DISSERTATION ON

CANAL OPTIMIZATION FOR LONGA IRRIGATION PROJECT

Submitted in partial fulfilment for the requirement for the award of degree of

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

(WATER RESOURCES ENGINEERING)

UNDER

Assam Science and Technology University

For the session: 2022-2024

Submitted By

PALLABI GOGOI

ROLL NO: 220620061011

Under the guidance of

DR. BIBHASH SARMA

Professor

Department of civil Engineering

ASSAM ENGINEERING COLLEGE

JALUKBARI, GUWAHATI-781013,

ASSAM

DEPARTMENT OF CIVIL ENGINEERING

ASSAM ENGINEERING COLLEGE

Jalukbari, Guwahati- 781013

Assam, India

CERTIFICATE OF APPROVAL

SESSION (2022-2024)

This is to certify that Pallabi Gogoi, Roll no-220620061011, a student of M. Tech. 4th Semester, Civil Engineering Department (Water Resources Engineering), Assam Engineering College has submitted the dissertation entitled "**CANAL OPTIMIZATION FOR LONGA IRRIGATION PROJECT**" in partial fulfillment for the requirement of the award of the degree of Masters of Technology in Civil Engineering with specialization in Water Resources Engineering under Assam Science and Technology University.

Place: Guwahati

Date:

Dr. Jayanta Pathak

Professor and Head of the Department

Department of Civil Engineering

Assam Engineering College

Jalukbari,Guwahati-781013

DEPARTMENT OF CIVIL ENGINEERING

ASSAM ENGINEERING COLLEGE

Jalukbari, Guwahati- 781013

Assam, India

CERTIFICATE OF SUPERVISION

SESSION (2022-2024)

This is to certify that the Dissertation entitled **''CANAL OPTIMIZATION FOR LONGA IRRIGATION PROJECT**'' is a project report prepared by Pallabi Gogoi, Roll no-220620061011, a student of M.Tech. 4th Semester, Civil Engineering Department (Water Resources Engineering), Assam Engineering College under my supervision and guidance in partial fulfillment for the requirement of the award of the degree of Masters of Technology in Civil Engineering with specialization in Water Resources Engineering under Assam Science and Technology University.

Place: Guwahati

Date:

Dr. Bibhash Sarma

Professor

Department of Civil Engineering

Assam Engineering College

Jalukbari, Guwahati-781013

DEPARTMENT OF CIVIL ENGINEERING

ASSAM ENGINEERING COLLEGE

Jalukbari, Guwahati- 781013

Assam, India

CANDIDATE'S DECLARATION

I hereby declare that the Dissertation entitled **''CANAL OPTIMIZATION FOR LONGA IRRIGATION PROJECT**" is a report prepared by me in partial fulfillment for the requirement of the award of the degree of Masters of Technology in Civil Engineering with specialization in Water Resources Engineering submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati-781013 under Assam Science and Technology University under the supervision and guidance of Dr. Bibhash Sarma, Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati-781013.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Place: Guwahati

Date:

Pallabi Gogoi

M. Tech. 4th Semester

Roll No-220620061011

Department of Civil Engineering

Assam Engineering College

Jalukbari, Guwahati-781013

ACKNOWLEDGEMENT

I would like to express my deepest gratitude and sincere thanks to my respected guide Dr. Bibhash Sarma, Professor, Department of Civil Engineering, Assam Engineering College for his constant guidance, constructive suggestion and full co-operation throughout the study and preparing the finalized dissertation.

I also express my sincere thanks to Dr. Jayanta Pathak, professor & Head of the Department of Civil Engineering, Assam Engineering College for the kind departmental support and facility for carrying out my work.

I also thank all the faculty members and staff of Department of Civil Engineering, Assam Engineering College for their free exchange of idea and lending their helping hand whenever I needed them.

I would like to express my deepest gratitude and sincere thanks to Er. Ajay Kishore, AEE, Longa Division, Gossaigaon, Kokrajhar, BTAD, Assam for kind cooperation in data collection in related to Longa Irrigation Project and all the staff members of the office concerned.

Lastly, I thank all my classmate, family members and well- wishers for their constant encouragement, valuable advice and inspiration during the course of my study.

Place: Guwahati

Date:

Pallabi Gogoi

M. Tech. 4th Semester

Roll no-220620061011

Department of Civil Engineering

Assam Engineering College

Jalukbari, Guwahati-781013

CONTENTS

SL NO	TITLE	Page no.
	CANDIDATE'S DECLARATION	i
	CERTIFICATE OF SUPERVISION	ii
	CERTIFICATE OF APPROVAL	iii
	ACKNOWLEDGEMENT	iv
	CONTENTS	v
	LIST OF FIGURE	vii
	LIST OF TABLE	ix
	NOTATIONS	x
	ABSTRACT	xi
	CHAPTER 1: INTRODUCTION	
1.1	PROLOGUE	1
1.2	MOTIVATION FOR THE WORK	2-3
1.3	MICROSOFT EXCEL SOLVER	3
1.4	IRRIGATION CANAL SYSTEMS	3
1.5	STUDY AREA	3
1.6	CROP WATER DEMANDS	4
1.7	OBJECTIVE	4
1.8	METHODOLOGY	4-5
1.9	CHAPTERWISE SCHEME OF STUDY	5
	CHAPTER 2: LITERATURE REVIEW	
2.1	INTRODUCTION	6
2.2	LITERATURE SURVEY	6-15
	CHAPTER 3:STUDY AREA	
3.1	INTRODUCTION	16-18
3.2	CANAL SYSTEM OF THE PROJECT	18-20
3.3	EXISTING CROPPING PATTERN	20
3.4	PROPOSED CROPPING PATTERN	20-21
	CHAPTER 4:CANAL SYSTEM	
4.1	INTRODUCTION	22
4.2	TYPES OF CANAL	22-25
4.3	DESIGN CONSIDERATION OF LINED CANALS	26-28
4.4	DISCHARGE OF CANAL SECTION	29
	CHAPTER 5:CROP WATER REQUIREMENT	
5.1	INTRODUCTION	30
5.2	CROPPING PROGRAM	31
5.3	REFERENCE CROP EVAPOTRANSPIRATION (ETo) AND THE EFFECTIVE RAINFALL(Eeff Rain)	31-32
5.4	SOIL SURVEYS	32
5.5	SHORT DESCRIPTION ON CROPWAT 8.0	32-33
5.6	INPUT DATA	33-39

5.7	FACTORS AFFECTING CROP WATER REQUIREMENT	40
5.8	COMPUTATION OF CROP WATER REQUIREMENT	40-45
5.9	IRRIGATION SCHEDULING	45-48
	CHAPTER 6:-MODEL FORMULATION FOR CANAL SECTION OPTIMIZATION	
6.1	INTRODUCTION	49
6.2	GRG NONLINEAR ENGINE OF MICROSOFT EXCEL SOLVER PLATFORM:	49-50
6.3	CONSIDERATIONS AND CALCULATIONS OF PARAMETERS REQUIRED FOR MODEL FORMULATION:	50-53
6.4	MODEL FORMULATION	53-56
	CHAPTER 7:-CANAL SECTION OPTIMISATION,RESULT AND DISCUSSION	
7.1	INTRODUCTION	57
7.2	OPTIMISATION OF CANALS	57-60
7.3	RESULTS	60-61
7.4	DESIGN CHECK AT TRANSITION	61-62
7.5	DISCUSSION	62
	CHAPTER 8:-CONCLUSION AND FUTURE SCOPE OF WORK	
8.1	INTRODUCTION	63
8.2	CONCLUSION	63-65
8.3	FUTURE SCOPE OF WORK	65
	REFERENCES	

LIST OF FIGURE

Figure No.	TITLE	Page No.
Fig. 2.1	Typical wide rectangular channel section	11
Fig. 2.2	Typical wide trapezoidal channel section	12
Fig. 3.1	Location map of Longa Irrigation Project	16
Fig. 3.2	District map of study area	16
Fig. 3.3	Land use Land Cover Map of Watershed area Longa Irrigation Project prepared by ArcGIS	17
Fig. 3.4	Soil Map for the Watershed area of Longa prepared by ArcGIS	17
Fig. 3.5	Soil map of crop area of Longa Irrigation Project prepared at ArcGIS	18
Fig. 3.6	Landuse Land cover map of the crop area of Longa Irrigation project Prepared at ArcGIS	18
Fig. 3.7	Line diagram of canal	19
Fig. 3.8	Index map of Longa irrigation project	19
Fig. 4.1	Trapezoidal channel section with notations	24
Fig. 4.2	Rectangular channel section with notations	25
Fig. 4.3	Triangular channel section with notation	25
Fig. 4.4	Circular channel section with notation	25
Fig. 5.1	Minimum temperature of Dhubri station	34
Fig. 5.2	Maximum Temperature of Dhubri station	34
Fig. 5.3	Humidity of Dhubri Station	35
Fig. 5.4	Wind speed for Dhubri Station	35
Fig. 5.5	Sunshine Hours for Dhubri Station	36
Fig. 5.6	Radiation for Dhubri Station	36
Fig. 5.7	Precipitation for Study area	36
Fig. 5.8	Crop Co-efficient curve	39
Fig. 6.1	Rectangular channel cross-section	50
Fig. 6.2	Trapezoidal channel section	51
Fig. 7.1	Calculation of canal parameter and minimum cost of construction for assumed initial depth and width value in excel solver platform	58
Fig. 7.2	Solver platform showing objective function, variable and constraints.	58

Fig. 7.3	Optimum value of objective function for the optimum values of variables along with drawing of cross-section of canal section as displayed in excel solver platform	59
Fig. 7.4	Comparative statement showing initial value and final value as displayed in excel solver platform	59
Fig.7.5	Cross Sectional area of M1 and M1S1 canals.	61

LIST OF TABLE

Table No.	TITLE	Page No.
Table 2.1	Channel Geometry of Best Hydraulic Section	15
Table 3.1	Details of Barrage of Longa Irrigation Project	18
Table 3.2	Details of head regulator of Longa Irrigation project	19
Table 3.3	Types of Crops, cropping Period and total area covered by the crops	21
Table 4.1	Recommended Side Slopes as per IS: 10430-2000	26
Table 4.2	Free board as per IS: 10430-2000	26
Table 4.3	Value of Rugosity co-efficient for different lining materials	27
Table 4.4	Maximum permissible velocity as per IS: 10430-1982	28
Table 4.5	C.W.C. S Recommendation for B/Y ratio	28
Table 5.1	Effective rainfall for Longa Irrigation Project computed by CROPWAT 8.0	37
Table 5.2	ETo for Longa Basin, computed by CROPWAT 8.0	37
Table 5.31	General crop data for Jute	41
Table-5.32	Crop water and irrigation requirements for Jute	41
Table 5.41	General crop data for Sali Crop	42
Table-5.42	Crop water and irrigation requirements for Sali crop	43
Table 5.51	General crop data for Rapeseed	43
Table 5.52	Crop water and irrigation requirements for Rapeseed	44
Table 5.61	General crop data for vegetable (sweet Melon)	44
Table 5.62	Crop water and irrigation requirements for Vegetable (Sweet Melon)	45
Table 5.7	Crop water requirement	45
Table 5.8	Maximum Crop water requirement per decadal	45
Table 5.9	Irrigation scheduling for Sali Crop	46
Table 5.10	Irrigation scheduling for Jute	46
Table 5.11	Irrigation scheduling for Vegetable (Sweet melon)	47
Table 5.12	Irrigation scheduling for Rapeseed	47
Table 5.13	Irrigation scheduling considering all proposed crops of the study area.	48
Table 6.1	Discharge required by Canal	53
Table 7.1	Ideal dimensions and construction cost of main canal and its distributaries	60

NOTATIONS

Q	Discharge
V	Velocity of flow
B	Width of channel
Y	Depth of channel
t	Thickness of lining
f	Free board
S_b	Bed slope
A_f	Cross sectional area with freeboard
A	Cross sectional area without freeboard
P_f	Wetted perimeter with freeboard
P	Wetted perimeter without freeboard
R	Hydraulic radius without freeboard
D	Hydraulic depth without freeboard
T	Top width without freeboard
Fr	Froude's no without considering freeboard
C_1	Cost of excavation per cubic meter
C_2	Cost of lining per cubic meter
n	Rugosity Coefficient
1:Z (V:H)	Side slope of trapezoidal channel

ABSTRACT

Open canals play a pivotal role in most of the irrigation projects, serving as the primary system for water delivery. The cost of these projects is largely determined by the length and cross-section of the canals. An economical canal section is one that minimizes the total construction cost and through which maximum discharge passes. Therefore, canal section should be designed in a way to achieve the optimised construction cost. Determination of crop water requirement plays an important role in obtaining the desired discharge which can be evaluated using CROPWAT 8.0. The overall construction cost of a canal typically includes excavation and surface lining costs, in addition to labour and maintenance costs. These costs are primarily dependent on the channel dimensions. In the present study, it is focussed on determination of crop water requirement for the proposed crops of the study area such as Jute, Sali crop(Ranjit), vegetable(Sweet Melon) and rapeseed, irrigation scheduling of the proposed crops and optimal section designing and estimation of cost of construction of the optimised canal. In the present study of Longa Irrigation Project, two nonlinear optimization models were developed - one for a rectangular canal section and another for a trapezoidal canal section. The objective function for both models is to minimize the total construction cost per unit length. These models were solved using the Microsoft Excel solver platform, taking into account various constraints and variables to determine the minimum construction cost per unit length of the channel in the optimal dimensions of the cross sections. In order to obtain the discharge of the canal, crop water requirement is evaluated using CROPWAT 8.0 considering the proposed crops in the study area. Moreover, irrigation scheduling has also been carried out in order to obtain the frequency of watering and thereby an increase in the efficiency of water supply to the field.

Keywords: Longa Irrigation Project, Nonlinear Optimization Models, Canal Section Optimization, Microsoft Excel Solver, Irrigation Scheduling.

CHAPTER 1

INTRODUCTION

1.1 PROLOGUE

In the areas where it is arid or semi-arid, water plays a major role and it should used to its fullest potential. In those areas, the water is released in an effective manner based on the experiences and especially during the start and finish of the growing season but there are no particular rules to be followed. Even during high times, water released into canal systems may results to underirrigation, if the requirement of water is more than the water supplied. There may be overirrigation too and due to which there may be waterlogging, high water bills, and loss of vital nutrients. Crop yield may lowers down holding the limits to irrigation, especially during times when crops are vulnerable. Therefore, water distribution may be done efficiently (Peng et al., 2012). The major conveyance system for delivering water for various purposes such as irrigation, water supply etc. are the manmade canals with an economic canal section which may be defined as the section of canal at which amount of total construction cost is the least. However, the total cost of construction of the canal consists of excavation costs and surface lining cost with labour cost and maintenance cost included. However, to construct the canal section with minimum cost of construction to deliver the specified discharge, design of open canal requires determination of optimum dimensions of the canal. The open canal section may be defined as having minimum area or the maximum velocity cross section or least wetted perimeter for a given rate of flow, roughness coefficient and longitudinal slope is considered as the most economic canal section since it involves least amount ofearth work and least lining surface. Hence, optimal canal design requires optimization of cost by managing flow area and flow perimeter to a minimum. (Swamee & Chahar, 2015).

Most optimization approaches are quite relevant when it requires evaluating continuous variables. However, it is very tedious to simulate the water distribution as it involves a number of non-linear equations. Moreover, there are a lot of iterations to be done in order to optimize even a small water distribution system using nonlinear equations. (Yao et al., 2019). And hence, optimisation models prove grateful in those cases. Optimization modelling is a mathematical technique that determines which option among several options is optimum for solving a given problem. It is an effective instrument utilized in many domains, including as engineering, economics, operations research, finance, logistics, and more. Mathematical optimization models can save expenses and increase operational efficiency across workflows by optimizing resource allocation, industrial processes, or logistics (https://www.ibm.com/topics/optimization-model).

1.2 MOTIVATION FOR THE WORK

The author is a working engineer in the Department of Irrigation, Government of Assam. It is observed that very less time available for implementation of a project and very often the department follows very simple procedure for laying of canals. It is also observed that the senior officials of the department are reluctant to adopt the optimisation methods due to its complexity. So, it is thought that a very simple technique can be derived for the use of the field engineers where they can directly obtain the optimisation without much complexity. The objective is to frame a simple optimisation model where a field engineer can fill up input data to get the optimised values.

1.3 MICROSOFT EXCEL SOLVER

In an optimization model, variables that would maximize or minimize an objective function under various constraints are determined. The most optimal dimensions for the canal and the most efficient construction cost are found by nonlinear programming utilizing the Microsoft Excel solver platform. A standard utility included with any Microsoft Office product is the Microsoft Excel-Solver tool, created by Frontline Systems, Inc. Linear and nonlinear programming problems, which arise in many scientific domains, can be solved with the help of solver applications (Chirila & Miron, 2017). It works with linear, nonlinear, and evolutionary models. As MS Excel-based design approaches are fairly well-known and well-liked among design engineers, the current study aims to develop an optimisation model using the generalized reduced gradient (GRG) method that explicitly considers cost and safety requirements through a straightforward and user-friendly interface. One method for resolving nonlinear issues is the generalized reduced gradient. Consequently, cost-based design issues can be resolved by using the GRG technique. The Excel add-in tool "Excel Solver" can be used to apply this strategy. Compared to other conventional procedures, this one has the advantage of being a very simple excel-based technique that can optimize the design to get the lowest construction cost in a short amount of time with few inputs (Nawaz et al., 2022).

1.4 IRRIGATION CANAL SYSTEMS

In India, the Irrigation canal system plays a very important role in the economy of country. Most of the people rely on the Irrigation canal for their livelihood. However, in irrigation projects apart from other major irrigation structure such as headwork, canals also involves as major part of project. So, proper designing and planning needs to be taken up while framing an irrigation project and keeping in consideration of type of soil, discharge, coefficient of roughness, velocity of flow, slope of canal and shape of canal. However, based on the discharge and needs the canal network may again be classified as-Main Canal, Distributary canal. Based on shape of canal, it may again be classified as trapezoidal, rectangular, circular and parabolic canals.

