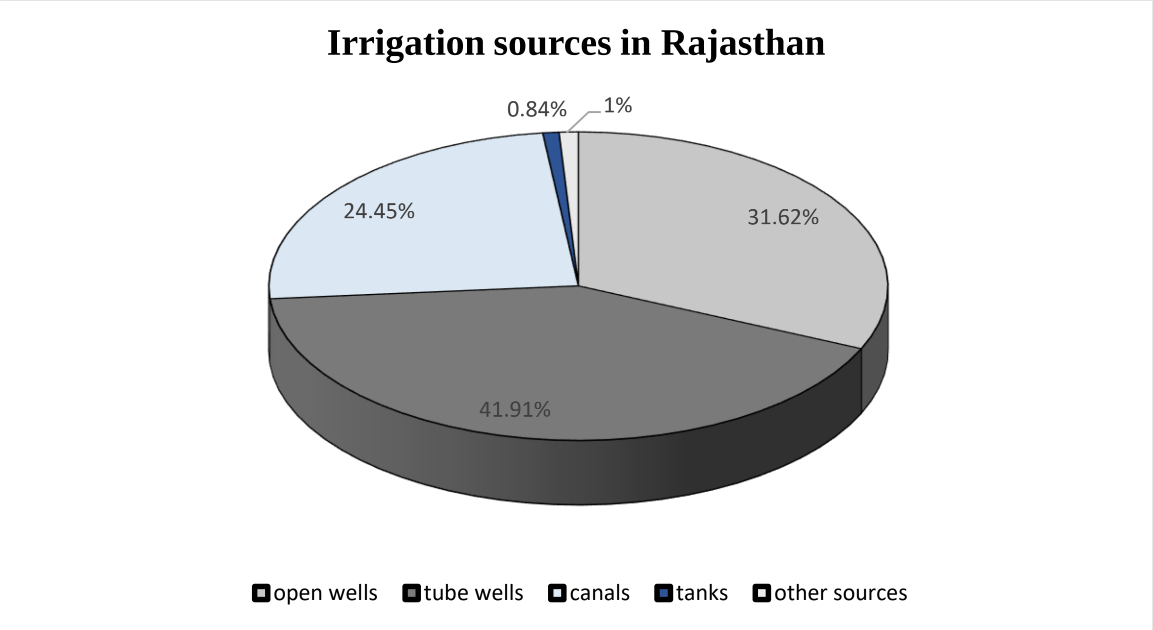

Fig. 1.6: Irrigational Resources in Rajasthan
Source: (S. Singh, 2018)

Along with crop allocation, availability of water resources, topographical characteristics of a region, fluctuating climatic conditions had a great impact on crop productivity. (Asseng et al., 2010) proposed, simulation model to determine the impact of varying temperature on wheat yield alone. Consequently, it is observed that the variation of ± 2°C can reduce production to about 50%. The temperature fluctuations over a region, result in yield variance.

Temperature and precipitation often impacted the mean yield and variability. The impact of temperature and precipitation varies across a crop. The allocation of arable land differs due to climatic variations too. Both parameters simultaneously influence the mean and spatial crop variability. Involvement of trend in panel data model made the model more realistic and stochastic. Crop variance and covariance affect crop allocation by impacting the variability profits (Isik & Devadoss, 2006). With this, it becomes easier for growers to make the decision. Thus, the crop with more mean yield or has decrement in variability in response to climatic variations is likely to have more area under cultivation. The potential impact of climatic variations on crop productivity has attracted the attention of policy-makers, farmers, environmentalists and mathematicians. However, weather variations are still a challenging issue. (Cai et al., 2009) predict the impact of weather change on crop yield through soil-water balance perspective.

Erratic rainfall pattern, arid topography, inadequate availability of water resources and fluctuating weather conditions motivates to formulate a mathematical model for Rajasthan cropping scenario. An analysis is carried out to maximize the farm revenues to support the decision-makers to alter the farm parameters within the feasible region.

