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IMPACT OF EFFECTIVE RAINFALL ON NET IRRIGATION WATER REQUIREMENT FOR A PARTICULAR REGION

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Abstract
Irrigation is an essential to increase agriculture production and productivity for sustainability of country's economy. Agriculture contributes one-third of national GDP and two-third of labour employment for livelihoods. Water greatly influences photosynthesis, respiration, absorption, translocation, utilization of mineral nutrients, and cell division in plant system. Rapid change in climate system has raised the concern of floods and droughts and their impacts on existing arrangements for irrigation design and management system. Glacial and snow melt is an important source of the lean flows of snow-fed rivers but it is predicted that possible decline in river and stream flows in future. All small farmers are vulnerable to the climate change impacts resulting adverse effects in agricultural productivity and food security. The current policies, plans, strategies emphasized on the climate change impacts and its adaptation in irrigation system. The absence of proper mechanisms for water augmentation, conservation, distribution, and efficient use are the major basis for climate change adaptation. This paper is intended to highlight the impacts of climate change and the climate change adaptation on irrigation system to build adaptive capacity and promote climate resilient irrigation system. This case study shows that millet is a good source of protein, fiber, key vitamins, and minerals. The potential health benefits of millet include protecting cardiovascular health, preventing the onset of diabetes, helping people achieve and maintain a healthy weight, and managing inflammation in the gut. Millet is an adaptable grain. Millet is an ancient grain that people have enjoyed for thousands of years. Millet is also food for livestock and birds. It is becoming increasingly popular as it is fast-growing, drought-resistant, and requires low input.
Keywords: Effective Rainfall, Net Irrigation, Millets.

I. Introduction

Rainfall is the main source of water for the globe, including for agricultural production. The three most important properties required about rainfall are amount, frequency, and intensity; and which varies from one place to the other and from time to time as well. Now a day the concept of effective rainfall is increasing and it is important to consider the contribution of natural rainfall made in design and operation of modern irrigation systems as natural rainfall contributes significantly in satisfying the consumptive demands of crops. All field crops need soil, water, air and light (sunshine) to grow. The soil gives stability to the plants; it also stores the water and nutrients which the plants can take up through their roots. The sunlight provides the energy which is necessary for plant growth (Fig. 1 .0).
The air allows the plants to "breath".

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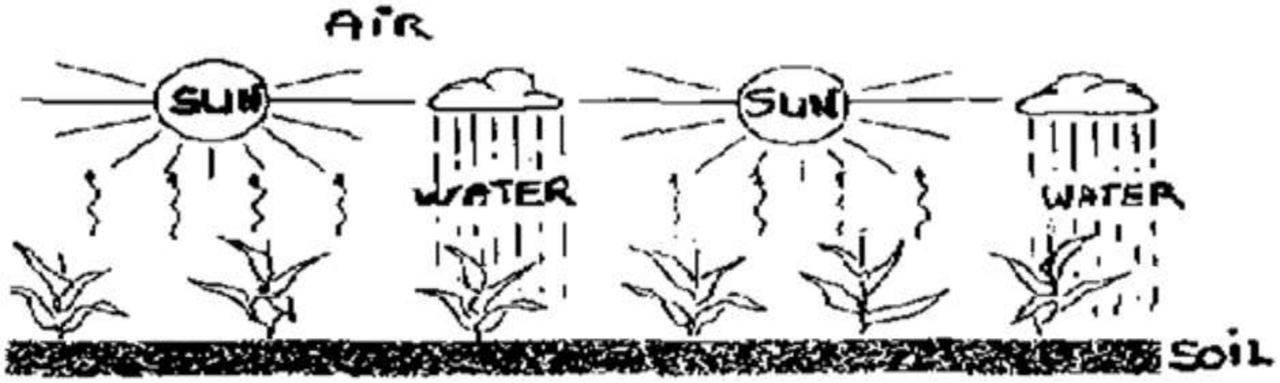

Fig. 1.0 Plants need soil, water, air and sunlight ......

Without water crops cannot grow. Too much water is not good for many crops either. Apart from paddy rice, there are only very few crops which like to grow "with their feet in the water". The most well-known source of water for plant growth is rain water. There are two important questions which come to mind: What to do if there is too much rain water? What to do if there is too little rain water?