1.5 STUDY AREA

The Longa Irrigation project has been taken as the study area which is located in the state Assam at Kokrajhar West constituency in the district of Kokrajhar in the northern bank of river Brahmaputra. The barrage of the scheme was constructed at village Ramfalbil near Serfunguri across the river Longa which is a perennial river originating from the foothills of Bhutan. The branch canals of the scheme was passed through several villages of the area Dwimuguri, Silsilitbari, Kalobari, Pachim Athaibari, Ganger Jwaflong, Habrubari, Tengaigaon, Gossainichina, Fulkumari, Ramani Ashram, Goybari, Harunari, Dakhin Shyamthaibari. This project is proposed to develop with two main canals designated as M1 and M2. Initially, M1 canal is proposed to construct by the department and hence considered for study.

1.6 CROP WATER DEMANDS

Due to increased urbanization in India, water demands has increased considerably. The main source of livelihood in India is agriculture and nearly 70% to 80% population depends upon agriculture.(Surendran et al., 2015) Therefore, water plays an important role in the people's lives and thus there is a need for conservation of water. Considering the usage of water in the field of agriculture, there is a need for optimal use of water and thus the crop water requirement is estimated before planning irrigation project (Memon & Jamsa, 2008). The amount of water that is required from the time the crop is sown to the crop is harvested is the crop water requirement. The amount of water varies seasonally, crop wise and type of soil. Water is required to meet the demands of consumptive use, application loss is known as water requirement. There are various factors that influences the crop water requirement which will be discussed in the chapter 5.

1.7 OBJECTIVE

The objective of the study are stated below:-

1. To determine the Crop Water Requirement (CWR) of the proposed crops of the study area.

2. To determine the Irrigation scheduling of the proposed crops of the study area.

3.To determine the optimal dimensions and cost of construction of the canal sections of Longa Irrigation Project.

1.8 METHODOLOGY

The following methodology is followed:-

a) To determine the crop water requirement with the help of decision supportive software CROPWAT 8.0. The input data such as meteorological data extracted from the software CLIMWAT 2.0, soil data prepared using ArcGIS, and other data are as per FAO standards.

b) Irrigation scheduling carried out for the crops proposed using the results of crop water requirement as obtained earlier.

c) Two non- linear optimisation models were prepared for the canal section as rectangular and trapezoidal on GRG NON-LINEAR ENGINE EXCEL platform. The objective function, constraints and variables are framed in a manner to obtain optimal dimensions and minimise the cost of construction for the canal sections considered for the Longa Irrigation project. The inputs were fed to the non-linear optimisation model, considering the canal sections as trapezoidal and rectangular.

1.9 CHAPTERWISE SCHEME OF THE STUDY

The dissertation contains the following chapters:-

Chapter 1: This chapter deals with a brief introduction on the topic of the study and discusses about the Microsoft excel solver application used to achieve the objective of the study. Furthermore, this chapter includes the area of study and brief introduction of open canal network used in irrigation project and the objective of the study.

Chapter 2: This chapter depicts the literature review.

Chapter 3: This chapter contains details of study area i.e. Longa Irrigation Project

Chapter 4: This chapter gives a general idea of classification of canal system and design consideration of lined canal as per IS: 10430-2000.

Chapter 5: This chapter will contain evaluation of crop water requirement for the crops of the study area.

Chapter 6: This chapter deals with model formulation.

Chapter 7: This chapter deals with Canal Section Optimization, Result and Discussion.

Chapter 8: This chapter deals with conclusion and future scope of the work.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A total of 75 to 80 per cent of total cost of Irrigation project in India accounts for cost of irrigation canal and remaining 20 to 30 percentage accounts for storage elements. Therefore, it is a very important component of irrigation project. Minimization of cost of canal system will minimise the cost of whole project. There are several methods to optimise the cost. Mostly Non-Linear programming model has been used by the researcher.

2.2 LITERATURE SURVEY

2.2.1 LITERATURE REVIEW ON CROP WATER REQUIREMENT

Madhusudhan M S ,Vinay S N ,Savitha J C ,Nazeer M Gadad ,Srikanth M N(2021) studied the water requirement of the major crops grown in Mandya city using CROPWAT 8.0 software. The main crops grown in the city include Rice, Millet, Sugarcane and Pulses. The climate data and the Meteorological data were collected and processed from the University of Agricultural Sciences, V C Farm Mandya from a period 2010-2020. The soil data are partially collected from the same university and the partial data are taken from the FAO-56 manual depending upon the crop and finally the crop data are obtained from the FAO-56 manual. It was observed that CROPWAT software can be used effectively in estimating the ETo values and also for the use of predicting CWR for different crops. The reference crop evapotranspiration, ETo varied from 2.95mm/day to 6.97mm/day. The crop evapotranspiration (ETc) and Net irrigation for Rice varied from 0.64mm/day to 8.61mm/day and 1145.8mm, for Millet 1.76mm/day to 7.23mm/day and 366.0mm, for Sugarcane 2.43mm/day to 7.57mm/day and 1164.3mm and for Pulses 2.29mm/day to 8.23mm/day and 361.8mm respectively(S et al., 2021)

Kumar Shashank , Aggile Lakshmi Prasanna, Bisht Himani and Gautam Shweta(2020) studied water requirements on vegetables (potato, pea and cabbage) over Uttar Pradesh with help of CROPWAT software using the weather data of minimum temperature, maximum temperature and rainfall for the period 1980-2014. The analysis was performed in two date of sowing 15th October and 15th November. Studies has allowed strategic planning in irrigation management and scheduling in the view of water saving technologies. The data used in this study are mainly meteorological data, including precipitation, minimum air temperature and maximum air temperature from 1980 to 2014 in 24 meteorological stations. The average ETc was found minimum at early sowing (15 Oct.) as compare to delay sowing (15 Nov) for potato. The water demands found higher for Late season sown season as that of early sown period. It was observed that in case of cabbage and potato early sowing plans better in regards to irrigation while in case of pea Late season sowing consumes less water.(Kumar et al., n.d.)

Dashora. R, Singh, P. K Purohit, R. C, Kothari. M, Jain. N, Kothari. S (2020) carried out his studies on computation of Crop Water Requirement for Wheat and Rapeseed Crop in Dharta Watershed which are the major crops grown in the watershed. Decision Supportive Software CROPWAT 8.0 was used while computing Crop Water Requirement. The Mean monthly data were collected from the nearest Meteorological Laboratory and the other Parameters that are required for calculation such as Maximum temperature (°C), Minimum temperature (°C), Relative Humidity (%), Wind speed (km/day), Sunshine (hrs). Rainfall data (mm) were collected in watershed area by semi-automatic tipping bucket instrument for year 2014. Irrigation scheduling was also done with the software. It was seen that due to low effective rainfall the crop water requirement and irrigation requirement for Rapeseed is almost same. For Wheat crop in Late season stage (Feb-march), temperature increased and results in increased evapotranspiration which increase crop water consumption.

Nivesh Shreya, Kashyap Pradeep Singh and Saran Bhagwat (2019) studied computation of crop irrigation requirement of major cultivated crops in Balangir district, Odisha, India . The main crops of the region includes Paddy, Pulses, Cotton, Sesame, Groundnut and Mango. Decision making software CROPWAT8.0 was used while calculating the irrigation water requirement. Reference evapotranspiration was calculated using Food and Agriculture

Organization-Penman Montieth equation. The effective rainfall was calculated using USDA S.C. method. This model found helpful to the farmers in selecting right crop and right frequency of irrigation.(Nivesh et al., 2019)

Gangwar Angshu, Nayak T.R, Singh R.M, Singh Ashutosh (2017) estimated the crop water requirement for Bina Command ,Madhya Pradesh using CROPWAT 8.0 Model. He has developed the model for effectively planning and managing irrigation practices in Bina Command. The reference evapotranspiration was estimated by FAO Penman Monteith Method. The main crops grown in the area are wheat, gram, pulses and Rapeseed. The crop details were considered as per guide for estimating irrigation water requirements, Ministry of Irrigation and FAO-Irrigation and Drainage paper. CROPWAT 8.0 model was used to study the irrigation requirement.(Gangwar et al., 2017)

2.2.2 LITERATURE REVIEW ON IRRIGATION SCHEDULING

Zhe Gu, Ph.D et al. (2020) (Gu et al., 2020) have studied various approaches such as ET-WB based, Θ-based, plant water-based, and model-based approaches to improve the growth of plant and high crop yield production and Irrigation scheduling with optimise water delivery at proper times. All these approaches are based on soil water moisture and these approaches enables to obtain targeted soil moisture content and the present soil moisture content. However, ET-based methods like ET-WB has highest applicability at field, since they depends on K_c and MAD values which can be obtained easily from FAO standards. It may lack accuracy under specific site conditions. But, Θ- and plant-based methods offer results at ultimate precision levels but its practicability is very less due to its sensor installation and maintenance requirements. If the installation is poor and maintenance is not well enough it may results to absurd values which may results in failure of model. Model-based methods are however accurate but requires calibration with field data. Combining more than one methods would improve the efficiency in irrigation scheduling and facilitate understanding of crop yield responses to water. Moreover, development of cost-effective tools would help the farmers to use the tools for better yield production.

Halimi H. Abdul and Tafera H. Ashebir (2019) did a case study at Godollo, Hungary on irrigation scheduling of tomato for the changing climate with the application of CROPWAT model. In this study he has analysed the irrigation scheduling for the two years 2010 and 2011 and reveals that there is 40% decrease in rainfall which results to 2011 year as the dry year and 2011 is the wet period. Crop yield remained unaffected due to efficient irrigation scheduling in spite of varying irrigation needs and timings with surface irrigation being the preferred method.(Halimi & Tefera, 2019.)

2.2.3 LITERATURE REVIEW ON OPTIMAL CANAL SECTION

Shahverdi Kazem, Maestre Jose Maria (2023) studied and developed a model on canal modernisation with the help of archimedes screw turbines which will results in renewable energy generation and improvement in efficiency of water distribution. While developing this model CROPWAT 8 has been used for computation of crop water requirement. However, HEC-RAS has also been practiced for simulation of canal. He has incorporated the Fuzzy Sarsa learning AI in MATLAB. With this application it is seen that there are lot of improvements in the water distribution indicators, energy generation, and reductions of CO_2 emissions, which has not only results to economic viability but also significant benefits to environment. This study emphasises on holistic approach to canal modernization, combining energy generation with efficient water management.

Shahverdi Kazem, Maestre. J.M (2022) studied the hunting behaviour of grey wolf and developed a optimisation model using the concept of metaheuristic approach. He has scheduled the irrigation water delivery. This model is tested for storage condition when it is normal and also when water is scarce. The results revealed that the GWO model proves best for condition when water availability is normal. In case of water scare situation, GWO results poor performance. However, algorithms perform well for the problems which is very complex. It works well when obtaining exact solution is computationally impossible. In this case, nonlinear model has been used for the simulations which was linked to the GWO model in MATLAB. GWO avoids local minima points when normal condition exists (Shahverdi & Maestre, 2022).

Wang Yijia (2022) developed an optimisation on canal system based on Genetic Algorithm with the lowest water supply cost as an objective function considering the section a trapezoidal and U-shaped. He has found that U-shaped section is best as compared to trapezoidal. Further, it was also stated that Genetic Algorithm has greater integration speed and better comprehensive perform (Wang, 2022)

Yao Weiwei, Ma Xiaoyi, Chen Yuansheng (2019) has carried out its studies on optimisation of models based on Genetic Algorithm that provides a reasonable arrangement of canal water allocation times and discharges and reduces the losses. It is seen that the total water requirement has been reduced after optimisation of canal. Also, it was suggested that revised scheduling of water reduces the water requirement and hence increase in productivity of crops (Yao et al., 2019).

Fazlali Ali & Shourian Mojtaba (2017) developed a model for solving optimum water allocation and cropping pattern problem. In his study, he has used integration of a network flow programming (NFP) based simulation model and the shuffle frog leaping optimization algorithm (SFLA) in the form of a simulation-optimization approach to determine optimum cropping pattern. MODSIM was applied to NFP to find water allocations and based on the agronomic equations the benefit of water supply for the agricultural crops is hence calculated. In his study, he has taken irrigation water depths and cultivation area as decision variables which were optimised with the help of SFLA. The objective was to maximise the net benefit gained from crop production. MODSIM has customisation ability and due to which the SFLA code was used as VB.NET language coupled with NFP. The Model SFLA-NFP was run and compared with existing situation and it is seen that the agricultural yield benefit and total water supply are increased 12% and 3.2% respectively in the optimum situation comparing the present condition. However, on sensitivity analyses it was found that on the parameters crops net price and maximum yield have a direct impact on the results of the model. The model has tried to allocate more cultivation area to that plant on increase of their value for a crop (Ali Fazlali & Mojtaba Shourian (2017).

Tabari. M.M.R & Tavakoli Shiva & Mari Mohsen Mazak (2014) developed a optimization model in which the objective was to minimize the cost per unit length of canal which includes the direct costs as well as indirect cost such as seepage due to water loss and per cubic meter earthwork cost per meter canal lining. Both the costs are related to shapes and size of canal. He has developed the model using MATLAB programing. He has used Flow discharge as the main constraint and the permissible velocity and Froude's number as the secondary constraints (Rezapour Tabari et. al., 2014).

Kentli. A and Mercan.O (2014) developed a optimisation model using genetic algorithm(GA) and sequential quadratic equation programming(SQP) technique. He has tried to minimise the water losses occurred due to evaporation, seepage. In his study, he had optimized the canal cross section as trapezoidal, rectangular and triangular. GA uses algorithm based on natural selection. It is best suited for optimization problems in which the objective function is discontinuous, non-differentiable, stochastic, or highly nonlinear. However, SQP is useful for nonlinearly constrained optimization. It uses derivative of objective function and constraints so that it quickly reaches to global maxima. However, GA generates population randomly and the best reaches the optimum while SQP generates single point in a deterministic computation and last single point reaches the optimum. In his study it was found that the rectangular cross section canals give better results as compared to trapezoidal sections. As compared to GA, SQP gives results that are robust and reliable. However, these algorithm gives better results as compared to classical studies (A. Kentli and O. Mercan, 2014).

Samani. H. M. V. PhD and Zanganeh. A (2010) has designed a model using integer real linear programming technique for determining optimal distribution of municipal canal networks. The hydraulic and optimisation analyses were linked through an iterative procedure and it satisfies all constraints at a minimum total cost. The constraints includes the pipe size, reservoir heights, available pumps, pipe flow velocities and nodal pressures. The model developed is more advantageous at short nodal pressure constraints and has the ability to optimize networks that contain pumps. In this study, the non-linear optimisation equations are linearized by using zero-unity variables. Unlike the optimisation method used by Samani and Mottaghi (2006), which has the disadvantage of having very long nodal pressure constraint equations, particularly in large networks, the proposed method uses node by node short equations. This method is advantageous as it is simple and computationally faster as compared to other widely used non-linear algorithms that employs linear programming.(Samani & Zanganeh, 2010)

Bhattacharjya. R.K (2006) has carried out its studies on optimal design of open channel section including the critical flow condition. He had developed a optimisation model in which he had used the sub critical or super critical conditions so as to avoid the critical flow condition. In his study he used Mannings equation and the objective of the study is to minimise the construction costs of channel. The model uses the Sequential quadratic programming which was solved by MATLAB. The model was applied over the trapezoidal section of canal. The model was developed restricting the velocity, side slopes and Top width. It is seen that the flow at critical depth of channel is unstable. So, if the design depth is found near critical depth then the dimension of channel is hence modified so as to avoid problems at critical state.(Rajiv Bhattacharjee, 2006)

Chow.V.T (1959) has defined that hydraulically efficient section is the optimal section for designing a non-erodible channel section. At this section, there is maximum conveyance i.e maximum discharge 'Q'. However, a channel is most economical when it conveys maximum discharge 'Q' through the cross-sectional area 'A', wetted perimeter 'P', resistance coefficient 'n' and bed slope 'S_b'. He had used the uniform flow equation as a constraint while computing the relation of hydraulically efficient section.(*Open_channel_ven_te_chow*, n.d.) From continuity equation, we get,

$Q=AV$ where, A= Cross Sectional Area

V= Maximum permissible Velocity

From Manning's equation we get,

$$V = \frac{1}{n} R^{2/3} S_b^{1/2}$$

To get maximum velocity at a given cross sectional area 'A', hydraulic radius 'R' has to be maximum.

i.e $R = \frac{A}{P}$

So, the Minimum wetted perimeter is used while computing optimal section of a channel.

MOST ECONOMICAL SECTION:-

The most economical section of a channel is the section through which maximum discharge passes.

Q=AXV

i.e, $Q \propto V$

However, $V = \frac{1}{n} \times R^{2/3} S^{1/2}$

i.e, $V \propto R^{2/3}$

However, R=A/P

i.e, $R \propto 1/P$

Thus, for an economical section, the wetted perimeter has to be minimum.

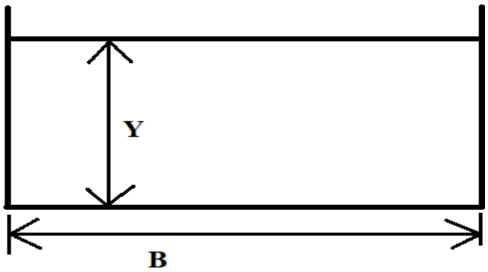


Fig 2.1: Typical wide rectangular channel section

I) **In case of wide rectangular channel,**

P=B+2Y

For P to be minimum, $\frac{dP}{dY} = 0$

So, $\frac{d}{dy}(B + 2Y) = 0$

And, A=BY, So,B=A/Y

or, P=B+2Y

or, $\frac{\mathbf{dP}}{\mathbf{dY}} = \frac{\mathbf{d}}{\mathbf{dY}}(\frac{A}{Y} + 2Y)$

=d/dY(A/Y+2Y)

$=-AY^{-2}+2$

or, $A=2Y^2$

or, $B \times Y=2Y^2$

or, B/2=Y

i.e The Most economical section for a rectangular channel is when the depth of flow 'Y' is half of the bed width.

Moreover, $\boldsymbol{R} = \frac{A}{P} = \frac{BY}{B+2Y} = \frac{Y}{2}$ is an another condition for a economical section of a rectangular section.