1.5 Motivation

Fast-growing population laid immense pressure on resources, particularly on agriculture sector to produce more. Many researchers proposed a viable solution to-sustainable intensification, increasing production and improving distribution.

Due to system’s complexity, the sector is facing a challenge in terms of resource accessibility, climatic fluctuations, topography and optimal utilisation of resources. Over an ancient time, analytical tools have been developed for optimal allocation of farm resources with the aim to maximize the farm revenue. For crop management and crop allocation in-depth analysis of the factors and interactions affecting the yield is essential. The topography is another parameter that affects the crop yield. However, researchers have done an extensive study to reveal the impact of topography on crop productivity. The studies carried out previously only focusses on the relationship between agronomic and topographical attributes and the impact of these two factors on crop productivity (Marques da Silva & Silva, 2008).

While reviewing the literature, we came across issues and challenges related to optimal crop selection under water-deficient conditions with the aim to maximize the revenue faced by the growers in every season. The crop loss faced by farmers due to sudden change in climatic conditions, atrocious decision making and pest attack motivates to take up an issue.

Since, Rajasthan is a state with arid topography it further poses a challenge to farmer to select an optimal crop combination to generate more farm revenue by minimizing the input cost. An erratic rainfall pattern adds challenge to the sector. As majority of crop cultivated in a region is rain-fed thus, most of the arable land remains fallow in Kharif season. The proposed model will support the grower decision of crop allocation and optimal crop-mix.

1.6 Methodology

Different mathematical and statistical tools were reviewed to determine an optimal crop-mix. To illustrate the feasibility of decision variable Multi-Objective Linear model is applied. The approach evaluates the feasible region to get an optimized value of the decision variable. The corner points of the feasible region provide an optimal value of an objective function. Further, to see the effect of one crop over the other crop when cultivated as a mix crop multiple regression analysis is employed. Fig. 1.7 represents systematic framework for analysis.