If there is too much rain, the soil will be full of water and there will not be enough air. Excess water must be removed. The removal of excess water - either from the ground surface or from the root zone - is called **drainage.**

If there is too little rain, water must be supplied from other sources; irrigation is needed. The amount of irrigation water which is needed depends not only on the amount of water already available from rainfall, but also on the total amount of water needed by the various crops. With respect to the need for irrigation water, a distinction can be made among three climatic situations:

1. Humid climates: more than 1200 mm of rain per year. The amount of rainfall is sufficient to cover the water needs of the various crops. Excess water may cause problems for plant growth and thus drainage is required.

2. Sub-humid and semi-arid climates: between 400 and 1200 mm of rain per year. The amount of rainfall is important but often not sufficient to cover the water needs of the crops. Crop production in the dry season is only possible with irrigation, while crop production in the rainy season may be possible but unreliable: yields will be less than optimal.

3. Semi-arid, arid and desert climates: less than 400 mm of rain per year. Reliable crop production based on rainfall is not possible; irrigation is thus essential.

1.1 CROP WATER NEEDS

Crops need water for transpiration and evaporation. The plant roots suck or extract water from the soil to live and grow. The main part of this water does not remain in the plant, but escapes to the atmosphere as vapour through the plant's leaves and stem. This process is called transpiration (Fig. 1.1). Transpiration happens mainly during the day time. Water from an open water surface escapes as vapor to the atmosphere during the day. The same happens to water on the soil surface and to water on the leaves and stem of a plant. This process is called evaporation. The water need of a crop thus consists of transpiration plus evaporation. Therefore, the crop water need is also called "evapotranspiration".

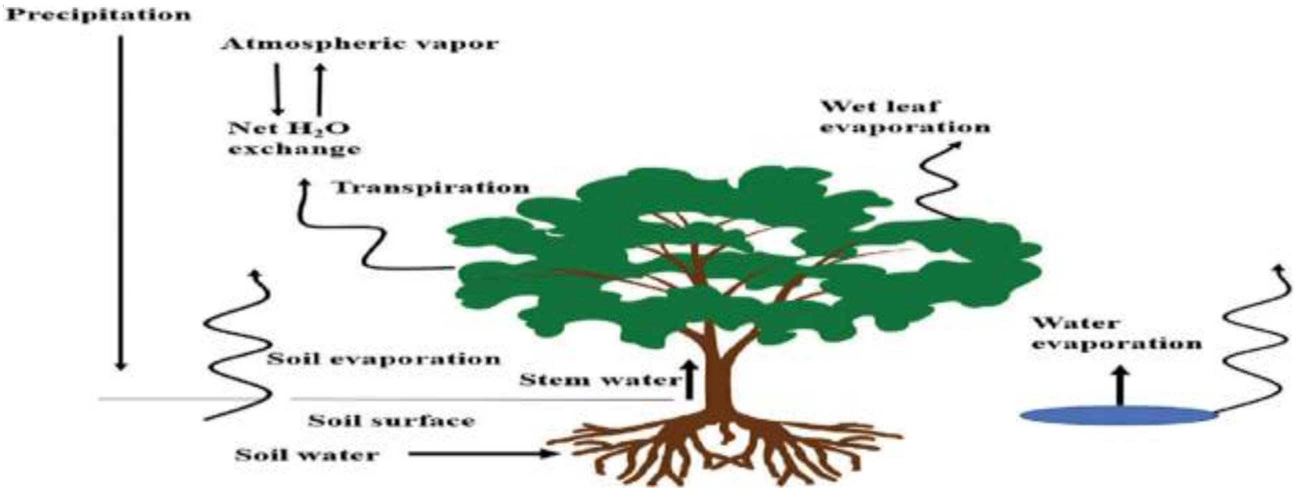

Fig. 1.1 Transpiration

The water need of a crop is usually expressed in mm/day, mm/month or mm/season. Suppose the water need of a certain crop in a very hot, dry climate is 10 mm/day. This means that each day the crop needs a water layer of 10 mm over the whole area on which the crop is grown (Fig. 1.2). It does not mean that this 10 mm has to indeed be supplied by rain or irrigation every day.