II) In case of Trapezoidal section,

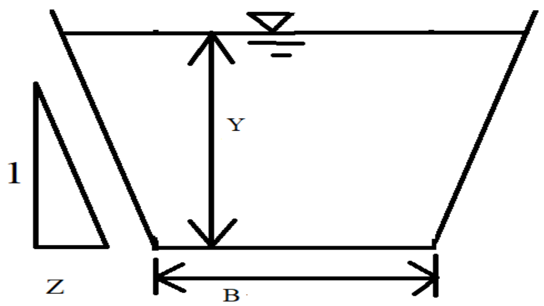


Fig 2.2: Typical trapezoidal channel section

Area, A= BY + ZY

$B=\frac{A}{Y} - ZY$

Top width, T= B+ 2ZY

Wetted perimeter, $P=B+2Y\sqrt{(1+Z^2)}$

$=\frac{A}{Y} - ZY + \sqrt{1 + Z^2}$

When a section have a minimum wetted perimeter "P", then the section is called most economical section. Now, taking derivative of P with respect to y and equating to zero for minimum, we get,

$$\frac{dP}{dY} = -\left(\frac{A}{Y^2}\right) - Z - 2\sqrt{1+Z^2} = 0$$

$$\text{or, } \frac{A}{Y^2} + Z = 2\sqrt{1+Z^2}$$

$$\text{or, } \frac{B}{2} + ZY = Y\sqrt{1+Z^2}$$

This condition implies that a trapezoidal canal section is economical when half of the top width is equal to length of one slanting side.

Again, hydraulic radius, $R = \frac{A}{P} = \frac{BY+ZY^2}{B+2Y\sqrt{1+Z^2}}$

Putting the value B=A/Y-ZY, we get, on simplification, R=Y/2, which is the most economical trapezoidal canal section.

Similarly, he also established conditions for triangular, trapezoidal and circular channels also. The below table 2.1 contain the channel geometry of best hydraulic section.

Table 2.1: Channel Geometry of Best Hydraulic Section

Cross section	Area A	Wetted perimeter P	Hydraulic radius R	Top width T	Hydraulic depth D	Section factor Z
Trapezoid, half of a hexagon	$\sqrt{3}\,y^2$	$2\sqrt{3}\,y$	$\frac{1}{2}y$	$\frac{4}{3}\sqrt{3}\,y$	$\frac{3}{4}y$	$\frac{3}{2}y^{2.5}$
Rectangle, half of a square	$2y^2$	$4y$	$\frac{1}{2}y$	$2y$	y	$2y^{2.5}$
Triangle, half of a square	y^2	$2\sqrt{2}\,y$	$\frac{1}{4}\sqrt{2}\,y$	$2y$	$\frac{1}{2}y$	$\frac{\sqrt{2}}{2}y^{2.5}$
Semicircle	$\frac{\pi}{2}y^2$	πy	$\frac{1}{2}y$	$2y$	$\frac{\pi}{4}y$	$\frac{\pi}{4}y^{2.5}$
Parabola, $T = 2\sqrt{2}\,y$	$\frac{4}{3}\sqrt{2}\,y^2$	$\frac{8}{3}\sqrt{2}\,y$	$\frac{1}{2}y$	$2\sqrt{2}\,y$	$\frac{2}{3}y$	$\frac{8}{9}\sqrt{3}\,y^{2.5}$
Hydrostatic catenary	$1.39586y^2$	$2.9836y$	$0.46784y$	$1.917532y$	$0.72795y$	$1.19093y^{2.5}$

CHAPTER 3

STUDY AREA

3.1 INTRODUCTION

Longa Irrigation Project is located in the Kokrajhar district of Bodoland territorial council. It is a Flow Irrigation scheme. The headwork of the project is located at latitude 26.548096^{0}N longitude 90.162317^{0}E. Watershed delineation maps of the watershed area are prepared with the help of ArcGIS using SWAT tool shown at Fig 3.3 and Fig 3.4. Maps for Land use land cover and soil type of the area for the cropped area are prepared with the help of ArcGIS using SWAT tool shown at Fig 3.5 and Fig 3.6.

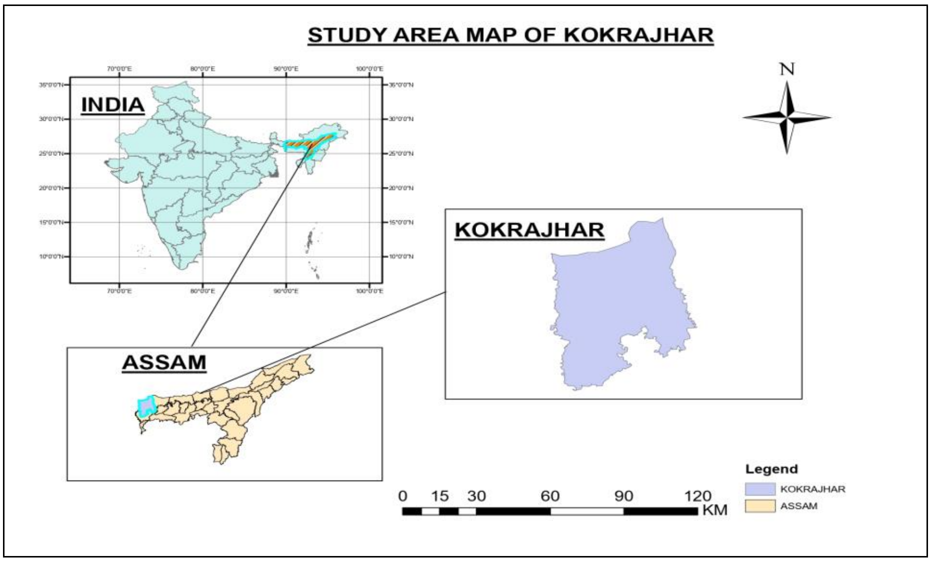


Fig 3.1:- Location Map of Study Area prepared by ArcGIS

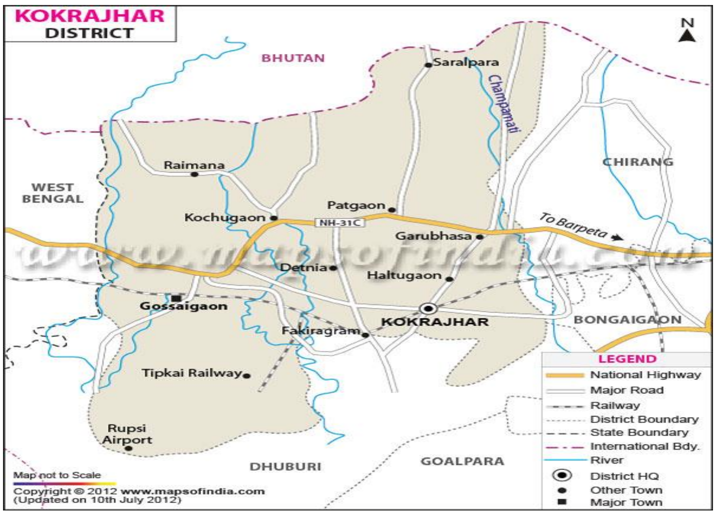


Fig 3.2:- District Map of Study Area

Source: http://www.mapsofindia.com

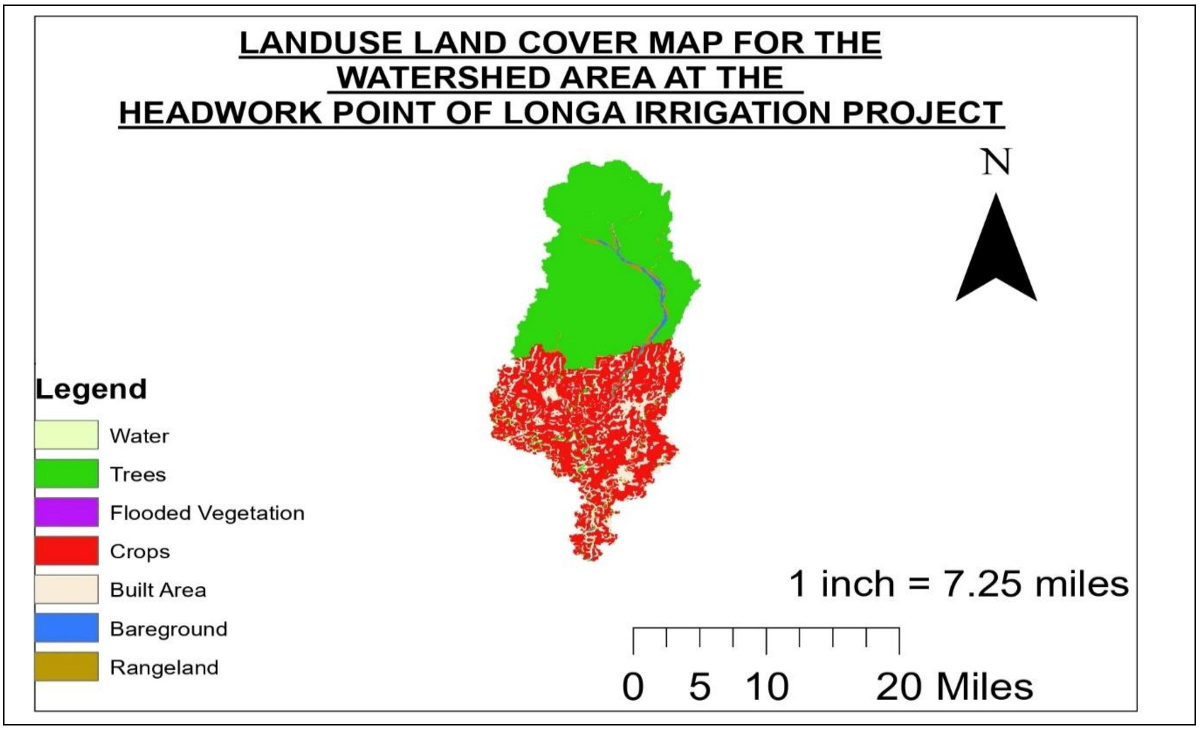


Fig 3.3 :- Land use Land Cover Map of Watershed area Longa Irrigation Project prepared by ArcGIS

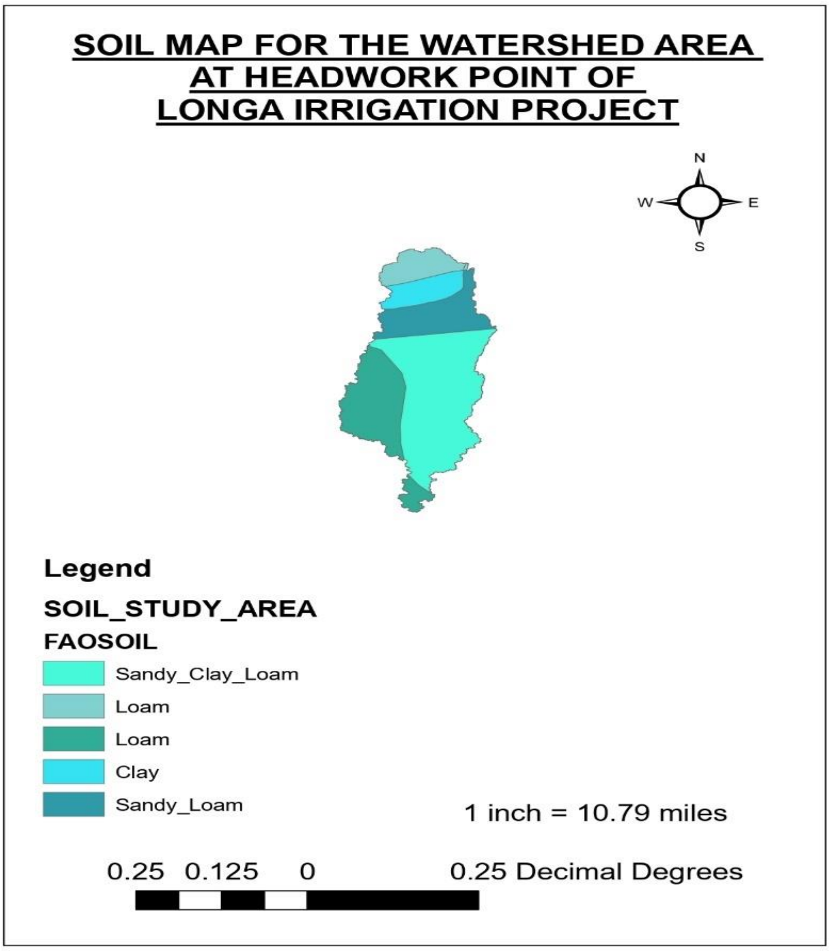
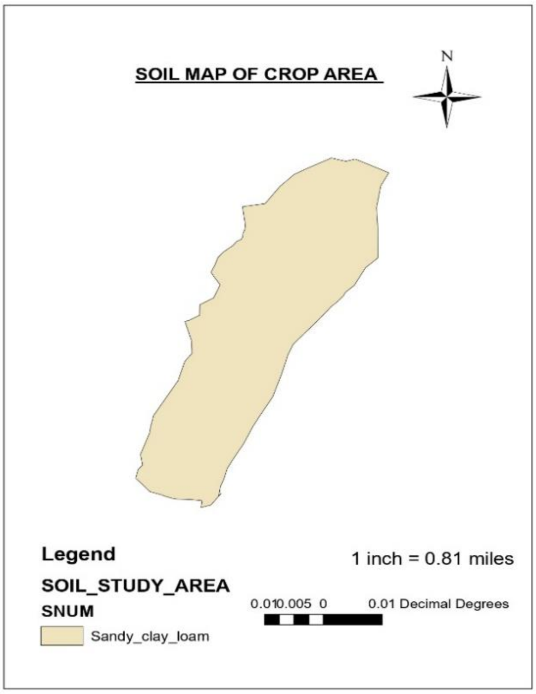


Fig 3.4 :- Soil Map for the Watershed area of Longa prepared by ArcGIS.



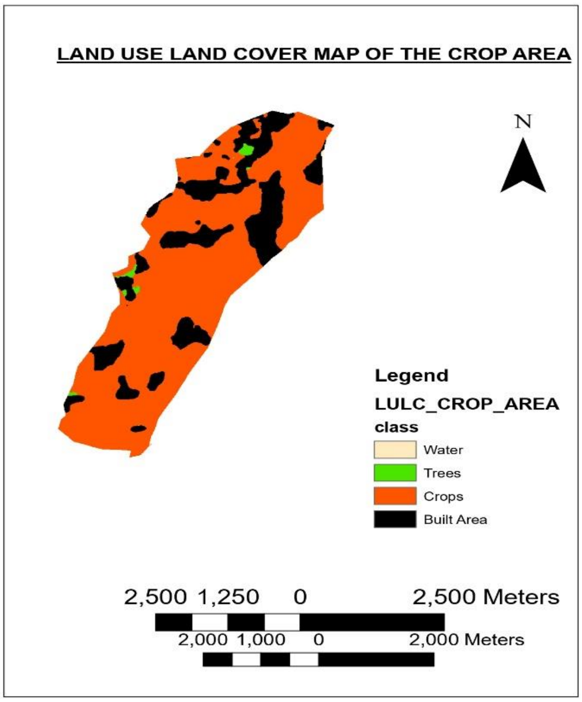


Fig 3.5 Soil map of crop area of Longa

Fig 3.6 Landuse Land cover map of the crop area of Longa Irrigation project

3.2 CANAL SYSTEM OF PROJECT

The scheme has a barrage of length 86.58 meters and the canal system will be provided mainly on the right bank of river Longa. The Right Bank canal system of the scheme proposed of one main canal M1 and six numbers of branch canal. The left bank canal system has only one main canal M2 of length 600m without any branch canal. The Scheme was proposed and sanctioned as Medium Irrigation project with proposed Canal Length of 34.60 Km with NIA of 2791.22 Ha. The river has maximum flood discharge of 510 cumec and 6.50 cumec minimum discharge. This scheme was completed in the year 1978. Now, the department has proposed to layout the canal for the right bank.

Table 3.1 Details of Barrage of Longa Irrigation Project

Barrage features	
Design Discharge	510.00 Cumec
Floor Length	36.58 M
Floor Width	86.58 M
No of Bays	12
Clear span of Each Bay	5.79 M

Barrage features	
Pond Level	60.30 M
D/S HFL	60.91
Crest Level	57.92
U/S Floor Level	56.55
D/S Floor Level	55.99

Table 3.2 Details of Head Regulator of Longa Irrigation Project

Floor Length	12.19 M
Floor Width	8.84 M
Clear span of Each Bay	3.65 M
D/S FSL	60.00 M
U/S Floor Level	59.29 M
D/S Floor Level	58.69 M