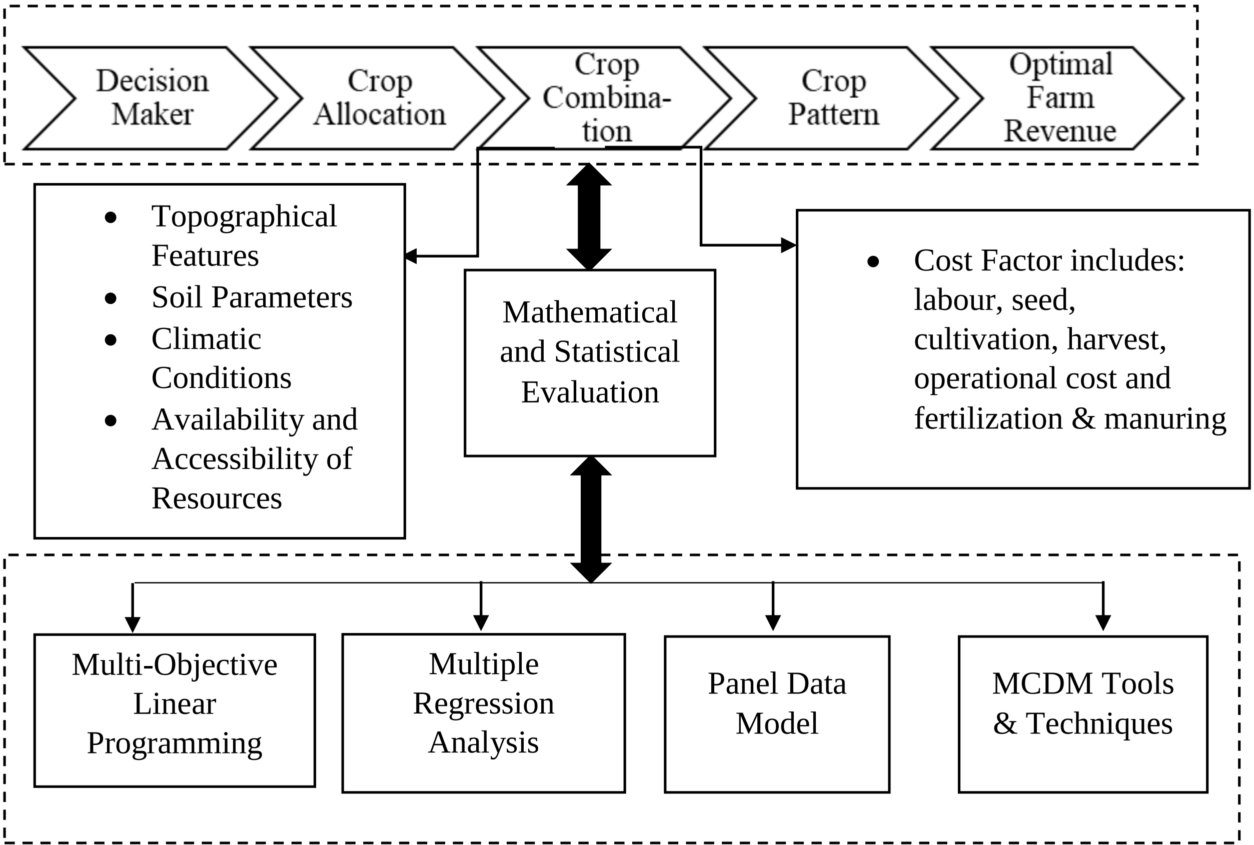

Fig. 1.7: Systematic Framework for Analysis

To investigate the impact of climate parameters on crop yield and its variability Just & Pope production function is employed. To evaluate the parameter factors, Maximum Likelihood Estimation (MLE) is applied. Generally, Feasible Generalised Least Square (FGLS) approach is employed but (Saha et al., 1997) explains that MLE is more appropriate than FGLS as it is more consistent method with small mean square error than FGLS and efficient approach to determine the vectors.

Different Multi-Criteria Decision-Making (MCDM) techniques were discussed for optimal crop selection, to evaluate the available crop alternatives in a decision space based on criteria i.e., beneficiary and non-beneficiary costs variable. The technique by allotting a preference to the available alternatives, supports the decision-making of growers. Standard Deviation method is used to assign an attribute to the decision variables. Ten different MCDM techniques were applied for analysis. For the result verification, the technique proposed was compared with the crop preference allotted by (Qureshi et al., 2018) using Fuzzy-TOPSIS.