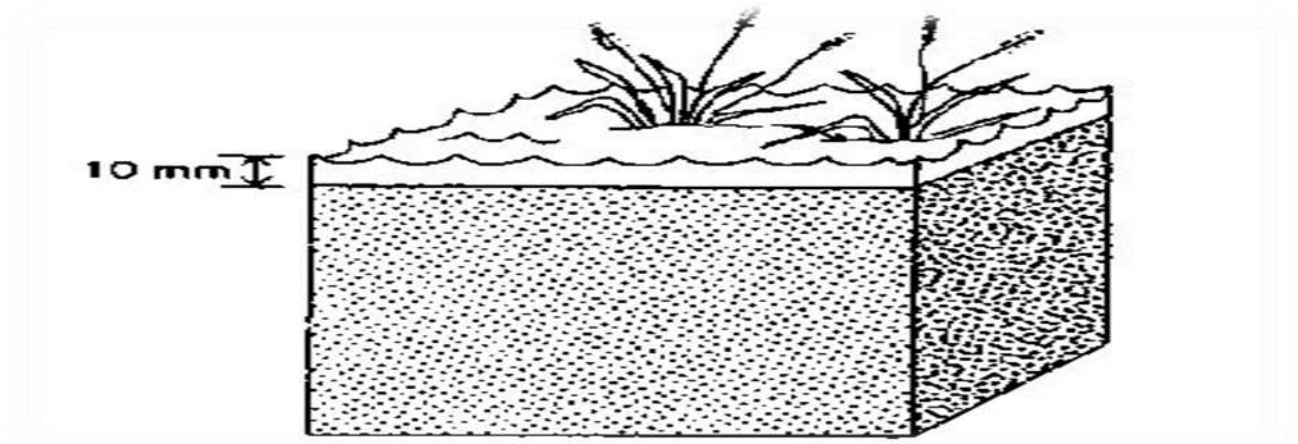

Fig. 1.2 A crop water need of 10 mm/day

1.2 THE INFLUENCE OF THE CLIMATE ON CROP WATER NEEDS

A certain crop grown in a sunny and hot climate needs per day more water than the same crop grown in a cloudy and cooler climate. There are, however - apart from sunshine and temperature - other climatic factors which influence the crop water need. These factors are the humidity and the windspeed (Fig. 1.3). When it is dry, the crop water needs are higher than when it is humid. In windy climates the crops will use more water than in calm climates.

Fig. 1.3 Major climatic factors influencing crop water needs

1.3 INFLUENCE OF THE CROP TYPE ON THE CROP WATER NEEDS

The influence of the crop type on the crop water need is important in two ways:

1. The crop type has an influence on the daily water needs of a fully-grown crop; i.e. the peak daily water needs: a fully developed maize crop will need more water per day than a fully developed crop of onions.
2. The crop type has an influence on the duration of the total growing season of the crop. There are short duration crops, e.g. peas, with a duration of the total growing season of 90-100 days and longer duration crops, e.g. melons, with a duration of the total growing season of 120-160 days. And then there are, of course, the perennial crops that are in the field for many years, such as fruit trees.

While, for example, the daily water need of melons may be less than the daily water need of peas, the seasonal water need of melons will be higher than that of beans because the duration of the total growing season of melons is much longer.

The influences of the crop type on both the daily and seasonal crop water needs are discussed in the sections below.

1.3.1 Influence of Crop Type on the Daily Crop Water Needs

In the previous section it has been indicated how the daily water need of standard grass can be estimated. In this section it will be explained how the daily water needs of other crops can be estimated using as a basis the daily water need of the standard grass.

It will be easy to understand that a fully-grown maize crop - with its large leaf area - will use more water per day than, for example, a fully-grown crop of radishes or onions; that is when the two crops are grown in the same area.

When determining the influence of the crop type on the daily crop water needs, reference is always made to a fully-grown crop; the plants have reached their maximum height; they optimally cover the ground; they possibly have started flowering or started grain setting. When the crops are fully grown their water, need is the highest. It is the so-called "peak period" of their water needs.

1.3.2 Influence of Crop Type on the Seasonal Crop Water Needs

The crop type not only has an influence on the daily water need of a fully-grown crop, i.e. the daily peak water need, but the crop type also has an influence on the duration of the total growing season of the crop, and thus on the seasonal water need.

Data on the duration of the total growing season of the various crops grown in an area can best be obtained locally. These data may be obtained from, for example, the seed supplier, the Extension Service, the Irrigation Department or Ministry of Agriculture.

The duration of the total growing season has an enormous influence on the seasonal crop water need. There are, for example, many rice varieties, some with a short growing cycle (e.g. 90 days) and others with a long growing cycle (e.g. 150 days). This has a strong influence on the seasonal rice water needs: a rice crop which is in the field for 150 days will need in total much more water than a rice crop which is only in the field for 90 days. Of course, for the two rice crops the daily peak water need may still be the same, but the 150-day crop will need this daily amount for a longer period. The time of the year during which crops are grown is also very important. A certain crop variety grown during the cooler months will need substantially less water than the same crop variety grown during the hotter months.