*Source : Department of Irrigation, Assam

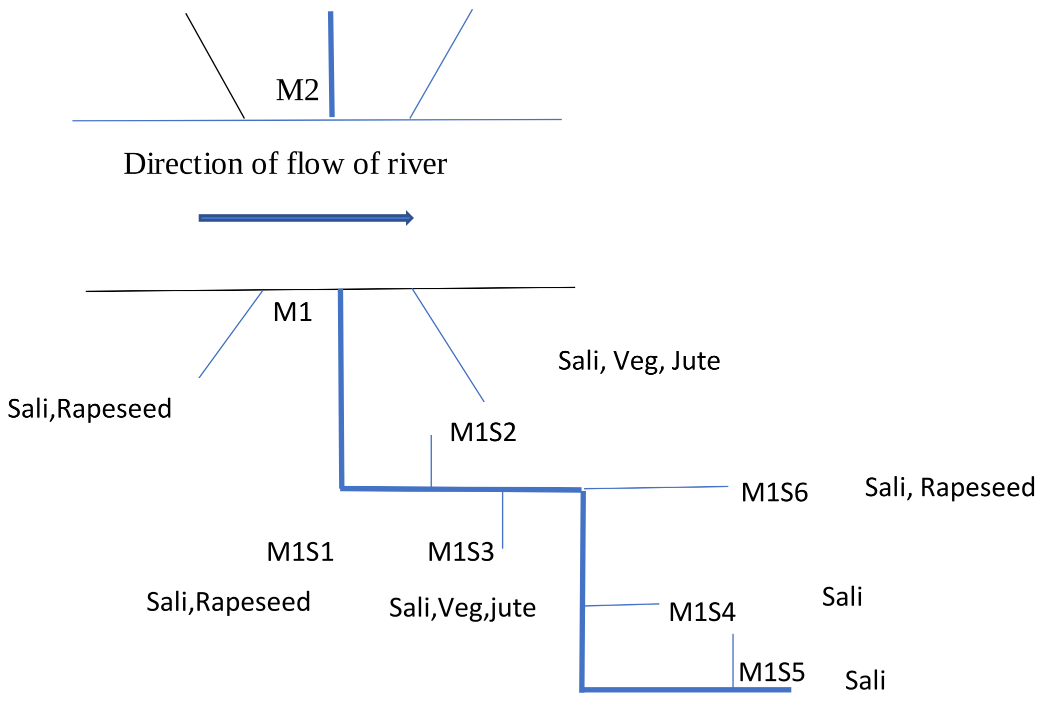


Fig 3.7:-Line Diagram of Canal system

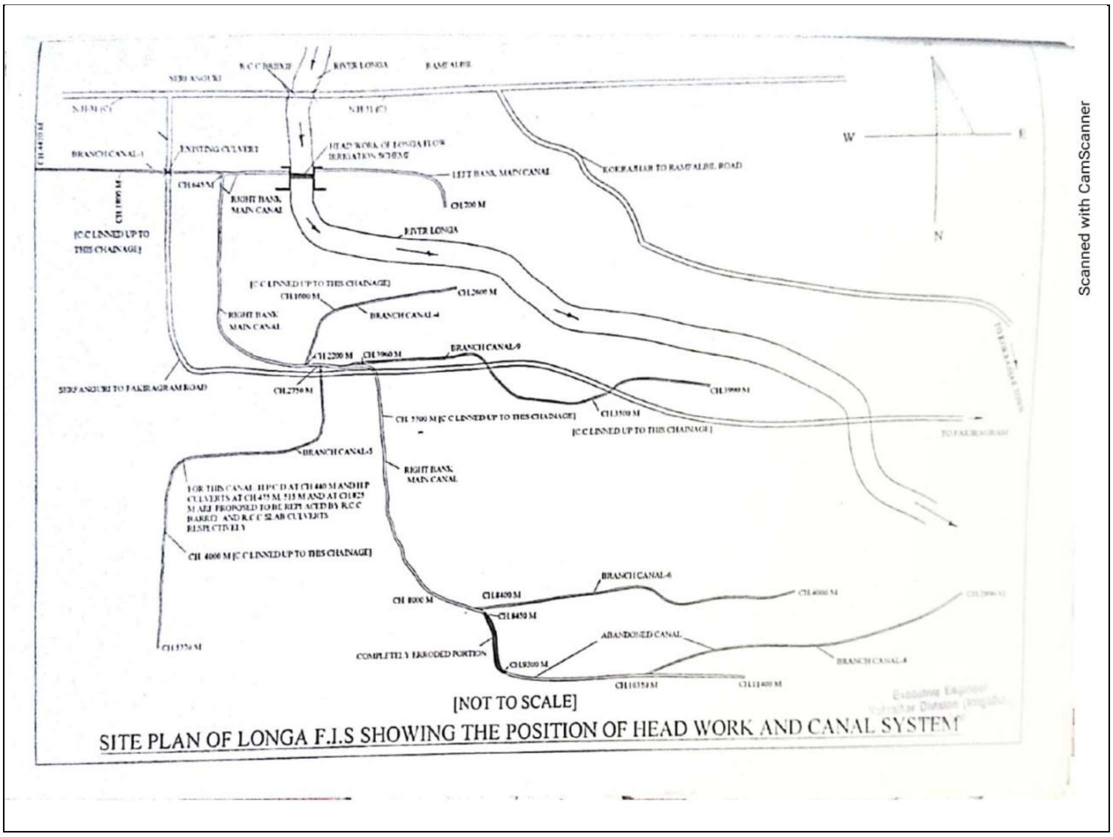


Fig 3.8 :- Index map of canal system

*Source: Department of Irrigation, Assam

3.3 EXISTING CROPPING PATTERN

The cultivators in the area have only used the traditional cropping pattern with the crop sali until this point because there were no regular irrigation facilities in the area. In the command area, there is very little cropping now taking place. Assam is an agrarian state whose economy is reliant on its agricultural output. Low cropping intensity can be increased by up to 150% with guaranteed irrigation facilities.

3.4 PROPOSED CROPPING PATTERN

It is assured that the proposed scheme will irrigate 2791.22 Ha of net irrigable area (NIA) with the crops sali, jute, vegetable sweet melon and rapeseed. In the entire command area, only rain-fed farming is now practiced. The project will result in a net increase of 2791.22 Ha NIA in irrigation infrastructure. With the installation of guaranteed irrigation facilities, the conventional cropping pattern can be changed. With the provision of irrigation, cropping intensity can be increased to 150% and more lands can be put under cultivation. Currently, the majority of farmers only grow one type of rice. Rabi crops are farmed on a very small area with conventional crop varieties and practices due to a lack of irrigation. The proposed cropping pattern is given in the Table 3.3.

Table 3.3: Types of crops, cropping period and area covered by the crops.

Sl no.	Name of crop	Cropping period	Area(in Ha)
1	Sali	28th July -24th Nov	2791.22
2	Jute	01st March- 28th June	700.22
3	Rapeseed	25th Dec - 3rd April	1595
4	Vegetable (sweet melon)	21st Dec - 19th April	700.22

CHAPTER 4

CANAL SYSTEM

4.1 INTRODUCTION

To supply water to fields from the head regulator, a well distribution system consisting of a number of canals are required. The canals are artificial canals which are constructed on land to carry water to the fields. These canals are used for the various purposes such as Irrigation, hydropower & navigation etc. In India, canals are mainly used for Irrigation. Generally, supplies takes off from the main canal which is controlled by a head regulator. The main canal divides into various branch canals, distributaries and water courses. The capacity of irrigation canals mainly depends upon the irrigated area and thus the crop water requirement.

To design a canal standards are used which varies from place to place. The Indian Standard Code for design of Lined Canals IS: 10430-2000 provides the necessary design considerations for lined canals in India. Guidelines were provided to design a canal in code to which various factors required such as side slope, free board, berm width, bank width, limiting velocities etc.

4.2 TYPES OF CANAL

Based on different criteria, the canals have been classified into different types:-

i) Classification based on size

a) **Main canal**: In these canals, the water comes directly from the river or reservoir. It carries maximum discharge. It is the largest canal of the canal system and it is the primary source of water distribution to other branch canals. Generally, the canal system has two primary canals, Left bank canal (LMC) and Right Main Canal (RMC).

b) **Branch Canal**: The main function of branch canal is to supply water to the major and minor distributaries. Those canals comes out from the main canal. They carry a discharge more than 5.0 cumec.

c) **Major Distributary**: It carries a discharge of 0.25 cumec to 5.0 cumec. It is used for direct irrigation. They are the main source of water to minor distributaries.

These canals comes out from the branch canal and sometimes from the main canal too.

d) **Minor distributary**: It carries discharge less than 0.25 cumecs. They are main source of water to the water courses. It takes off water from the main canal.

e) **Water course**: These canals are constructed, controlled and maintained by the cultivators. These are small canals which carries water from the outlets. Now a days, government is taking up various program for development of command area and development of water courses are also included in those programs.

ii) Classification based on soil

a) **Alluvial canal:**- Those canals that are set up on alluvial soil such as silt are the alluvial canals. And, those type of soils are found in Northern India.

b) **Non-Alluvial canal**:- Those canals that are set up on non-alluvial soil such as clay, mooram etc. are non-alluvial canals. And those type of soils are found in Central and Southern India.

iii) Rigid surface canal:- Canals that are constructed on where the surface of canal is lined are rigid surface canals.(Autor: K R Arora, 2002)

iv) Classification based on lining

a) **Unlined canals**:-In these canals the bed and banks of canals are made up of natural soil. The velocity in these canals are kept low in such a way that bed and banks of canal is not scoured.

b) **Lined canals**:- Lined canals are those that are provided with a layer of impervious material on its bed and banks resisting seepage. The velocities allowed are considerably higher as compared to unlined canals. Moreover, the size of lined canals are reduced as compared to unlined ones.

v) Classification based on function of canal

a) Feeder Canal: The canal that is used to feed other canal is known as feeder canal.

No irrigation is done through this canal.

b) **Carrier Canal:** Inspite of carrying out irrigation through this canal, it is used to feed other canals too.

c) **Irrigation Canal**

d) **Power Canal**

vi) Classification based on shape of canal

a) Man made canals or naturally occurring canals

b) Rectangular canals

c) Trapezoidal canals

d) Triangular canals

e) Parabolic

f) Compound canals

vii) Classification based on canal alignment.

a) Contour canal

b) Ridge canal or watershed canal

c) Side slope canal.

4.2.1 CLASSIFICATION BASED ON SHAPE ON CANAL

a) Trapezoidal canal:- Due to ease in construction, mostly trapezoidal canal section is used while constructing engineering canals.

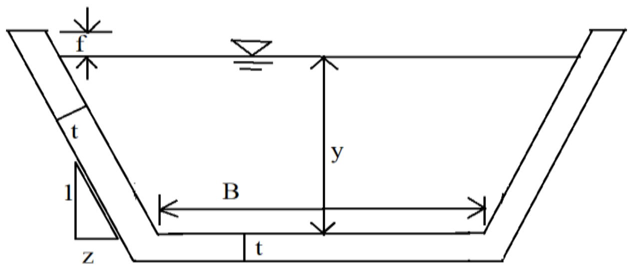


Fig 4.1: Trapezoidal canal section with notations.

a) Rectangular canal:- As compared to other canal types, smaller top width is required for construction in case of rectangular canal sections. They are generally used in engineering due to their widespread popularity and ease in construction. This property of rectangular canals makes it favorable to work at situations where there are various limitations for land usage.

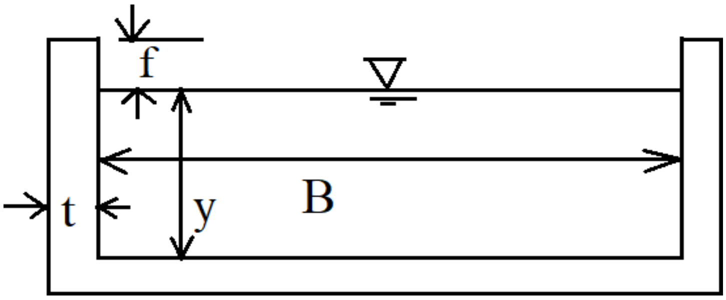


Fig 4.2: Rectangular canal section with notations.

b) Triangular Canal:- They serve to gather surface water and runoff from side slopes (cut areas), directing them to designated areas where potential adverse effects on the roadway structure are minimized such as hilly areas. Triangular open section canals are commonly employed in the drainage systems of roadways.

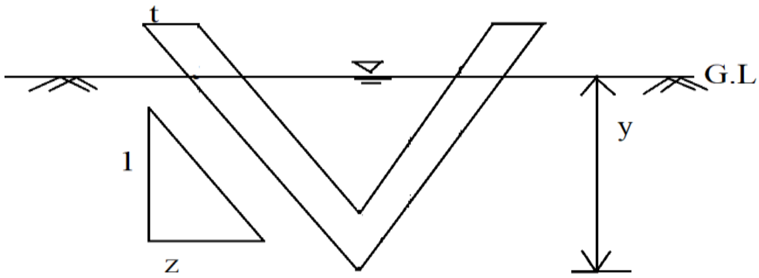


Fig 4.3: Triangular canal section with notations.

c) Circular Canal:- The wetted perimeter is the least hence it is the most economic section. Semi circle is the most efficient amongst the canal section. This type of shape is generally not considered for design of canal due to difficulty in construction.

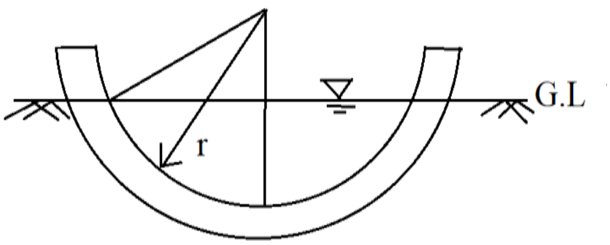


Fig 4.4: Circular canal section with dimensions.

4.3 DESIGN CONSIDERATION OF LINED CANALS

The following are the parameters to be considered while designing lined canal(Bureau of Indian Standards, 2000).

4.3.1 Side slope:-Inner slope of the lining should be provided in such a manner such that there is no occurrence of external pressure. Sudden drawdown of water should be controlled. If there occurs sudden drawdown, then the designing may be done considering IS:7894 which considers slip circle. The berms should be provided for an embankment of height above 6m.

Table 4.1: Recommended Side Slopes as per IS: 10430-2000

Sl. No	Type of soil	side slopes
1	Very light loose sand to average sandy soil	2:1 to3:1
2	Sandy loam	1:5 to 2:1(in cutting) 2:1 (in embankment)
3	Muram gravel mixed soil	1:1.5 to 2:1(in cutting) 1.5:1 to 2:1 (in embankment)
5	Black cotton soil	1.5:1 to 2.5:1(in cutting) 2:1 to 3.5:1 (in embankment)
6	Clayey soil	1.5:1 to 2:1(in cutting) 1.5:1 to 2.5:1 (in embankment)
7	Rock	0.25:1 to 0.5:1

4.3.2 Freeboard:- The following outlines the minimum freeboard requirements corresponding to different canal discharge capacities.

Table 4.2: Recommended Free Board as per IS: 10430-2000

Discharge (m3/s)	Free- Board (m)
Q > 10.0	0.75
3.0>Q>10.0	0.60
1.0>Q<3.0	0.50
Q<1	0.30

Discharge (m3/s)	Free- Board (m)
Q<0.10	0.15

4.3.3 Rugosity Coefficient:- The value of Rugosity coefficient for various types of lining are as follows.

Table 4.3: Value of Rugosity coefficient for different lining materials

Sl. No	Surface characteristics	Value of n
1	Concrete with surface as indicated below a) Formed, no finish/PCC tiles or b) Trowel float finish c) Grunted finish	 0.018-0.020 0.015-0.018 0.018-0.022
2	Brick/tile lining	0.018-0.020
3	U.C.R./Random rubble masonry with pointing	0.024-0.026
4	Asphalt a) Smooth b) Rough	 0.013-0.015 0.016-0.018
5	Concrete bed trowel/float finish and slopes as indicated below a) Hammer dressed stone masonry b) Coursed rubble masonry c) Random rubble masonry d) Masonry plastered e)Stone pitched lining	 0.019-0.021 0.018-0.020 0.020-0.025 0.015-0.017 0.020-0.030
6	Gravel bed with side slope characteristics as given below a) Formed concrete b) Random rubble in mortar c) Dry rubble (rip-rap)	 0.02-0.022 0.017-0.023 0.023-0.033

4.3.4 LIMITING VELOCITIES:

The maximum permissible velocity for some types of canal lining are given in table below.

Table 4.4: Maximum permissible velocity as per IS: 10430-2000

Types of lining	Limiting Velocity(m/s)
1. Stone-pitched lining	1.5
2.Burnt clay tile or brick lining	1.8
3.Cement concrete lining	2.7

4.3.5 TYPE OF SECTION:

a) Trapezoidal section with or without rounded corners. This section can be used for all types of lined canals.

b) Cup shaped section. It may be used for distributaries/minors for discharge upto $3m^3/s$ as far as possible.

4.3.6 DEPTH TO WIDTH RATIO:

The ratio of width to depth varies widely depending upon design practice, design discharge and lining materials.

For Trapezoidal Section most economical section is $\frac{B}{Y} = 2(\sqrt{1+Z^2}$ -Z)

For Rectangular Section, hydraulically efficient section is $\frac{B}{Y} = 2$

The Central Water Commission (CWC), a technical entity under the Ministry of Water Resources of the Government of India focusing on water resources, suggests the $\frac{B}{Y}$ ratio in relation to discharge, as detailed in Table 4.5.

Table 4.5: C.W.C. S Recommendation for B/Y ratio

Q (m3/s)	0.3	3.0	14.0	28.0	140.0	285.0
B/Y	2.0	4.0	6.0	7.50	14.0	18.0

4.4 DISCHARGE OF CANAL SECTION:

The discharge in a canal is calculated from manning's equation Q=A x V

$$Q = A\ X \frac{1}{n}\ X\ R^{\frac{2}{3}}\ X\ S^{\frac{1}{2}}$$

Where , A= Area of cross section of the canal

n= Manning's rugosity coefficient given in table 4.3

R= Hydraulic Radius of the canal

S= Longitudinal slope of the canal

CHAPTER 5

CROP WATER REQUIREMENT

5.1 INTRODUCTION

India is an agriculture based country with 51% of food grains grown depends on irrigation. However, out of the total water used in the country, 84% of water has been used for irrigation. Hence, water should be used judiciously in order to combat the water stress. While allocating water to the water resources sector, optimal allocation of water should be put into consideration (Madhusudhan, M.S et al.). Crop water requirement is the right amount of water that is required by the crop to grow fully during their growth period. Also, the maximum yield is taken into consideration while planning and designing a irrigation project in which the optimum water requirement plays an important role. To achieve the maximum yield optimum water requirement needs to be computed for each and every crop (K.R Arora,2002). In order to obtain that, an accurate estimation of crop co-efficient and evapotranspiration is however required. The evapotranspiration depends on factors, such as the type of crop and its developmental stages, the environment, management practices, and field conditions like ground coverage, plant density, irrigation type, and cultivation practices (P.N Modi,2008). Accurate crop coefficient and evapotranspiration estimation are however required to determine the ideal water need.

A database for calculating agricultural water requirements is CLIMWAT 2.0 combined with CROPWAT 8.0. FAO developed the software CROPWAT 8.0. It is based on a water balance model in which daily evapotranspiration calculations are used to evaluate the soil moisture state. The application calculates reference evapotranspiration using monthly meteorological data, including temperature, relative humidity, wind speed, sunlight hours, and rainfall. (Nivesh et al., 2019)

5.2 CROPPING PROGRAM

Cropping pattern may be defined as the systematic arrangement of crops on a piece of land to get maximum production. Now a days studies could be done through remote sensing. It has enabled mapping of cropping pattern. (Mahlayeye et al., 2022). Considering the factors such as farmers' wishes and aspirations, financial considerations, climate and soils, water availability, labour requirements, marketing aspects, availability of inputs, rotational considerations and susceptibility to diseases the crop may as such be selected to be grown. Once the crops are selected, a cropping programme showing the seasonal cropping patterns and indicating the place and the occupying area for each crop is made. The next step is the sowing or transplanting dates, the length of the growing season and the time needed for harvest and land preparation for the next crop. While calculating the crop water requirements, it must be noted that the time needed for harvest and land preparation may not be included. Also, the farmer's intention e.g which crop to be grown may be taken care of while designing cropping pattern.