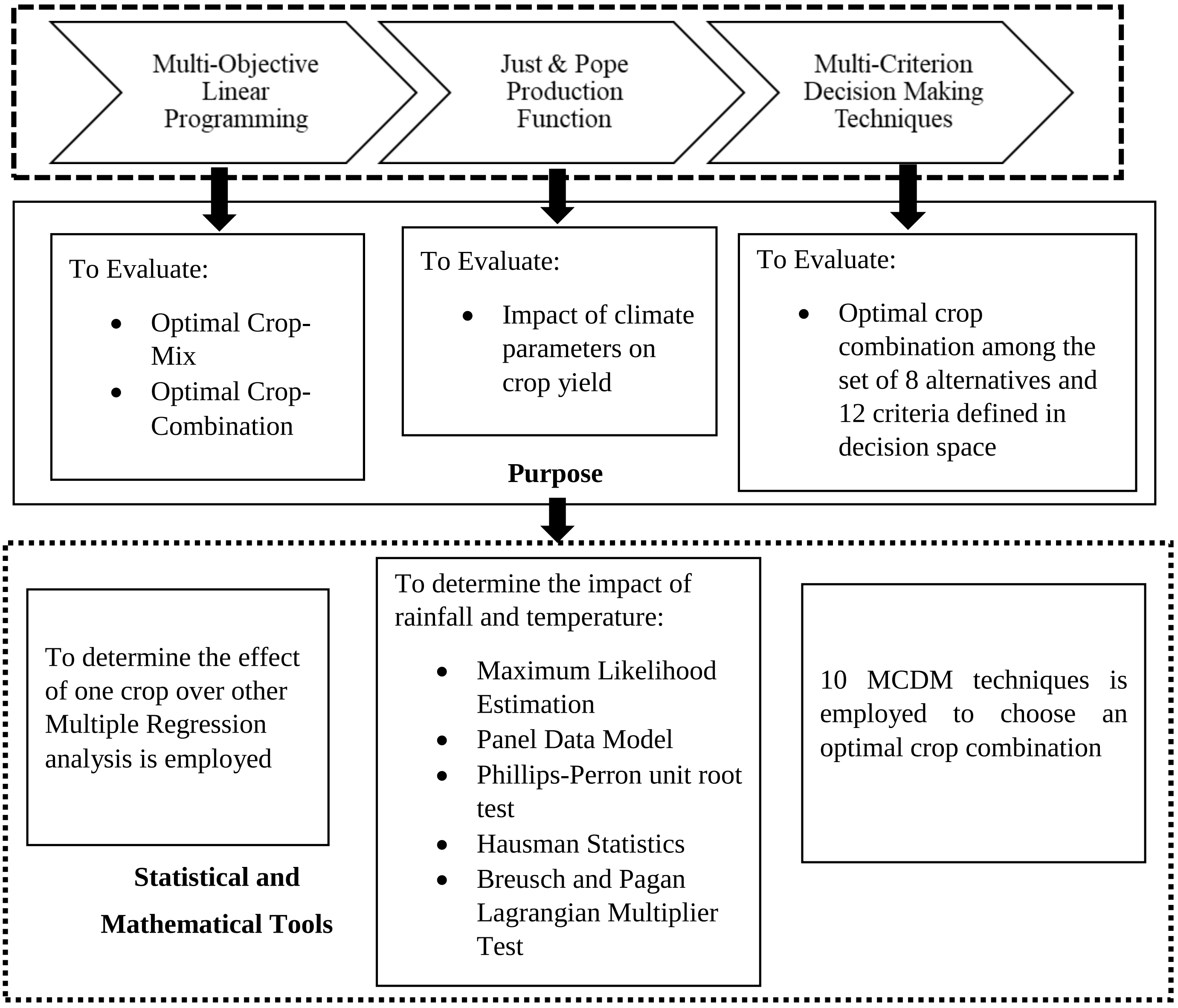

Fig. 1.8: Methodology Followed for an Analysis

1.7 Objectives of the Study

1. To develop a mathematical model to optimise the crop mix for Rajasthan farm scenario.
2. To study the problem using various mathematical and statistical tools to develop a best optimal decision model and a comparative analysis will be carried out to compare the results of the tools.

The research work is conducted to develop a mathematical model for Rajasthan farm model to analyze the crop combination to maximize the farm revenues. To achieve the research objective different mathematical and statistical tools were applied that are discussed in further chapters. The detailed discussion about the cropping pattern and the effect of climatic fluctuations on crop yield were illustrated in subsequent chapters. However, as per researcher's knowledge, no study has been conducted so far to determine the optimal crop combination with a mathematical approach for Rajasthan farm scenario. Thus, the research work conducted significantly contribute to extend the literature in this direction.

1.8 In Scope of the Study

1. The study focusses to maximize the farm profit by considering a set of defined constraints.
2. The study conducted will support the farmers to opt an optimal crop mix and their allocation.
3. The survey is conducted only in the districts with intense cultivation.
4. Only the impact of average rainfall and temperature is considered to determine the variability of these parameters on crop yield.

1.9 Out scope of the Study

1. The biological parameters such as soil pH, light intensity, variety of seed were not considered.
2. The crops cultivated in minority by farmers were not considered for analysis.
3. Attack by pests and any natural calamity that results in crop failure were not taken under consideration.
4. Topographical parameters were not considered for analysis.
5. The addition of any other constraints or parameter impacts the solution optimality.