1.4 INFLUENCE OF THE GROWTH STAGE OF THE CROP ON CROP WATER NEEDS

A fully-grown maize crop will need more water than a maize crop which has just been planted.

As has been discussed before, the crop water need or crop evapotranspiration consists of transpiration by the plant and evaporation from the soil and plant surface. When the plants are very small the evaporation will be more important than the transpiration. When the plants are fully grown the transpiration is more important than the evaporation.

Fig. 1.4 shows in a schematic way the various development or growth stages of a crop. At planting and during the initial stage, the evaporation is more important than the transpiration and the evapotranspiration or crop water need during the initial stage is estimated at 50 percent of the crop water need during the mid - season stage, when the crop is fully developed.

During the so-called crop development stage, the crop water need gradually Increases from 50 percent of the maximum crop water need to the maximum crop water need.

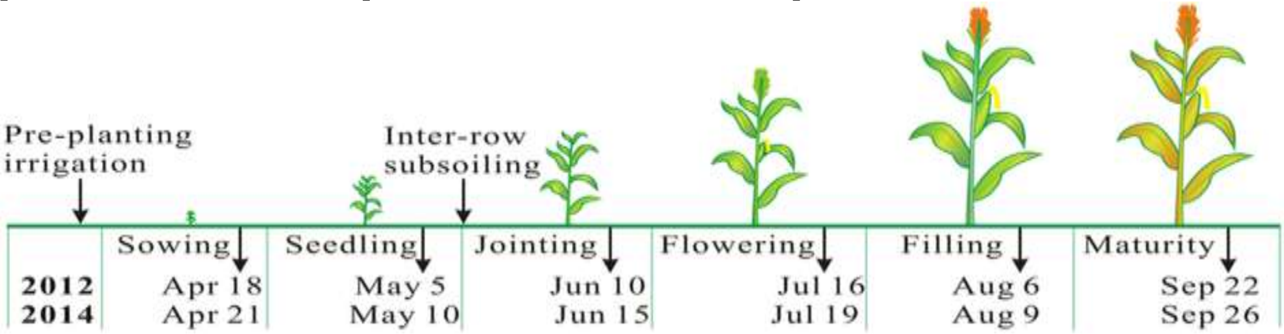

Fig. 1.4 Growth stages of a crop

1.5 DETERMINATION OF CROP WATER NEEDS

In the previous sections it has been explained on which factors - the climate, the crop type and the growth stage - the crop water need depends. To calculate the water needs for the various months during which the crop is grown is fairly complicated.

As stated before, it is often possible to obtain data on crop water needs locally and it is thus not necessary to calculate them. However, to give the reader some idea on values of seasonal water needs for the most important field crops.

1.6 INTRODUCTION TO EFFECTIVE RAINFALL

Apart from soil, air and sunlight, crops need water to grow. This water can be supplied to the crops by rainfall (also called precipitation), by irrigation or by a combination of rainfall and irrigation. If the rainfall is sufficient to cover the water needs of the crops, irrigation is not required. If there is no rainfall, all the water that the crops need has to be supplied by irrigation. If there is some rainfall, but

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not enough to cover the water needs of the crops, irrigation water has to supplement the rain water in such a way that the rain water and the irrigation water together cover the water needs of the crop. This is often called supplemental irrigation: the irrigation water supplements or adds to the rain water. Part of the rain water percolates below the root zone of the plants and part of the rain water flows away over the soil surface as run-off (Fig. 1.5). This deep percolation water and run-off water cannot be used by the plants. In other words, part of the rainfall is not effective. The remaining part is stored in the root zone and can be used by the plants