The Irrigation Department, Assam has proposed and commissioned the Longa Irrigation Project. The projected command area's agricultural activities are entirely reliant on rainfall. The sole source of crop water that meets standards is rain. The farmers now have no option but to choose what crops to grow. The farmers will be encouraged to use the suggested cropping pattern, which includes Rabi and other cash crops in addition to the traditional crops, if irrigation facilities are guaranteed.

5.3 REFERENCE CROP EVAPOTRANSPIRATION (ETo) AND THE EFFECTIVE RAINFALL(Eeff Rain)

To compute ET_o, CROPWAT 8.0 uses the FAO Penman-Monteith method. However, effective rainfall and meteorological data are taken from the CLIMWAT 2.0 database (FAO, 1993). Further, to determine the effective rainfall and reference crop evapotranspiration (ETo), meteorological data, such as temperature, relative humidity, wind speed, sunlight hours, rainfall, etc., are incorporated into CROPWAT 8.0.

The USDA Soil Conservation Method has been applied in this work to determine the effective, reliable rainfall. CROPWAT 8.0 calculates effective rainfall using monthly rainfall data that is taken from the CLIMWAT 2.0 program for the climate station in Dhubri. The effective rainfall and ETo, as determined by CROPWAT 8.0, are displayed in Tables 5.1 and 5.2 respectively.

5.4 SOIL SURVEYS

As per report of Mining Plan Gurufela-2s and stone material Mahal at Gurufela River bed, and as per soil map prepared in ArcGIS, soil of the study area is categorised as Light(Sand) as per FAO standards.

5.5 SHORT DESCRIPTION ON CROPWAT 8.0

CROPWAT 8.0 is a decision support system developed by FAO which is used to determine crop water requirement and net irrigation required. It is a means to calculate season reference crop evapotranspiration, crop water requirements, crop irrigation requirement and design and management practices of Irrigation. It allows the development and recommendation of improved irrigation practices planning of Irrigation schedule under various water supply. It is based on soil water balance. There are various version of the software which is based on FAO,1992 Penman Monteith method to calculate season the crop evapotranspiration. All calculations on CROPWAT 8.0 are based on FAO publications of the Irrigation and Drainage Series, namely, No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements” and No. 33 titled "Yield response to water". The software requires climatic data, soil data crop data to estimate crop water requirement. If however, the climatic data is unavailable CLIMWAT may be used as representative data. CLIMWAT 2.0 offers observed agroclimatic data of over 5000 stations worldwide. CLIMWAT 2.0 provides long-term monthly mean values of seven climatic parameters for CROPWAT 8.0. The parameters are:-

- Mean daily maximum temperature in °C
- Mean daily minimum temperature in °C
- Mean relative humidity in %

- Mean wind speed in km/day
- Mean sunshine hours per day
- Mean solar radiation in MJ/m2/day
- Monthly rainfall in mm/month
- Monthly effective rainfall in mm/month
- Reference evapotranspiration calculate with the Penman-Monteith method in mm/day.

These data can be extracted for one or more stations in .cli and .pen format which is supported by the CROPWAT. The first file contains long-term monthly rainfall data [mm/month]. Additionally, effective rainfall is also included in the same file. The second file consists of long-term monthly averages for the other climatic parameters, mentioned above. This file also contains the coordinates and altitude of the location. Similarly, if local data for soil, crop details are unavailable, standard data is available at CROPWAT. It uses climatic data values in monthly or decadal and converts these into daily soil water balance to develop optimum irrigation schedules using various irrigation practices. Scheme water supply is estimated as per the cropping pattern provided to the software and is limited upto 20 crops. This software is location based and is independent of GIS.

5.6 INPUT DATA

5.6.1 Meteorological Data:-

The climatic data such as temperature, relative humidity, wind speed, sunshine hours, rainfall etc. are required to be incorporated into CROPWAT, so as to calculate season the reference crop evapotranspiration (ETo) and the effective rainfall which were extracted from the software CLIMWAT 2.0 for the area Dhubri.

5.6.1.1 Minimum Temperature:-

The Minimum temperature of the study area is recorded as 11.70 C in the month of January while the minimum temperature rises highest to 26.10 C in the month of August as shown in Figure below.

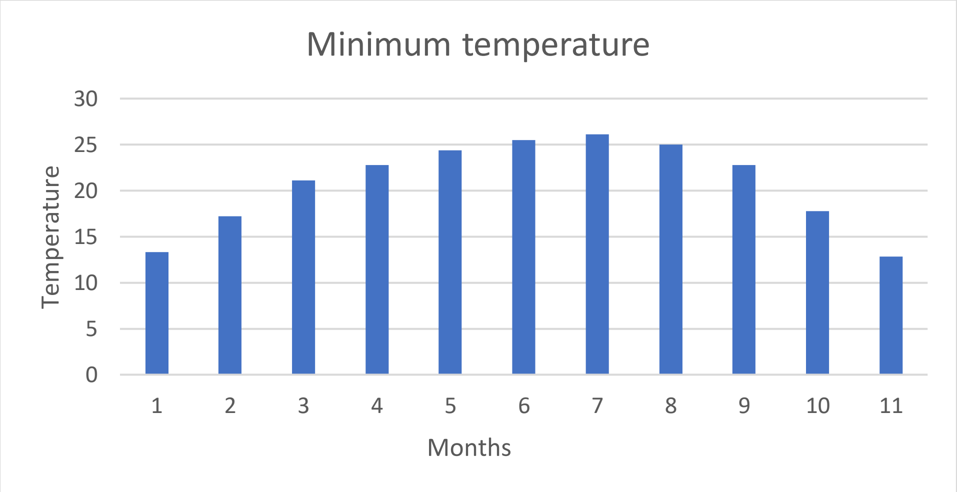


Fig 5.1: Minimum Temperature of Dhubri Station

5.6.1.2 Maximum Temperature: -

Figure below shows that the maximum temperature of the study area is 30.5^{0}C in the month of April. It is observed that the warmest months are from March to October. While the mean temperature recorded as 28.2^{0}c.

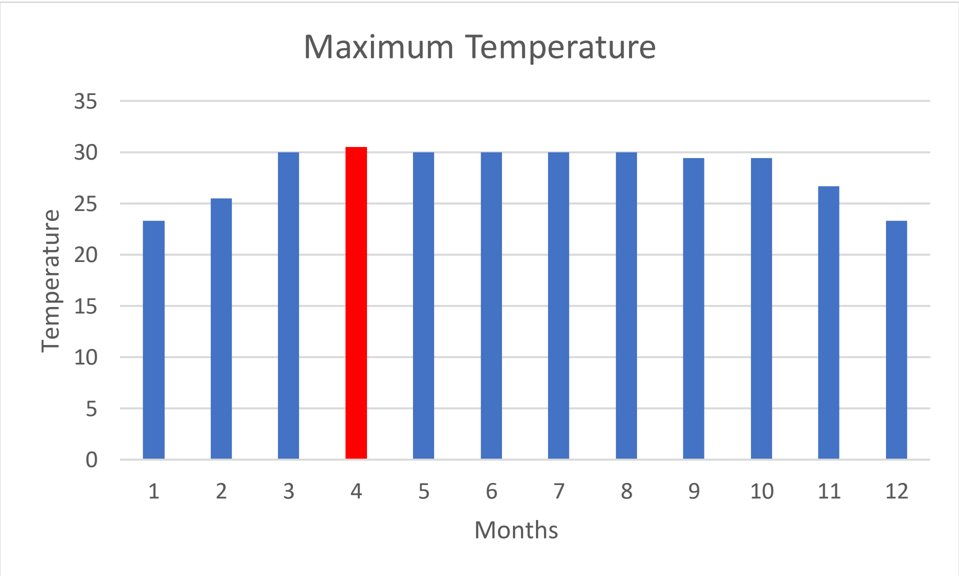


Fig 5.2: Maximum Temperature of Dhubri Station

5.6.1.3 Humidity

It is seen that humidity drops considerably during the months of March and April and almost constant in other months and found to be highest during the month of June.

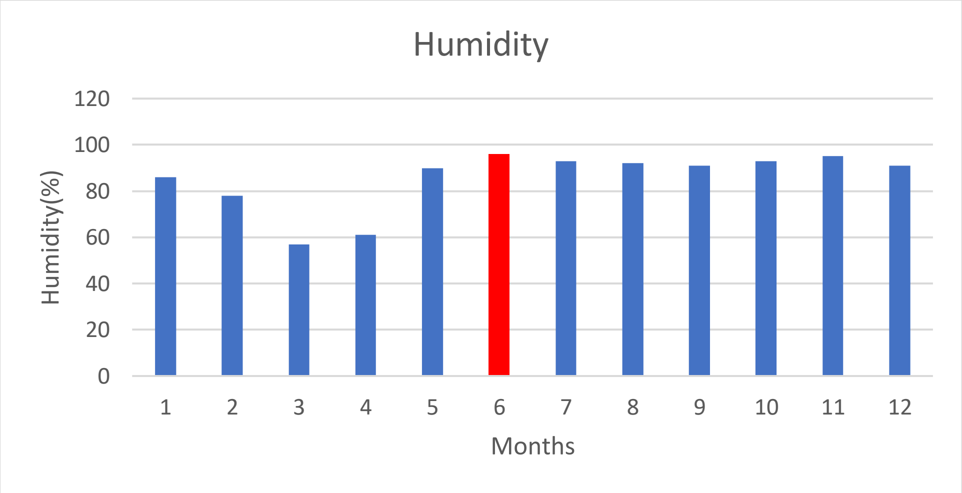


Fig 5.3: Humidity(%) for Dhubri station.

5.6.1.4 Wind Speed

Figure below shows that the wind speed for the study area is quite high in the month of April while lowest during the months of November, December and January.

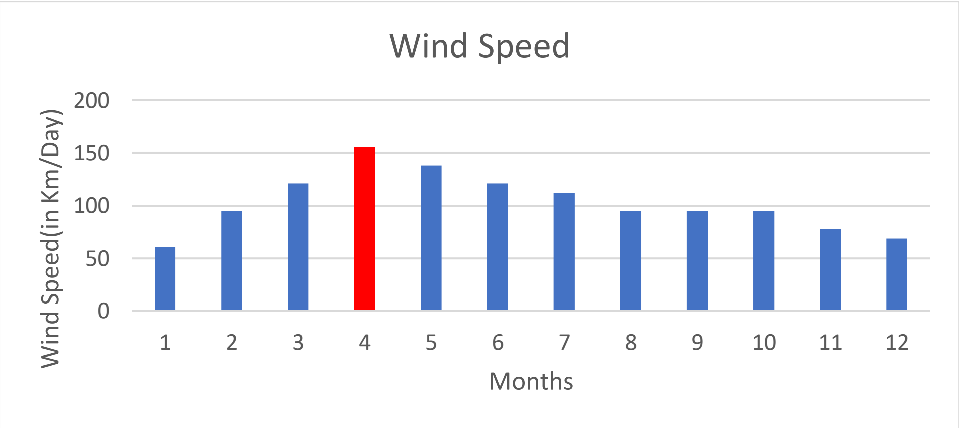


Fig 5.4: Wind Speed for Dhubri station

5.6.1.5 Sunshine

Sunshine is also an important parameter for computing evaporation. It is directly related with evapotranspiration. Long hours of sunshine leads to more emission of heat. When this heat energy hits earth surface the temperature of the surface increases. The intensity of sunshine hours have a significant impact on the evapotranspiration. The sunshine hours has been collected from CLIMWAT 2.0.

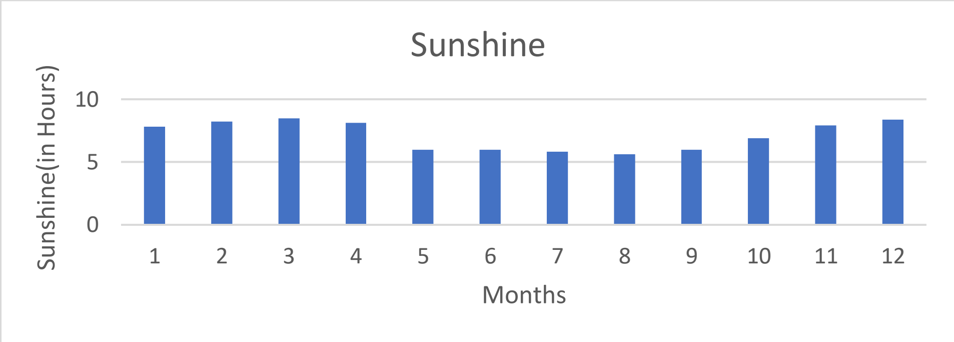


Fig 5.5: Sunshine Hours for Dhubri station.

5.6.1.6 Radiation

Radiation and light regimes depend on the latitude and orography of the area as well as on sky conditions and range of visibility. Mean annual and monthly values of radiation and sunshine gradually increases from north to south during the months of January to May while the data tells that radiation is constant from June to December.

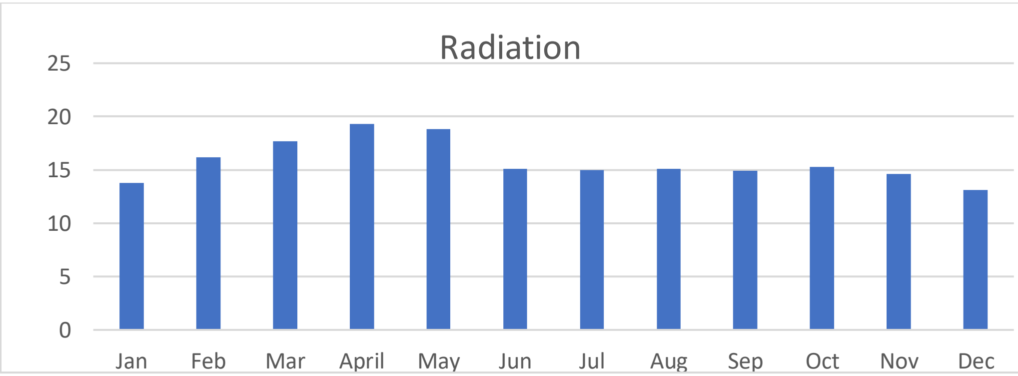


Fig 5.6 : Radiation of Dhubri Station.

5.6.1.7 Precipitation

Figure below shows that the maximum rainfall occurred during the month of June for the study area. Moreover, rainfall occurred at a considerable rate from the months April to October.

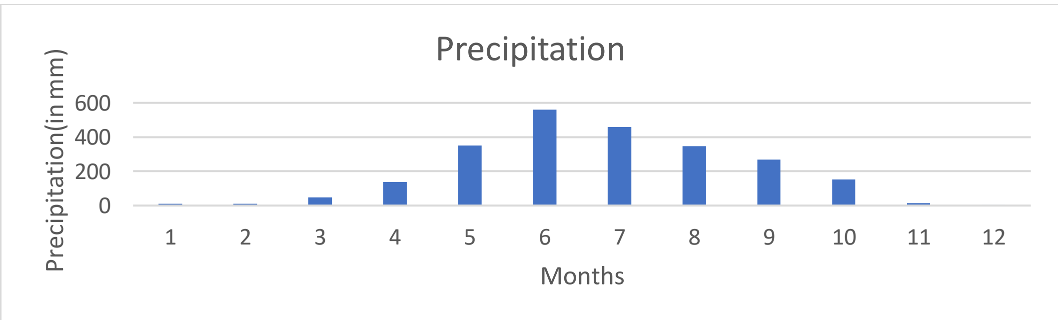


Fig 5.7: Precipitation of the Dhubri Station

5.6.2 Crop data

The major crops grown in the study area are Sali, Jute, Rapeseed and Vegetables as per data collected from the State Department of Irrigation, Assam and on verbal communication with the farmers of the study area. The salient details of crops considered for the study are as per FAO,1992. Crop coefficient values (Kc) are taken from FAO. Kc values for Initial, Mid-Season and Late season growth stages of annual and seasonal crops are used. In the case of perennial crops, same Kc value is used for the whole year. The cropping pattern was collected from the Irrigation Department, Assam. The effective rainfall and ETo for the study area is computed by CROPWAT 8.0 are shown in Table-5.1 and Table 5.2 shown below respectively.

Table-5.1 Effective rainfall for Longa Irrigation Project computed by CROPWAT 8.0

Country: INDIA Altitude: 35 m.	Latitude: 26.01 °N	Station: DHUBRI Longitude: 89.98 °E
Month	Rain (mm)	Eff rain (mm)
January	10.0	9.8
February	9.0	8.9
March	47.0	43.5
April	136.0	106.4
May	349.0	159.9
June	562.0	181.2
July	458.0	170.8
August	347.0	159.7
September	267.0	151.7
October	153.0	115.5
November	16.0	15.6
December	3.0	3.0
Total	2357.0	1126.0
Eff. rain method: USDA Soil Conservation Service formula: Peff = Pmon * (125 - 0.2 * Pmon) / 125 for Pmon <= 250 mm Peff = 125 + 0.1 * Pmon , for Pmon > 250 mm		

Table-5.2: ETo for Longa Basin, computed by CROPWAT 8.0

Country: INDIA					Station: DHUBRI		
Altitude: 35 m.				Latitude: 26.01 °N	Longitude: 89.98 °E		
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	11.7	23.3	86	61	7.8	14.6	2.01
February	13.3	25.5	78	95	8.2	17.2	2.75
March	17.2	30.0	57	121	8.5	20.0	4.22
April	21.1	30.5	61	156	8.1	21.4	4.96
May	22.8	30.0	90	138	6.0	19.0	3.87
June	24.4	30.0	96	121	6.0	19.2	3.81
July	25.5	30.0	93	112	5.8	18.7	3.86
August	26.1	30.0	92	95	5.6	17.8	3.75
September	25.0	29.4	91	95	6.0	17.0	3.49
October	22.8	29.4	93	95	6.9	16.1	3.15
November	17.8	26.7	95	78	7.9	15.2	2.55
December	12.8	23.3	91	69	8.4	14.6	2.02
Average	20.0	28.2	85	103	7.1	17.6	3.37

5.6.3 Total Available Soil Moisture

The difference in soil moisture content between field capacity and wilting point soil, measured in millimetre per day, is known as total available soil moisture and has indicative values for each texture class. The soil to be light sandy, the TAM is taken to be 60 mm/meter.

5.6.4 Maximum Rain Infiltration Rate

Both the texture and the structure of the soil affect the maximum rate at which rain can penetrate it. Given that the soil type is light(sand), the maximum rain infiltration rate taken into account for analysis is 40 mm/day (FAO, 56).