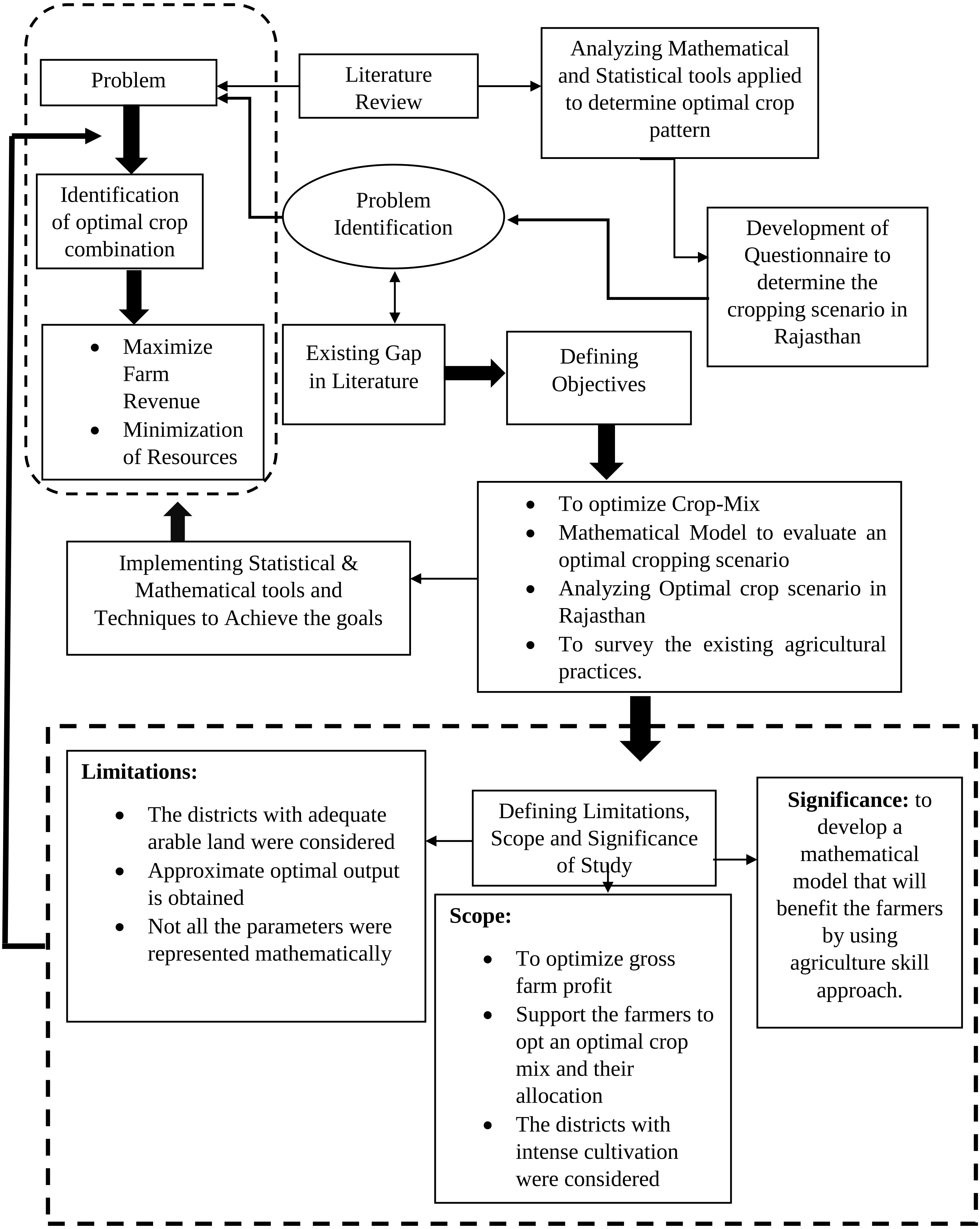

Fig. 1.9: Systematic Flow of Research Work