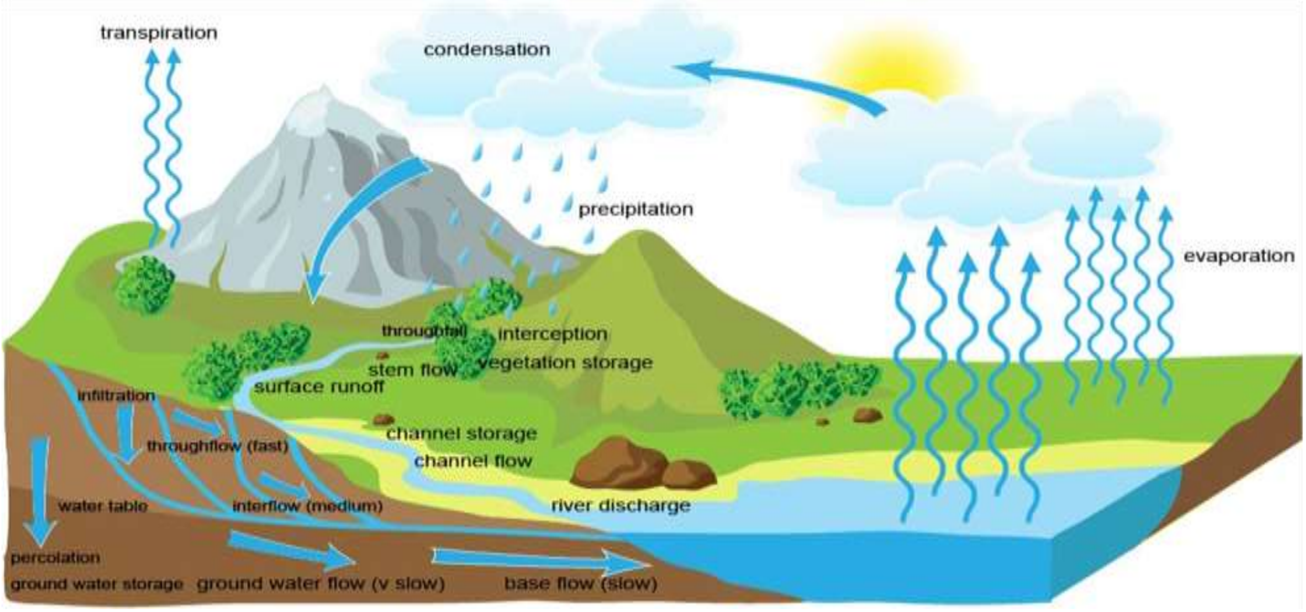

Fig. 1.5 Part of the rain water is lost through deep percolation and run-off

This remaining part is the so-called effective rainfall. The factors which influence which part is effective and which part is not effective include the climate, the soil texture, the soil structure and the depth of the root zone. If the rainfall is high, a relatively large part of the water is lost through deep percolation and run-off.

Deep percolation: If the soil is still wet when the next rain occurs, the soil will simply not be able to store more water, and the rain water will thus percolate below the root zone and eventually reach the groundwater. Heavy rainfall may cause the groundwater table to rise temporarily.

Run-off: Especially in sloping areas, heavy rainfall will result in a large percentage of the rainwater being lost by surface run-off. Another factor which needs to be taken into account when estimating the effective rainfall is the variation of the rainfall over the years. Especially in low rainfall climates, the little rain that falls is often unreliable; one year may be relatively dry and another year may be relatively wet. In many countries, formulae have been developed locally to determine the effective precipitation. Such formulae take into account factors like rainfall reliability, topography, prevailing soil type etc. If such formulae or other local data are available, they should be used.

1.7 RAINFALL IMPACT ON IRRIGATION SYSTEM & WATER RESOURCES MANAGEMENT

1.7.1 Impact on the Irrigation System

If the rainfall is sufficient to cover the water needs of the crops, irrigation is not required. If there is no rainfall, all the water that the crops need has to be supplied by irrigation (Fig. 1.6). Global food security threatened by climate change is one of the serious challenges in the twenty-first century to supply sufficient food for the burgeoning population while sustaining the already stressed environment. Changes in temperature and precipitation due to global climate change may have serious impacts on hydrologic processes, water resources availability, irrigation water demand, and thereby affecting the agricultural production and productivity. Meanwhile, climate variability is one

of the most significant factors influencing year to year crop production, even in high yielding and high-technology agricultural areas. There are reports suggesting that decline in grain yields of rice and wheat in Indo-Gangetic Plains (IGP) could have been partly due to weather changes (Fig. 1.7).
Agricultural productivity is sensitive to climate change due to direct effects of changes in temperature, precipitation and carbon dioxide concentrations, and also due to indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases. The increase in temperature under climate change scenarios is expected to increase the evapotranspiration (ET) demand. Therefore, understanding the impacts of climate change on crop production and water resources is of utmost importance for developing possible adaptation strategies.