5.6.5 Maximum Rooting Depth

The maximum rooting depth varies from plant to plant and is determined by genetics. The FAO (Allen et al., 1998)has recommended a maximum rooting depth of 56 for various crops, which has been gathered from various literature sources.

5.6.6 Initial Soil Moisture Depletion

The degree of soil dryness at the start of the growth season determines the first depletion of soil moisture. It is considered as there is no initial moisture depletion.

5.6.7 The Crop Coefficient (Kc)

Numerous factors affect the value of the crop coefficient (Kc). The crop coefficient is impacted by variations in crop heights, crop cover, climate, etc, leaf area variations, and ground covering all affect Kc values of a crop. Four stages are taken into account while determining crop's Kc values. The initial, mid-season, late-season, and crop development stages are these four phases. When there is less than 10% soil coverage, the first stage is the early stage. When the surface is dry in the first stage, the Kc value is low. On the other hand, the Kc value is high in this stage when the soil is wet from irrigation or rainfall. The stage of crop development is recognized when there is 70–80% effective full groundcover. At this point, the earth is more covered and the crops are developed. Transpiration therefore rises while soil evaporation decreases.

When the ground is completely covered and crops begin to mature, as seen by changes in leaf colour, this is known as the mid-season stage. The Kc value is at its maximum. The mature stage to harvest is known as the late season. At this stage, the ground is typically less covered with leaves that have fallen. If the soil is wet, transpiration decreases and soil evaporation rises. Fig 5.1 illustrates how Kc values significantly vary according to growth stages. For the purpose of estimating agricultural water requirements, the crop coefficient (Kc) value is obtained from the FAO-56(Allen et al., 1998.) paper and numerous literatures.

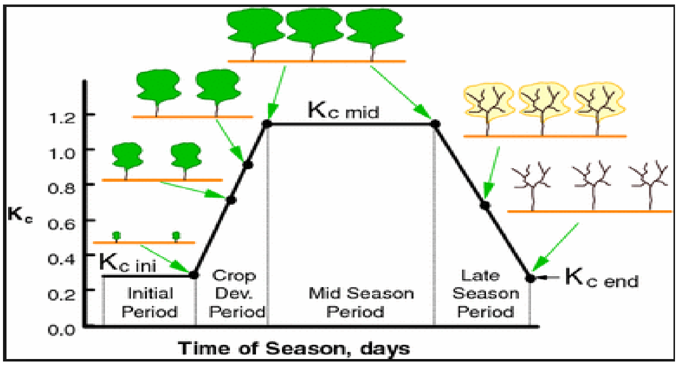


Fig-5.8 Crop Co-efficient curve

5.7 FACTORS AFFECTING CROP WATER REQUIREMENT

1. Water Table:-How much water is required to the crops depends upon the depth of water table. If the water table is at sufficiently below than the required that leads to more requirement of water to the crops as compared to the water table when it is at high.

2.Climate:- Water requirement is more during hot climate than the cold climate.

3.Type of soil:- Water requirement is more for sandy soil rather than the clayey soil since sandy soil percolates very fast and hence retention of water is less.

4.Method of ploughing:- Water requirement is less when there is a deep ploughing of soil since retention of water is more.

5. Intensity of Irrigation:- More intensity of irrigation means more area under cultivation and hence water requirement is more.

6. Ground slope :- When the ground slope is steep water flows down quickly which results in less absorption of water and hence requirement of water is more. When the ground slope is less ,water will be retained more and there will be more water absorption and requirement of water is less.

7.Method of application of water :- Evaporation is more for surface flow irrigation as compared to sub-surface irrigation.

5.8 COMPUTATION OF CROP WATER REQUIREMENT

The data entered in CROPWAT 8.0 is used to calculate the crop water requirements for various crops. The crop planting dates, the (Kc) values for the various growth stages, the duration of the growth stages, the rooting depth of each crop at each growth stage, the soil moisture depletion, and the yield response parameters are the crop data needed to run the CROPWAT 8.0. CROPWAT 8.0 uses the previously determined ETo and effective rainfall values along with the provided crop data to determine the crop water and irrigation requirements of the specified cropping pattern. Crop water requirements are calculated on a ten-day (or decade) basis.

For each crop, the input crop data and the crop water requirements for each crop as obtained from CROPWAT 8.0 is shown in consecutive Table 5.31 to 5.62 for the crops of proposed irrigation scheme at Longa River.

Table-5.31:- General crop data for Jute

CROP DATA							
Crop name: JUTE							
Growth stage		Initial	Development	Mid	Late	Total	Planting Date
Crop coefficient	[coeff.]	0.4	→	1.15	0.5		
stage	[days]	25	35	35	25	120	01st Mar
Rooting depth	[metre]	0.2	→	→	0.45		
Critical Depletion	[fract.]	0.4	→	0.5	0.65		
Yield response factor	[coeff.]	0.75	1.0	1.0	1.2	1.15	
Crop height (optional)	[metre]					2.0	

Table-5.32 Crop water and irrigation requirements for Jute

ETo station: Dhubri Rain station: Dhubri						Crop: Jute Planting date:01st March	
Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Mar	1	Init	0.40	1.49	14.9	9.8	5.2
Mar	2	Init	0.40	1.69	16.9	13.2	3.7
Mar	3	Deve	0.44	1.95	21.4	20.6	0.8
Apr	1	Deve	0.62	3.00	30.0	28.7	1.2
Apr	2	Deve	0.81	4.17	41.7	35.9	5.8
Apr	3	Mid	0.99	4.70	47.0	41.7	5.4
May	1	Mid	1.06	4.43	44.3	48.4	0.0
May	2	Mid	1.06	4.01	40.1	54.8	0.0
May	3	Mid	1.06	4.02	44.2	56.7	0.0
Jun	1	Late	0.99	3.78	37.8	59.0	0.0
Jun	2	Late	0.72	2.75	27.5	61.8	0.0
Jun	3	Late	0.48	1.83	14.6	48.2	0.0
					380.5	478.7	22.1

Table 5.41:- General crop data for Sali crop

CROP DATA							
Crop name: Sali(Ranjit)							
Growth stage		Initial	Development	Mid Season	Late season	Total	Planting Date
Crop coefficient	[coeff.]	1.1	→	1.2	0.95		
Stage	[days]	30	40	45	35	150	28th JULY
Rooting depth	[metre]	0.2	→	→	0.4		
Critical Depletion	[fract.]	0.3	→	0.4	0.4		
Yield response factor	[coeff.]	0.4	1.5	0.5	0.2	1.25	
Crop height (optional)	[metre]					1.0	

Table-5.42 :- Crop water and irrigation requirements for Sali Crop.

ETo station: Dhubri Crop: Sali(Ranjit)

Rain station: Dhubri Planting date: 28/07

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Jun	3	Nurs	1.2	0.46	1.4	18.1	1.4
Jul	1	Nurs/LPr	1.16	1.55	15.5	58.1	116.7
Jul	2	Nurs/LPr	1.06	4.12	41.2	56.9	0
Jul	3	Init	1.08	4.12	45.3	55.7	180.2
Aug	1	Init	1.1	4.16	41.6	54.4	0
Aug	2	Deve	1.1	4.12	41.2	53.1	0
Aug	3	Deve	1.1	4.03	44.3	52.3	0
Sep	1	Deve	1.1	3.93	39.3	52.3	0
Sep	2	Mid	1.1	3.84	38.4	51.9	0
Sep	3	Mid	1.1	3.71	37.1	47.4	0
Oct	1	Mid	1.1	3.59	35.9	44.5	0
Oct	2	Mid	1.1	3.46	34.6	41.5	0
Oct	3	Late	1.09	3.22	35.4	29.4	6

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Late	1.05	2.89	28.9	13.6	15.3
Nov	2	Late	1.01	2.58	25.8	1.1	24.7
Nov	3	Late	0.98	2.33	9.3	0.4	8.8
					515.2	630.7	353.1

Table 5.51:- General crop data for Rapeseed

CROP DATA							
Crop name: Rape Seed							
Growth stage		Initial	Development	Mid Season	Late season	Total	Planting Date
Crop coefficient	[coeff.]	0.45	→	1.0	0.35		
Stage	[days]	20	30	30	20	100	25th Dec
Rooting depth	[metre]	0.3	→	→	1.0		
Critical Depletion	[fract.]	0.3	→	0.4	0.6		
Yield response factor	[coeff.]	0.45	0.8	0.8	0.3	1.1	
Crop height (optional)	[metre]					0.6	

Table-5.52:- Crop water and irrigation requirements for Rapeseed

ETo station: Dhubri Rain station: Dhubri						Crop: RAPESEED Planting date: 25th Nov	
Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	3	Init	0.45	0.91	6.4	0.7	5.8
Jan	1	Init	0.45	0.91	9.1	2.8	6.3
Jan	2	Deve	0.50	1.01	10.1	3.6	6.4
Jan	3	Deve	0.68	1.53	16.9	3.4	13.5
Feb	1	Deve	0.86	2.16	21.6	2.0	19.7

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Feb	2	Mid	0.98	2.69	26.9	1.3	25.6
Feb	3	Mid	0.98	3.17	25.4	5.7	19.7
Mar	1	Mid	0.98	3.65	36.5	9.8	26.7
Mar	2	Late	0.91	3.85	38.5	13.2	25.3
Mar	3	Late	0.60	2.69	29.6	20.6	8.9
Apr	1	Late	0.38	1.85	5.6	8.6	0.0
					226.4	71.7	157.9

Table 5.61:- General crop data for Vegetable

CROP DATA							
Crop name: Vegetable(Sweet Melon)							
Growth stage		Initial	Development	Mid Season	Late season	Total	Planting Date
Crop coefficient	[coeff.]	0.5	→	1.05	0.75		
Stage	[days]	25	35	40	20	120	21st Dec
Rooting depth	[metre]	0.3	→	→	1.0		
Critical Depletion	[fract.]	0.4	→	0.4	0.5		
Yield response factor	[coeff.]	0.5	0.6	1.1	0.8	1.05	
Crop height (optional)	[metre]					0.4	

Table-5.62:- Crop water and irrigation requirements for Vegetable(Sweet Melon)

ETo station: Dhubri Rain station: Dhubri						Crop: Sweet Melon Planting date: 21st Dec	
Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	3	Init	0.50	1.01	11.1	1.2	9.9
Jan	1	Init	0.50	1.01	10.1	2.8	7.3
Jan	2	Deve	0.53	1.07	10.7	3.6	7.1
Jan	3	Deve	0.68	1.54	17.0	3.4	13.6
Feb	1	Deve	0.84	2.11	21.1	2.0	19.2

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Feb	2	Mid	0.99	2.73	27.3	1.3	26.0
Feb	3	Mid	1.03	3.35	26.8	5.7	21.1
Mar	1	Mid	1.03	3.85	38.5	9.8	28.8
Mar	2	Mid	1.03	4.36	43.6	13.2	30.4
Mar	3	Late	1.03	4.61	50.7	20.6	30.1
Apr	1	Late	0.93	4.51	45.1	28.7	16.4
Apr	2	Late	0.78	4.04	36.3	32.3	0.5
					338.4	124.5	210.3

*Eff rain denotes Effective Rainfall
*Irr. Req. denotes Irrigation requirement
*Init denotes Initial
*Deve denotes Development
* Mid denotes Mid Season
*Late denotes Late season

Table 5.7:- Crop water requirement

Name of Crop	**Crop Water Requirement(mm/dec)**
Sali	515.2
Vegetable(Sweet Melon)	338.4
Jute	380.5
Rapeseed	226.4

Table 5.8:- Maximum Crop water requirement per decadal

Name of crop	**Maximum Crop Water requirement (mm/dec)**
Sali	45.3
Vegetable	50.7
Jute	47
Rapeseed	38.5

5.9 Irrigation Scheduling

It is the frequency at which water is supplied to the crops optimizing crop production. It is a practice that carefully coordinates the timing and amount of water application, taking into account factors like weather, soil moisture, and plant conditions. In addition to (internet of things) IoT and smartphone apps were added to the process integrating machine learning to bring it to the highest precision. The main objectives are to improve water-use efficiency, reduce waste, and boost yields. However, when there is under irrigation the plant would be in stress while over irrigation would lead to loss the nutrients from soil. Irrigation scheduling involves supplying water to fields precisely when needed, drawing from both natural sources and artificial means, guided by parameters such as soil moisture tension and content. Several approaches are there for irrigation scheduling such as Feel and appearance, Gravimetric method, Weather based, Sensor based, plant based, IoT sensor technology and Smartphone App. However, integrating the soil moisture measurements and model based methods would bring more utilization of Irrigation Scheduling methods (Zhe,Gu et al.) Table 5.9 to Table 5.12 showing the irrigation scheduling of the proposed crops of the study area

Table 5.9: Irrigation scheduling for Sali Crop.

Date	Day	Stage	Rain	Ks	ETa	Puddl.	Percolation	loss	Depl. SAT
			(Mm)	(fract .)	(%)	(State)	(Mm)	(mm)	(mm)
08 Jul	-19	PrePu	0	1	100	Prep	0	0	116
23 Jul	-4	Puddl	70.3	1	100	Prep	25.5	0	69
25 Jul	-1	Puddl	0	1	100	OK	9.1	0	10.8
06 Nov	98	End	0	1	100	OK	3.4	0	0.1
23 Nov	115	End	0	1	100	OK	3.4	0	-3.4
24 Nov	End	End	0	1	0	OK	0		

Table 5.10: Irrigation scheduling for Jute

Date	Day	Stage	Rain (mm)	Ks (fraction)	ETa (%)	Depl (%)	Net Irri (mm)	Deficit (mm)	Loss (mm)	Gross Irri (mm)	Flow (l/s/ha)
06 Mar	6	Init	0	1	100	44	6	0	0	8.5	0.16
10 Mar	10	Init	0	1	100	41	6	0	0	8.5	0.25
16 Mar	16	Init	0	1	100	42	6.8	0	0	9.7	0.19
21 Mar	21	Init	0	1	100	50	8.7	0	0	12.4	0.29
26 Mar	26	Dev	0	1	100	42	7.8	0	0	11.1	0.26
31 Mar	31	Dev	0	1	100	49	9.7	0	0	13.9	0.32
06 Apr	37	Dev	0	1	100	56	12	0	0	17.1	0.33
10 Apr	41	Dev	0	1	100	54	12	0	0	17.1	0.5
15 Apr	46	Dev	0	1	100	53	12.5	0	0	17.9	0.41

19 Apr	50	Dev	0	1	100	51	12.5	0	0	17.9	0.52
22 Apr	53	Dev	0	1	100	54	13.6	0	0	19.4	0.75
25 Apr	56	Dev	0	1	100	54	14.1	0	0	20.2	0.78
29 Apr	60	Dev	0	1	100	52	14.1	0	0	20.2	0.58
02 May	63	Mid	0	1	100	50	13.6	0	0	19.4	0.75
06 May	67	Mid	0	1	100	66	17.7	0	0	25.3	0.73
10 May	71	Mid	0	1	100	66	17.7	0	0	25.3	0.73
16 May	77	Mid	0	1	100	59	16	0	0	22.9	0.44
20 May	81	Mid	0	1	100	59	16	0	0	22.9	0.66
26 May	87	Mid	0	1	100	60	16.1	0	0	23	0.44
30 May	91	Mid	0	1	100	60	16.1	0	0	23	0.66
06 Jun	98	End	0	1	100	56	15.1	0	0	21.6	0.36
10 Jun	102	End	0	1	100	56	15.1	0	0	21.6	0.62
28 Jun	End	End	0	1	0	7					

Table 5.11 : Irrigation Scheduling for Vegetable(Sweet Melon)

Date	Day	Stage	Rain (mm)	Ks (fraction)	ETa (%)	Depl (%)	Net Irri (mm)	Deficit (mm)	Loss (mm)	Gross Irri (mm)	Flow (l/s/ha)
01 Jan	12	Init	0.0	1	100.0	41	10.9	0	0	15.6	0.15
22 Jan	33	Dev	0.0	1	100.0	41	16.8	0	0	24	0.13
05 Feb	47	Dev	0.0	1	100.0	43	21.8	0	0	31.1	0.26
16 Feb	58	Dev	0.0	1	100.0	43	25.4	0	0	36.2	0.38
25 Feb	67	Mid	0.0	1	100.0	41	24.6	0	0	35.2	0.45
06 Mar	76	Mid	0.0	1	100.0	42	25.2	0	0	36.1	0.46
12 Mar	82	Mid	0.0	1	100.0	40	24.1	0	0	34.5	0.67
20 Mar	90	Mid	0.0	1	100.0	47	28.3	0	0	40.4	0.58
30 Mar	100	Mid	0.0	1	100.0	41	24.9	0	0	35.6	0.41
12 Apr	113	End	0.0	1	100.0	47	28.4	0	0	40.6	0.36
19 Apr	End	End	0.0	1	100.0	13					

Table 5.12 : Irrigation Scheduling for Rapeseed

Date	Day	Stage	Rain mm	Ks (fract.)	ETa (%)	Depl (%)	Net Irri (mm)	Deficit (mm)	Loss (mm)	Gross Irri (mm)	Flow (l/s/ha)
05 Jan	12	Init	0.0	1	100	32	8.9	0	0	12.7	0.12
25 Jan	32	Dev	0.0	1	100	36	15.9	0	0	22.8	0.13
08 Feb	46	Dev	0.0	1	100	41	23.1	0	0	33	0.27
18 Feb	56	Mid	0.0	1	100	41	24.6	0	0	35.2	0.41
28 Feb	66	Mid	0.0	1	100	41	24.7	0	0	35.3	0.41
10 Mar	76	Mid	0.0	1	100	44	26.7	0	0	38.1	0.44
22 Mar	88	End	0.0	1	100	51	30.6	0	0	43.7	0.42
3 Apr	End	End	0.0	1	100	2					

Table 5.13: Irrigation scheduling considering all proposed crops of the study area

Name of Crop	Date	Day	Stage	Discharge (in m3/s/ha)
Sweet Melon	01 Jan	12	Init	0.00015
Rapeseed	05 Jan	12	Init	0.00012
Sweet Melon	22 Jan	33	Dev	0.00013
Rapeseed	25 Jan	32	Dev	0.00013
Sweet Melon	05 Feb	47	Dev	0.00026
Rapeseed	08 Feb	46	Dev	0.00027
Sweet Melon	16 Feb	58	Dev	0.00038
Rapeseed	18 Feb	56	Mid	0.00041
Sweet Melon	25 Feb	67	Mid	0.00045
Rapeseed	28 Feb	66	Mid	0.00041
Jute	06 Mar	6	Init	0.00016
Sweet Melon	06 Mar	76	Mid	0.00046
Rapeseed	10 Mar	76	Mid	0.00044
Jute	10 Mar	10	Init	0.00025
Sweet Melon	12 Mar	82	Mid	0.00067
Jute	16 Mar	16	Init	0.00019
Sweet Melon	20 Mar	90	Mid	0.00058
Jute	21 Mar	21	Init	0.00029
Rapeseed	22 Mar	88	End	0.00042
Jute	26 Mar	26	Dev	0.00026
Sweet Melon	30 Mar	100	Mid	0.00041
Jute	31 Mar	31	Dev	0.00032
Jute	06 Apr	37	Dev	0.00033
Jute	10 Apr	41	Dev	0.0005
Sweet Melon	12 Apr	113	End	0.00036
Jute	15 Apr	46	Dev	0.00041
Jute	19 Apr	50	Dev	0.00052
Jute	22 Apr	53	Dev	0.00075
Jute	25 Apr	56	Dev	0.00078
Jute	29 Apr	60	Dev	0.00058
Jute	02 May	63	Mid	0.00075
Jute	06 May	67	Mid	0.00073
Sali Rice	08 Jul	-19	PrePu	0.00045
Sali Rice	23 Jul	-4	Puddl	0.000137
Sali Rice	25 Jul	-1	Puddl	0.000137
Sali Rice	06 Nov	98	End	0.00049
Sali Rice	23 Nov	115	End	0.000273

Note that :-

*Depl. denotes Depletion
*Eta denotes Actual evapotranspiration
*Puddl. denotes Puddling stage
*Depl SAT denotes Depletion Saturated water
*Init denotes Initial
*Deve denotes Development stage
* Mid denotes Mid Season

CHAPTER 6

MODEL FORMULATION FOR CANAL SECTION OPTIMIZATION

6.1 INTRODUCTION:

In a optimization model, several constraints and variables are set up to achieve at the objective function which is either to maximise or minimise. However, these models prove great in the field of water resource engineering. In the present study a nonlinear programming model will be developed aiming to design the optimum canal section and to minimize canal construction cost is found using a GRG solver engine in Microsoft Excel, nonlinear engine. The technique of addressing an optimization model where some of the constraints or functions are nonlinear is known as nonlinear programming, or NLP. Components of the Nonlinear Programming model include: a) An objective function b) Constraints c) Variables.