Fig. 1.6 Artificial Irrigation System


Fig. 1.7 Natural Irrigation System

Various studies conducted to study the effects of climate change on the crop production showed that the effect of climate change on crop production varied with the climate change scenario used, current climate, cropping systems, management practices and also from region to region.

1.7.2 Impacts on the Water Resources Management

Water scarcity affects more than 40% of the global population. Water-related disasters account for 70% of all deaths related to natural disasters. The World Bank helps countries ensure sustainability of water use, build climate resilience and strengthen integrated management.
Today, most countries are placing unprecedented pressure on water resources. The global population is growing fast, and estimates show that with current practices, the world will face a 40% shortfall between forecast demand and available supply of water by 2030. Furthermore, chronic water scarcity, hydrological uncertainty, and extreme weather events (floods and droughts) are perceived as some of the biggest threats to global prosperity and stability. Acknowledgment of the role that water scarcity and drought are playing in aggravating fragility and conflict is increasing.
Climate change will worsen the situation by altering hydrological cycles, making water more unpredictable and increasing the frequency and intensity of floods and droughts. The roughly 1 billion people living in monsoonal basins and the 500 million people living in deltas are especially vulnerable. Flood damages are estimated around $120 billion per year (only from property damage), and droughts pose, among others, constraints to the rural poor, highly dependent on rainfall variability for subsistence.
The World Bank is committed to assisting countries meet their economic growth and poverty reduction targets based on the Sustainable Development Goals (SDGs). Particularly, water resource management is tackled in SDG 6.5, but other SDGs and targets require water resource management for their achievement.

Accordingly, the Bank has a major interest in helping countries achieve water security through sound and robust water resource management.

Water security is the goal of water resources management. For a rapidly growing and urbanizing global population, against a backdrop of increasing climatic and non-climatic uncertainties, it is not possible to "predict and plan" a single path to water security.

Water Resources Management (WRM) is the process of planning, developing, and managing water resources, in terms of both water quantity and quality, across all water uses. It includes the institutions, infrastructure, incentives, and information systems that support and guide water management (Fig. 1.8). Water resources management seeks to harness the benefits of water by ensuring there is sufficient water of adequate quality for drinking water and sanitation services, food production, energy generation, inland water transport, and water-based recreational, as well as sustaining healthy water-dependent ecosystems and protecting the aesthetic and spiritual values of lakes, rivers, and estuaries.

Fig. 1.8 Water Resources Management

Water security is achieved when water's productive potential is leveraged and its destructive potential is managed. Water security differs from concepts of food security or energy security because the challenge is not only one of securing adequate resource provision – but also of mitigating the hazards that water presents where it is not well managed. Water security reflects the actions that can or have been taken to ensure sustainable water resource use, to deliver reliable water services, and to manage and mitigate water-related risks.

The Water Security and Integrated Water Resources Management Global Solutions Group (GSG) supports the Bank's analytical, advisory, and operational engagements to help clients achieve their goals of water security. Achieving water security in the context of growing water scarcity, greater unpredictability, degrading water quality and aquatic ecosystems, and more frequent droughts and floods, will require a more integrated and longer-term approach to water management. Key areas of focus will be ensuring sustainability of water resources, building climate resilience, and strengthening integrated management to achieve the Global Practice's (GP) goals and the SDGs.

II. Literature

This study describes in general terms the principles to determine the water need of standard crops; how the water need of crops relates to the water needs of the crops actually grown on an irrigation scheme. Lastly it indicates how the irrigation water needs can be estimated for the various crops, taking into account the effective rainfall.

Study is intended for use by village level extension workers who will not be involved - on a project basis - with the determination of the irrigation water needs, but who need to understand the principles behind and the factors involved in their determination. This study uses only very elementary arithmetic, provides tables indicating approximate values or orders of magnitude only, but does not elaborate on their more accurate determination.

Following an introductory discussion of various aspects of irrigation in this paper, subsequent subjects discussed will be:

- Topographic surveying
- Crop water needs
- Irrigation scheduling
- Irrigation methods
- Irrigation system design
- Land grading and levelling
- Collection of rainfall data in desired location
- Selection of crop

At this stage, all the papers will be marked provisional because experience with the preparation of irrigation training material for use at the village level is limited.
After a trial period of a few years, when there has been time to evaluate the information and the use of methods outlined in the draft papers, a definitive version can then be issued.

1. Feilong Jie (2022) "Effects on Net Irrigation Water Requirement of Joint Distribution of Precipitation and Reference Evapotranspiration"

i. To establish the uncertain influence that the joint distribution of precipitation and reference evapotranspiration has on net irrigation water requirement, a Copula function–Monte Carlo method (CFMC) was proposed to calculate the probability of irrigation water requirement.
ii. Taking the Jingdian Irrigation District in Northwest China as an example, the distribution laws of precipitation and reference evapotranspiration were studied. Furthermore, five typical years under different crop planting structure conditions were selected, and the variation characteristics of net irrigation water requirement in each typical year under the conditions of climate uncertainty were analyzed.
iii. The results revealed the optimal distribution functions of precipitation and reference evapotranspiration to be gamma distribution and lognormal distribution. The probability density map of the joint distribution of precipitation and reference evapotranspiration has a "saddle" shape; that is, irrigation water requirement and reference evapotranspiration are usually inversely related. As the probability of the irrigation water requirement increases, the net irrigation water requirement in the irrigation area also increases.
iv. The CFMC method can determine the design value of the net irrigation water requirement under a specific probability for typical years under different crop planting structure conditions, which can provide a reference for agricultural water resource allocation in irrigation areas.

2. Wanqi Luo (2022) "Analysis of crop water requirements and irrigation demands for rice: Implications for increasing effective rainfall"

i. Determining the irrigation demands of rice in a humid region is essential for water conservation through improving rainfall utilization in southern China. In this paper, six representative rice areas in southern China were selected, and the daily reference evapotranspiration (ETo) of the representative stations during 1953–2017 was calculated using the Penman-Monteith method.
ii. The daily crop evapotranspiration (ETc) was computed using the single crop coefficient method, and the irrigation scheduling under flood irrigation (FI) was obtained by establishing a field water balance model. The characteristics and trends of the irrigation demand of early, middle and late rice, as well as the irrigation changes under a "double-to-single" cropping pattern, were also analyzed with advanced statistical tests.
iii. The results indicated that most of the abundant rainfall was concentrated in the growth period of early rice in southern China. Early rice required less water (135.0 mm) and even no irrigation in some wet years, while middle and late rice required more irrigation water (288.1 mm and 265.2 mm,

respectively). The key reasons for the differences in irrigation demand among the three rice types are the amount and distribution characteristics of rainfall during the rice growth period.

iv. In addition, the irrigation demands of rice showed a downward trend as a response to a decrease in ETc and the increase in rainfall in the past 60 years, where rainfall was the dominant factor. With this increasing trend of rainfall and its better and efficient utilization in the future, rice irrigation demands may be further reduced or completely stopped. Under the "double-to-single" cropping pattern, irrigation demand decreased by 16% on average, and the irrigation frequency, as well as the drainage volume burden, were simultaneously reduced.

3. Yaling Zhang (2022) "Encounter risk analysis of crop water requirements and effective precipitation based on the copula method in the Hilly Area of Southwest China"

i. The effective precipitation (Pe) and crop water requirements (ETc) can reflect the agricultural water supply and demand situations under natural precipitation conditions, and the encounter risk analysis of Pe and ETc is a prerequisite for regional water resources allocation and irrigation planning. Considering an entire growing season of rape-maize in the Hilly Area of Southwest China during 1961–2017, this study employed the popular copula functions to fit two-dimensional joint distribution of annual ETc and Pe, and analyzed the natural agriculture water shortages risk of different encounter situations. The results indicated ETc and Pe presented a negative relativity, and the Gaussian copula was found to be more suitable to estimate the joint distribution of ETc and Pe.

ii. The asynchronous encounter probability was higher two times than the synchronous encounter probability, and the pairs (rich Pe-poor ETc, poor Pe-rich ETc) had the greatest probability with value of 16.59%, indicating the natural water supply and demand usually was unmatched. The conditional probability of Pe without exceeding a certain value for different ETc states increased with increased Pe, and the conditional probability of ETc with exceeding a certain value for different Pe states decreased with increased ETc.

iii. The conditional probability of Pe without exceeding Pe 37.5%, Pe 62.5%, Pe average (ETc exceeding ETc 37.5%, ETc 62.5%, ETc average) for different ETc (Pe) states was 44.97–69.12% (the corresponding return period was 1.45–2.22 years), showing natural agriculture water shortages risk was high under general situations.

iv. However, the conditional probabilities of extremely high ETc (low Pe) with given low Pe (high ETc) were less than 3%, so extreme water shortages rarely occurred in the Sichuan Hilly Area. This study successfully applied the copula method to regional agricultural water shortages risk analysis and could provide a theoretical basis for regional water resources management and planning.