6.2 GRG NONLINEAR ENGINE OF MICROSOFT EXCEL SOLVER PLATFORM:

There are three tools in the Microsoft Office Excel Solver which defines the best solutions:

- GRG Nonlinear- for solving smooth nonlinear problem.
- Evolutionary- for solving non smooth nonlinear problem.
- Simplex LP- for solving linear problem.

In order to solve optimization model where at least one of the constraints or decision variables are non-linear and smooth, non-linear programming is used to solve the issue. In that case GRG non-linear engine of Microsoft Excel is implemented. A smooth nonlinear function of the decision variables is used as the aim or at least one of the constraints in a smooth nonlinear programming (NLP). The Generalized Reduced Gradient (GRG2) code, which was developed by Leon Lasdon of the University of Texas at Austin and Alan Waren of Cleveland State University and improved by Frontline Systems, Inc. In this method, the solver observes the change of gradient or slope of the objective function, which is an input. When the partial derivative reaches to zero, the model states that it has reached the optimum level. "Generalized Reduced Gradient" is what GRG stands for. Non linear graphs are produced with the non-linear equations. And to get such type of equations, the equation either contains a power or root.

The Solver selects a starting point for its analyses while the GRG algorithm is run. The starting point changes on each and every run. For this reason, after every run, there is a different set of answers . Upon rerun, the solver uses the values of the Decision Variable that arises during the run to determine whether the desired Objective is produced at the lowest or maximum value. The solver is run again until the values are either maximized or minimized. And that leads to optimized values. Nondeterministic processes are those that yield distinct results for various runs.

In addition to that, the GRG Nonlinear Solver has a Multi-start facility which allows the user to choose many starting points, resulting in a different set of locally optimal solutions. There is a maximum probability of arriving the solution at a Globally Optimal solution. However, GRG Nonlinear Solver attain a Globally Optimal solution if all functions of the Objective and all constraints are convex. If any of the functions or Constraints is non-convex, the GRG Nonlinear Solver may find only Locally Optimal Solutions.

6.3 CONSIDERATIONS AND CALCULATIONS OF PARAMETERS REQUIRED FOR MODEL FORMULATION:

6.3.1 Type of canal section:

A rectangular and a trapezoidal canal sections are considered for Longa Irrigation Project.

6.3.1.1 Rectangular canal section:

Consider a rectangular canal section as shown in the figure 5.3.1.1. The parameters B, Y, f, and t are the bed width, depth of flow, free board and thickness of canal lining.

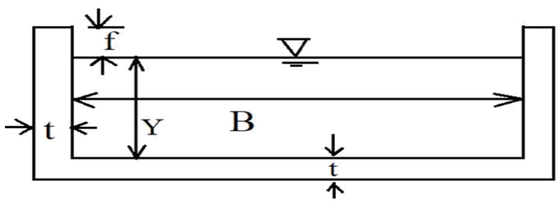


Fig 6.1: Rectangular canal cross-section

Let A_f and P_f are the cross sectional area and wetted perimeter of the canal with free board f.

A_f=B x (Y + f)

P_f = B + 2(Y + f)

Similarly A, P, R, T, D,V and Fr are the area, wetted perimeter, hydraulic radius, top width, hydraulic depth, velocity of flow in the canal and Froude"s no of the canal without freeboard. These parameters can be written as

A=B x Y

P=B+2Y

T=B

D=A/T

R=A/ P

Fr=V/$\sqrt{gD}$ where, g= Acceleration due to gravity=9.81m^2/s

6.3.1.2Trapezoidal canal section:

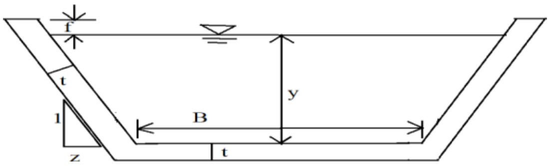


Fig 6.2: Trapezoidal canal section

Consider a trapezoidal canal section, as seen in figure 5.3.1.2, where the following parameters are present: bed width of the canal (B), flow depth (Y), Manning's roughness coefficient (n), thickness of the canal lining (t), free board (f), and side slope in the ratio 1:Z (V:H) = 1:1 on both sides.

Let A_f and P_f are the cross sectional area and wetted perimeter of the canal with free board f.

A_f= (B+Z(Y+f)) x (Y+f)

P_f= B+ (2(Y+f)$\sqrt{(1 + Z^2)}$

Similarly A, P, R, T, D, L, V and Fr are the area, wetted perimeter, hydraulic radius, top width, hydraulic depth, length of slanting side, velocity of flow and Froude's no of the canal without freeboard. These parameters can be written as

A= (B+ZY) x Y

P= B + 2Y$\sqrt{1 + Z^2}$

$T = B + 2ZY$

$D = A/P$

$L = Y\sqrt{1+Z^2}$

$R = A/P$

$Fr = V/\sqrt{gD}$

6.3.2 Design discharge of canal section:

Based on the NIA that each canal in the Longa Irrigation project covers, the discharge that is required by each canal needs is determined. Table 6.1 provides a list of the canals, NIA covered and discharge requirements for each canal section.

6.3.3 Discharge of canal section:

The discharge in a canal is calculated from manning's equation.

$$Q = A\,x\,\frac{1}{n}\,x\,R^{2/3}x\,S^{1/2}$$

Where, A= Area of cross section of the canal

n= Manning's rugosity coefficient

R= Hydraulic Radius of the canal

S= Longitudinal slope of the canal

6.3.4 Velocity in the canal:

The velocity in the canal is calculated from Manning's equation.

$$V = 1/n \text{ x } R^{2/3} \text{ x } S^{1/2}$$

Where, n= Manning's rugosity coefficient

R= Hydraulic Radius of the canal

S= Longitudinal slope of the canal

6.3.5 Most Efficient Canal Section:

A canal section is most efficient when it has minimum wetted perimeter. For a rectangular canal wetted perimeter is minimum when B/Y=2. For a trapezoidal section, B/Y=$2\sqrt{(1+Z^2)}$ at R=Y/2

6.3.6 Free Board:

The free board is provided as per Table 4.2

6.3.7 Calculations for discharge required by each Canal

The discharge required by the canal is find out with the help of crop water requirement per day. The maximum water requirement for each crops in a decadal and area is considered to find out the discharge required by the canal for the command area covered.

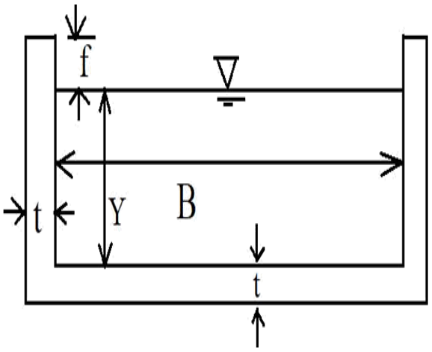
Required Discharge by the canal $= Annual\ Irrigable\ Area\ x \frac{Max.CWR\ per\ decadal}{10\ x\ 24\ x\ 60\ x\ 60}\ x\ \frac{10000}{1000}$ m^3/s

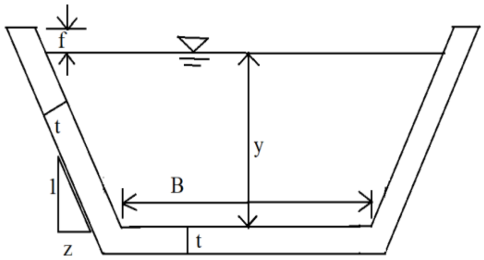
Table 6.1:- Discharge required by the canal

NAME	DESIGNATION OF CANAL	TYPE OF CROPS GROWN AND NET IRRIGABLE AREA (Ha)	ANNUAL IRRIGABLE AREA(in Ha)	DISCHARGE REQUIRED BY THE CANAL (m^3/s)
Main Canal	M1	Sali=1145 Rapeseed=1145	2290	1.1
Branch Canal	M1S1	Sali=200 Ha Rapeseed=200Ha	400	0.193
	M1S2	Sali=200.22Ha Veg=200.22Ha Jute=200.22Ha	600.66	0.3
	M1S3	Sali=500 Ha Veg=500 Ha Jute=500Ha	1500	0.83
	M1S4	Sali=336Ha	336.00	0.176
	M1S5	Sali=360Ha	360.00	0.188
	M1S6	Sali=250Ha Rapeseed=250	500	0.2

6.4 MODEL FORMULATION:

In order to minimize the net cost of construction of the canal, two nonlinear programming models are considered, one as rectangular and as trapezoidal canal section, which are created and solved using the Microsoft Excel solver platform. The components of the nonlinear programming model include variables, constraints, and an objective function. Based on the CCA that each canal in the Longa Irrigation project covers, the discharge that each canal needs is determined. While developing a model, the Froude's no. is kept at sub-critical zone in order to avoid to avoid hydraulic jump of the section.





6.4.1 OBJECTIVE FUNCTION:

The objective function of the Nonlinear Programming (NLP) model consists of cost of excavation and cost of lining to minimize the total cost of construction of the canal of Longa Irrigation project.

6.4.1.1 Objective function for Rectangular canal section:

Min R=Cost of excavation + Cost of lining

= C_1 x Cross-sectional area of the canal+ C_2 x Cross sectional area of lining

$$= C_1 \times B \times (Y+f) + C_2 \times (B+2 \times (Y+f)) \times t$$

Where, Min R = Minimum cost of construction of canal per running meter.

C_1 = Cost of excavation per cubic meter.

C_2 = Cost of lining per cubic meter.

B = Width of the canal.

Y = Depth of the canal.

f = Free board provided in the canal.

t = Thickness of lining.

6.4.1.2 Objective function for Trapezoidal canal section:

Min R = Cost of excavation + Cost of lining

= C1 x Cross-sectional area of the canal+ C2 x Cross sectional area of lining.

= C1 x {(B +Z(Y + f)}(Y + f)) + C2 x (B x t) + {C2 x 2 x ((Y + f) x$\sqrt{(1 + Z^2}$) x t)}

+ {C2 x (B xt)}

Where, Min R = Minimum cost of construction of canal per running meter.

C_1 = Cost of excavation per cubic meter.

C_2 = Cost of lining per cubic meter.

B = Width of the canal.

Y = Depth of the canal.

f = Free board provided in the canal.

t = Thickness of lining.

1: Z (V: H) =side slope.

Z=1(side slope is considered as 1:1 for Trapezoidal section)

6.4.2 CONSTRAINTS:-

The following constraints may be applied to the objective functions :-

i) Constraint on Discharge in the canal:

The discharge calculated from Manning's formula for the canal is greater than or equal to the discharge required or the design discharge for the canal.

ii) Constraints for the Condition of most economic canal section:

a) The condition for most economic rectangular canal section is B=2Y.

b) For a Trapezoidal Section, hydraulic radius, R=Y/2, Half the top width equals to one of its sloping side.

iii) Constraint on Width of the canal

The width of the canal cannot be negative, i.e. B > 0. Considering the construction point of view, let the minimum width of the canal be 0.1m.

iv) Constraint on Depth of the canal:

The depth of the canal cannot be negative i.e. $Y > 0$. Let the minimum depth of the canal be 0.1m.

v) Constraint on limiting velocity:

The limiting velocity for the canal is considered as per IS: 10430-1982 which is provided is table 4.4. The limiting velocity for cement concrete lining is 2.7 m/s.

vi) Constraint on critical velocity:

According to IS: 10430-2000, the critical velocity obtained by any formula should be less than the velocity of the canal obtained by Manning's formula. The critical velocity obtained by Kennedy's formula i.e. $V_0 = 0.546 \times D^{0.64}$ should be less than the velocity in the canal obtained by Manning's formula.

vii) Constraint on Flow condition:

The Froude's number calculated for the canal section should be less than 1(one) to maintain the subcritical flow condition in order to avoid hydraulic jump in the canal.

$Fr = V/\sqrt{gD}$,Where , V = velocity of flow in m/sec ,g=acceleration due to gravity , D=hydraulic depth

6.4.3 VARIABLES:

i. Bed width of the canal.
ii. Depth of the canal

CHAPTER 7

CANAL SECTION OPTIMIZATION, RESULT AND DISCUSSION

7.1 INTRODUCTION:

For every canal section, the nonlinear optimization model is applied in the Microsoft Excel solver platform, yielding the lowest possible construction costs and the ideal canal dimensions.

7.2 OPTIMIZATION OF CANALS:

7.2.1 Optimization of main canal M1 from chainage 0.00m to 11400m:

The nonlinear model at first considers a depth of 1.5 m and bed width of 2 m for the canal section. All the parameters and the minimal construction cost are computed for it, and the canal section is drawn in Microsoft Excel (Fig 7.1). And then, the objective function, variables, and constraints for the model are put in the solver as shown in (Fig 7.2) The GRG Nonlinear Engine is then used to solve the nonlinear programming model. The model automatically generates the canal section upon evaluating the variables that satisfy all constraints and the objective function's optimal value (Fig. 7.3). However, if any of the restrictions are not met, the solver will not be able to get any solution. A comparative statement between the initial and ending values is generated by the solver and presented in Fig 7.4.

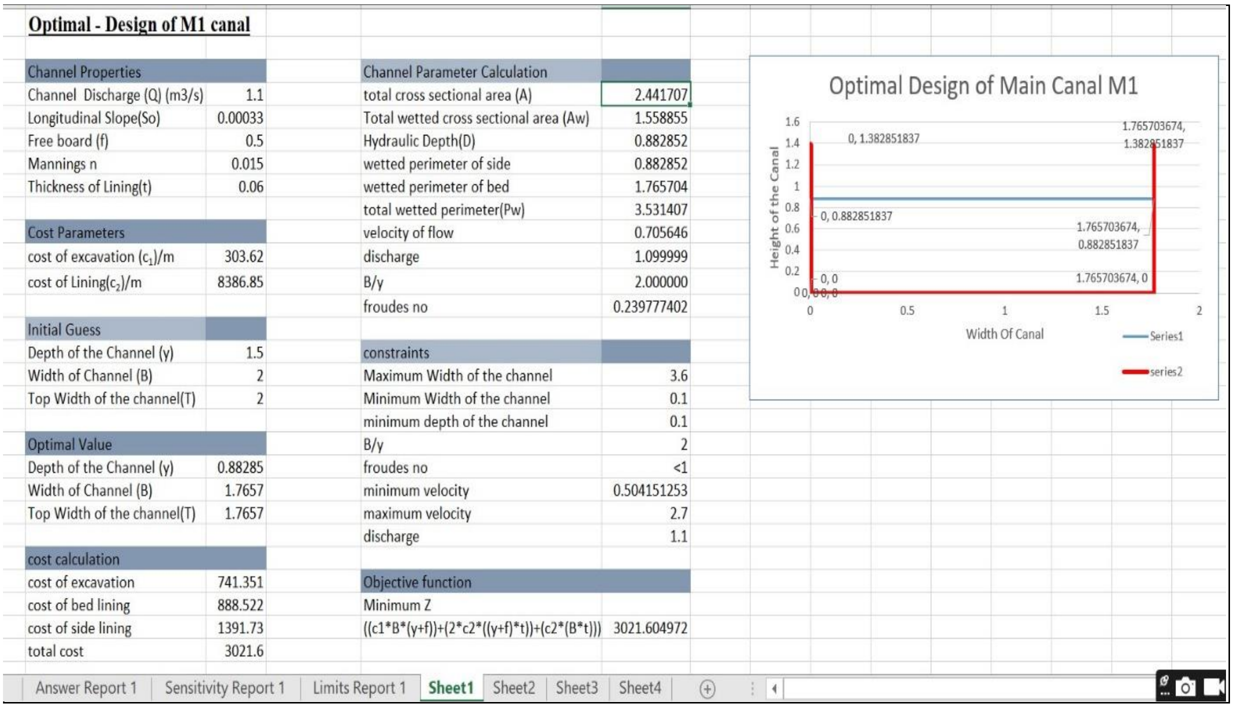


Fig 7.1: Calculation of canal parameter and minimum cost of construction for assumed initial depth and width value in excel solver platform.

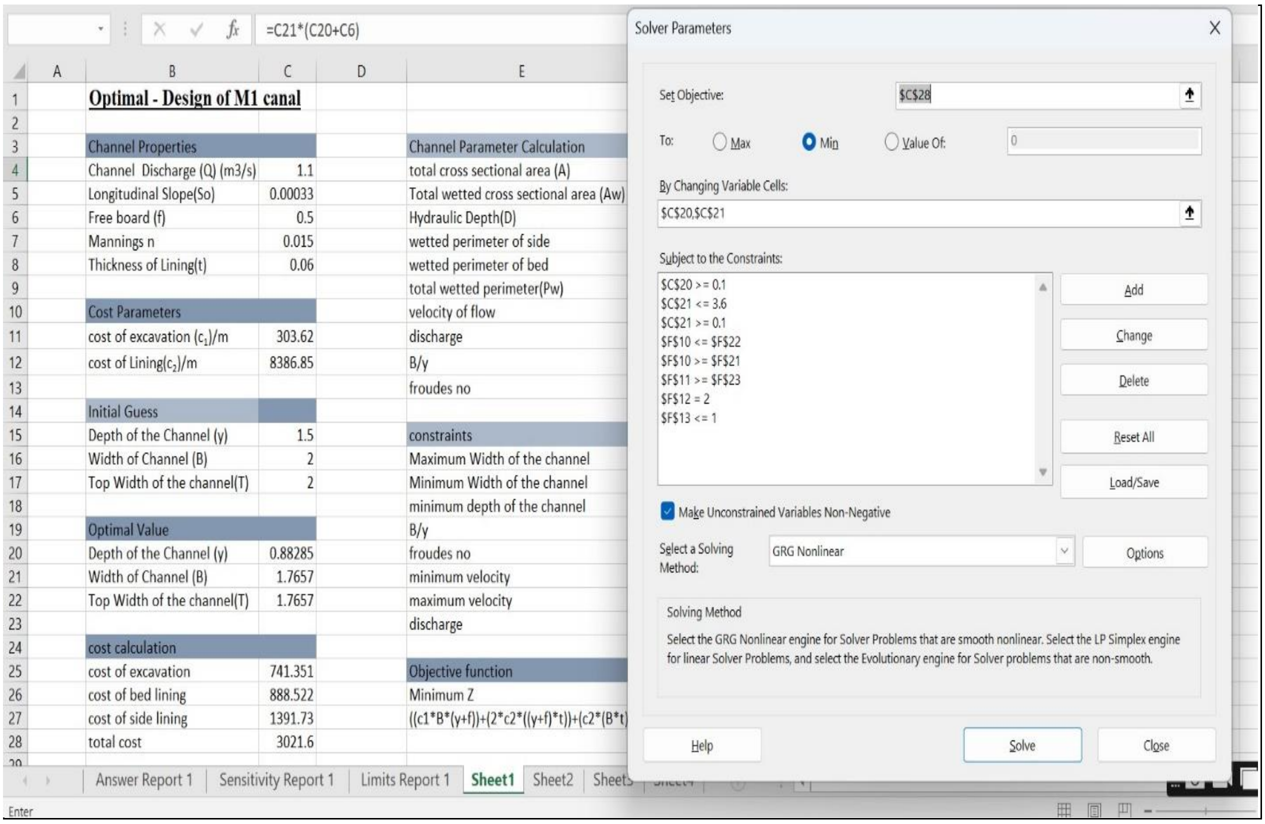


Fig 7.2: Solver platform showing objective function, variable and constraints.

Optimal - Design of M1 canal

Channel Properties	
Channel Discharge (Q) (m3/s)	1.1
Longitudinal Slope(So)	0.00033
Free board (f)	0.5
Mannings n	0.015
Thickness of Lining(t)	0.06
Cost Parameters	
cost of excavation (c_1)/m	303.62
cost of Lining(c_2)/m	8386.85
Initial Guess	
Depth of the Channel (y)	1.5
Width of Channel (B)	2
Top Width of the channel(T)	2
Optimal Value	
Depth of the Channel (y)	0.88285
Width of Channel (B)	1.7657
Top Width of the channel(T)	1.7657
cost calculation	
cost of excavation	741.351
cost of bed lining	888.522
cost of side lining	1391.73
total cost	3021.6

Channel Parameter Calculation	
total cross sectional area (A)	2.441707
Total wetted cross sectional area (Aw)	1.558855
Hydraulic Depth(D)	0.882852
wetted perimeter of side	0.882852
wetted perimeter of bed	1.765704
total wetted perimeter(Pw)	3.531407
velocity of flow	0.705646
discharge	1.099999
B/y	2.000000
froudes no	0.239777402
constraints	
Maximum Width of the channel	3.6
Minimum Width of the channel	0.1
minimum depth of the channel	0.1
B/y	2
froudes no	<1
minimum velocity	0.504151253
maximum velocity	2.7
discharge	1.1
Objective function	
Minimum Z	
((c1*B*(y+f))+(2*c2*((y+f)*t))+(c2*(B*t)))	3021.604972

Answer Report 1 | Sensitivity Report 1 | Limits Report 1 | Sheet1 | Sheet2 | Sheet3 | Sheet4

Fig 7.3: Optimum value of objective function for the optimum values of variables along with drawing of cross-section of canal section as displayed in excel solver platform.

Microsoft Excel 16.0 Answer Report
Worksheet: [optimal design for M1.xlsx]Sheet1
Report Created: 05 01 2024 22:48:16
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Engine: GRG Nonlinear
Solution Time: 0 Seconds.
Iterations: 0 Subproblems: 0
Solver Options
Max Time Unlimited, Iterations Unlimited, Precision 0.000001
Convergence 0.0001, Population Size 0, Random Seed 0, Derivatives Forward
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume No

Objective Cell (Min)

Cell	Name	Original Value	Final Value
$C$28	total cost	3021.60497	3021.60497

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$C$20	Depth of the Channel (y)	0.88285184	0.88285184	Contin
$C$21	Width of Channel (B)	1.76570367	1.76570367	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$F$10	velocity of flow	0.705646	$F$10<=$F$22	Not Binding	1.99435435
$F$10	velocity of flow	0.705646	$F$10>=$F$21	Not Binding	0.201494
$F$11	discharge	1.099999	$F$11>=$F$23	Binding	0.000000
$F$12	B/y	2.000000	$F$12=2	Binding	0
$F$13	froudes no	0.2397774	$F$13<=1	Not Binding	0.7602226
$C$20	Depth of the Channel (y)	0.88285184	$C$20>=0.1	Not Binding	0.78285184
$C$21	Width of Channel (B)	1.76570367	$C$21<=3.6	Not Binding	1.83429633
$C$21	Width of Channel (B)	1.76570367	$C$21>=0.1	Not Binding	1.66570367

Answer Report 1 | Sensitivity Report 1 | Limits Report 1

Fig 7.4: Comparative statement showing initial value and final value as displayed in excel solver platform.

In the similar way, the model is applied for branch canals too of the project such as M1S1,M1S2,M1S3,M1S4,M1S5.

7.3 RESULTS:-

For the Longa IP canal network, the nonlinear optimization model is put into practice, and the ideal dimensions and construction costs for the canal sections per running meter are found. Tables 7.1 will provide the ideal dimensions and construction costs for the main canal M1 and its distributaries. The total minimum cost of construction for the whole canal system considering rectangular section will be Rs. 7,36,15,939 (Rupees Seven crore thirty six lakh fifteen thousand nine hundred thirty nine only) and for trapezoidal section it will be Rs 9,44,91,454(Rupees nine crore twenty eight lakh forty nine thousand five hundred forty nine only).

Table 7.1:- Ideal dimension and construction costs for the main canal and its Distributaries.

Slno.	Name	Discharge (m3/s)	Rectangular Section			Trapezoidal Section		
			OptimumWidth B(m)	OptimumDepth Y(m)	Optimum cost of construct-ion per running meter (Rupees)	OptimumWidth B(m)	OptimumDepth Y(m)	Optimum cost of construction per running meter (Rupees)
1	M1	1.1	1.765704	0.882852	3021.605	0.561506	0.927268	4043.204
2	M1S1	0.193	0.919347	0.459673	1439.227	0.273039	0.450892	1818.818
3	M1S2	0.3	1.08472	0.54236	1671.03	0.322152	0.531998	2068.286
4	M1S3	0.83	1.58873	0.79436	2428.75	0.47184	0.779191	2880.492
5	M1S4	0.176	0.888101	0.444051	1396.361	0.263759	0.435569	1772.63
6	M1S5	0.188	0.910341	0.455171	1426.842	0.270364	0.446476	1805.476
7	M1S6	0.2	0.93171	0.46586	1456.271	0.276711	0.456957	1837.181

The cross-sectional area are shown below:-

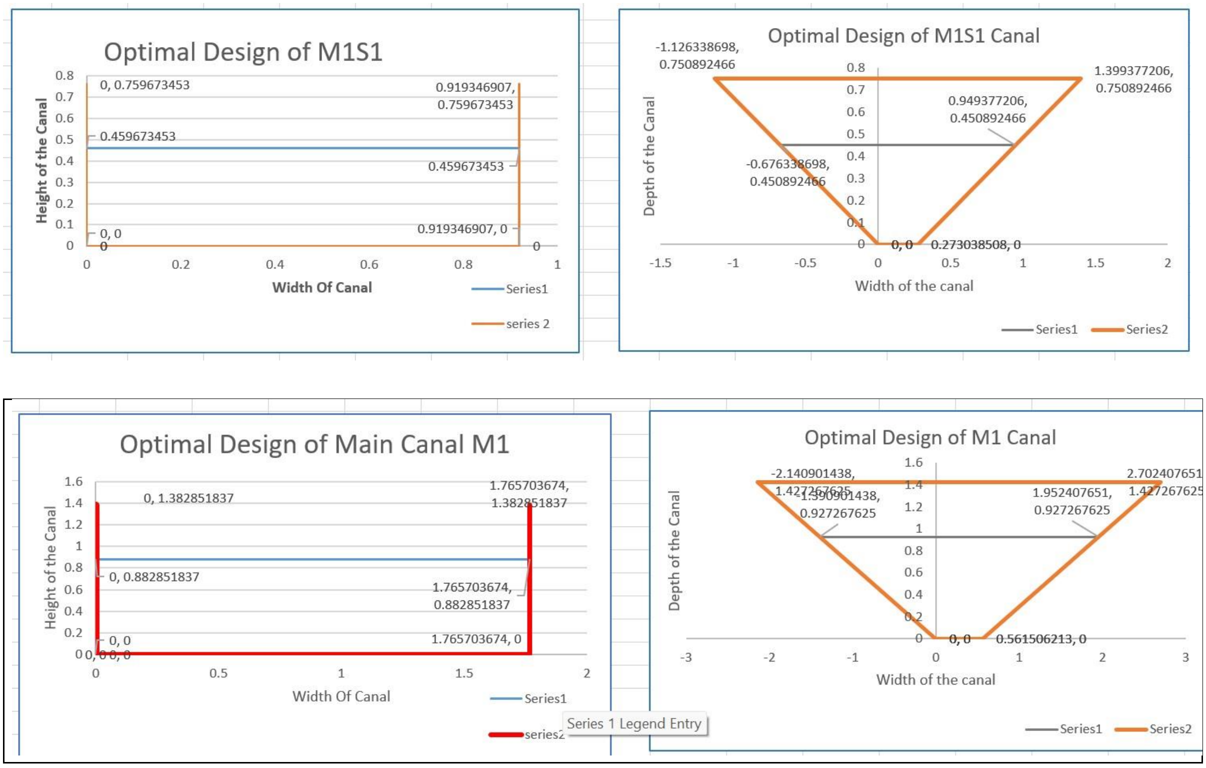


Fig 7.5:- Cross Sectional area of M1 and M1S1 canals.

7.4 DESIGN CHECK AT TRANSITION PORTION:

The canal segment within an irrigation project forms an integral part of its continuous canal network. When transitioning from one canal segment with varying width and depth to another within the network, it is imperative to carefully design the canal in the transition zone to ensure seamless flow. So, the design for the transition portion is checked.

At transition portion,

Average width=1.7657 m

Average depth=0.88285 m

Average discharge=1.1 Cumec

Average total cross sectional area=2.441707 sqm

Average total wetted cross sectional area=1.558855sqm

Average hydraulic depth=0.882852 m

Average wetted perimeter =3.531407 m

Average wetted radius= 0.441425919 m

Average calculated velocity of flow= 0.705646m/s

Average calculated discharge = 1.099cumec

Froude's no=0.239777402

Minimum velocity=0.5042 m/sec

It is seen that the average calculated discharge is approximately same as that of the average discharge in the canal. The Froude number is kept below one, to ensure a subcritical flow within the transition portion. Furthermore, the calculated velocity in this segment exceeds the minimum velocity requirement while staying below the maximum velocity threshold of 2.7 cumec for cement concrete lining canals. Therefore, this transition section is considered as safe. Similar procedures were implemented in other transition portions with satisfactory results as well.

7.5 DISCUSSION

The minimum cost of constructing the canal sections has been determined. The depth and width of the canal are identified as the two variables that minimize construction expenses. For the entire canal system, adopting a rectangular section results in a total minimum construction cost Rs. 7,36,15,939 (Rupees Seven crore thirty six lakh fifteen thousand nine hundred thirty nine only) and for trapezoidal section it will be Rs 9,44,91,454(Rupees nine crore twenty eight lakh forty nine thousand five hundred forty nine only).

While performing irrigation Scheduling it is found that the total percolation loss in case of Sali crop 732.6 mm and effective rainfall is 896.0 mm. Similarly, in case of Jute there is no irrigation losses and effective rainfall is found to be 97.7 mm. In case of rapeseed, there is no irrigation losses and effective rainfall as calculated by CROPWAT 8.0 comes out to be 68.6mm. In case of Melons, effective rainfall is 95.8 mm and there exits no irrigation losses as calculated by the software.

CHAPTER 8
CONCLUSION AND FUTURE SCOPE OF WORK

8.1 INTRODUCTION:

The Longa Irrigation project, situated in the Kokrajhar West constituency within the Kokrajhar district, serves as the study area. Positioned on the northern bank of the Brahmaputra River, the project features a barrage constructed at Ramfalbil village near Serfunguri, spanning the Longa River. Originating from the foothills of Bhutan, the Longa River is perennial in nature. The headwork of the project is located at latitude 26.548096^{0}N longitude 90.162317^{0}E. The project is proposed to cover an area of 2791.22Ha with the construction of lined canals. The optimization of the canal section for the Longa Irrigation Project has been conducted solely for academic purposes, aimed at exploring the potential for optimizing canal sections.

8.2 CONCLUSION:

This dissertation report comprises of determination of crop water requirement for the proposed crops viz. Sali, Rapeseed, jute and vegetables of the study area, determining the irrigation scheduling and outlining two nonlinear optimization models, one on a rectangular section and the other on a trapezoidal section, both has been solved using the Microsoft Excel Solver GRG to attain at the optimal construction cost of the canal for Longa Irrigation Project. Structural data were collected from the State Irrigation Department of Assam. The Crop water requirement for the proposed crops Sali, Jute, Vegetables (Melons) and Rapeseed were evaluated using the data from CLIMWAT 2.0 and FAO standards with the help of CROPWAT 8.0. However, the irrigation scheduling has also been carried out and it was found that the total gross irrigation amounts to 705.5 mm, while the total net irrigation stands at 493.9 mm in case of Sali Crop and the crop water requirement is 425.8mm. In case of Jute, the gross crop water requirement is 378.6 mm and actual irrigation requirement is 281mm. Furthermore, the highest flow is found to be

0.25,0.36,0.64,0.63,0.22 l/s/ha in the months of May, June, July, August September respectively. In case of Rapeseed crop, the crop water requirement is 224.8 mm and actual irrigation requirement is 155.9 mm. Moreover, the highest flow is found to be 0.13,0.41,0.44 l/s/ha in the months of Jan, Feb, March respectively. In case of vegetable(melons), crop water requirement is 334.3 mm and actual irrigation requirement is 238.5 mm the highest flow is found to be 0.15,0.45,0.67,0.36 l/s/ha in the month of Jan, Feb, March, April respectively.

Based on the usage, these two types of shapes were chosen for the optimization model. The objective function of the model is to minimize construction costs, comprising of excavation and lining expenses, while considering the standard free board as specified in IS:10430-2000 and the thickness as per standards of IS:3873-1993. In these models, the variables include the width and depth of the canal section, with constraints such as minimum and maximum widths, economic section criteria, Froude's number considered to control velocity, maximum permissible velocity, critical velocity, and maximum discharge. To determine velocity and discharge Manning's formula was used since the sections are lined. The models were then solved using Microsoft Excel Solver GRG Nonlinear engine, obtaining optimal construction cost per running meter which are drawn automatically for cross-sections of the canals and thus, the optimal depth and width values for the canals were also obtained, along with the minimum construction cost for the entire Longa IP canal system. The rates for costs for excavation per cubic meter and lining per square meter were considered as per schedule of rates of Irrigation Department 2021-22.

The most economical canal dimensions were identified, with the total minimum construction cost projected to be 7,36,15,939 (Rupees Seven crore thirty six lakh fifteen thousand nine hundred thirty nine only) and for trapezoidal section it will be Rs 9,44,91,454(Rupees nine crore twenty eight lakh forty nine thousand five hundred forty nine only).

The study highlights the increasing use of complex optimization techniques by researchers to determine the most economical canal cross sections. However, for field engineers, time constraints are often a challenge. Complex optimization methods also require expertise in system analysis techniques and the use of specialized software such as MATLAB, which may not be readily available within implementing agencies. Therefore, the primary aim of this work is to showcase how simple optimization algorithms, coupled with the widely accessible MS Office Excel platform, can be utilized by field engineers to design the most cost-effective canal cross sections in minimal time.

8.3 FUTURE SCOPE OF THE WORK:

The current study focuses on both rectangular and trapezoidal canal section models due to ease of construction at field levels. However, future research could be extended to other shapes of canals such as elliptical or compound canals with the minimum construction costs for equivalent discharges in additional open canal configurations. Optimal dimensions for these alternative canal sections could also be determined, allowing for a comparative analysis of minimum construction costs and canal dimensions across various open canal types.

The present study uses the GRG engine to solver the model. However, MATLAB can be set as an alternative tool for analysis.

The present study could further be done considering multiple cropping pattern with high yielding variety of crops which might to a better cropping pattern.