4. Madhusudhan M S (2021) "Crop Water and Net Irrigation Requirement of Major Crops Grown in Mandya City using Cropwat 8.0"

i. India being the second most populous country in the world, agriculture is their prime source of livelihood and the country is home to vast agro-ecological diversity. To meet the demands of growing population, agricultural sector is looking for the best management practices for the efficient use of water.

ii. In this direction, water requirement of crops and its net irrigation requirement plays a vital role. In the present study, an attempt is made to study 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 crop water requirements for each crop were determined using the data collected from V.C Farm, Mandya district for the period 2010-2020.

iii. The four crop growth stages (initial, development, mid and late) were considered for all crops and crop co-efficient (Kc) of various growth stages of the crops were obtained from Irrigation manual for each crop. Reference crop evapotranspiration (ETo) was determined by using FAO

Penman Monteith method and effective rainfall was calculated using USDA S.C method. The study shows that reference crop evapotranspiration, ETo varied from 2.95mm/day to 6.97mm/day.

iv. The crop evapotranspiration (ETc) and Net irrigation for Rice varied from .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. This study demonstrates that the CROPWAT model is helpful for computing the crop water requirement which needs for the appropriate administration of water assets.

5. Andualem Shigute Bokke (2020) "Impact of effective rainfall on net irrigation water requirement: The case of Ethiopia"

i. Irrigation is one means to increase food supply besides the rain fed agriculture. During designing irrigation schemes most of the time effective rainfall is needed to be estimated in order to know the amount of water that should be supplied from irrigation. The problem is which effective rainfall determination method to be used is not clear among the available four built in methods in CROPWAT 8.0.

ii. Therefore, in this study analysis was made for Ethiopia case by considering selected 11 (eleven) small scale schemes from different parts of the country designed by different consultant companies.

iii. The finding shows most of the schemes designed in Ethiopia use either USDA-SC method (gives minimum net irrigation water requirement) or dependable rain method (results maximum net irrigation water requirement) in determination of effective rainfall.

iv. Moreover, additional study needs to be conducted to test using soil–water balance method to identify which effective rainfall determination is the correct in planning and designing of irrigation schemes.

6. Marinus G. Bos (2020) "Determination of Water Requirements of Principal Crops Grown In Krishna District of Andhra Pradesh State, India"

i. Water is a precious national resource. The development of surface as well as ground water for increasing the agricultural production to meet the growing requirement of Indian population is a must. The object of work is aimed to supply the controlled water to vast cultivated area to improve the existing crop pattern and also ensure irrigation to the fields against vagaries of rainfall. Agriculture is the main stray for 70% of the households.

ii. Rice is a staple food of the people and Paddy is therefore the principal crop of the district followed by black gram, Sugarcane, maize, green gram, horse gram, red gram jowar etc., are important. The water requirement of crop varies widely from crop to crop and also during the entire crop period of individual crop.

iii. Thus estimation of crop water requirements considering the crop pattern has been an area which has attracted attraction of water resources planners and engineers. The main parameter which is required to be determined for estimating the crop water requirements is Crop Evapotranspiration (ETo) which when multiplied with the crop factor gives the value of water required for the crop.

iv. The actual evapotranspiration can be measured in the field with the help of lysimeter but it is not always possible. Therefore, some analytical methods are required for evaluating ETo values. In this paper Reference crop evapotranspiration (ETo) was determined using the FAO Penman Monteith method, and by Blaney criddle method. The values on the higher side are taken for scheduling of crops.

7. S. Kumar (2019) "NDVI-rainfall correlation and irrigation water requirement of different crops in the Sone river-command, Bihar"

i. The changing climatic conditions affect the vegetation posing a threat to ecology of the region in general and mankind at large. In this paper, an attempt has been made to understand the relationship between monthly precipitation and the NDVI (Normalised Difference Vegetation Index) data of the Sone river command. For irrigation scheduling and optimal management of water, estimation of irrigation water requirement of the crops is essentially required.

ii. Towards this direction, the study has been made to estimate the net irrigation requirement for rice, wheat and maize in the Sone command. The estimation of daily reference evapotranspiration (ET0) by FAO Penman-Monteith method was done for 4 years (2012-2015) using mean meteorological data of Bhojpur and Sasaram in the Sone command. The results show that a good correlation exists between rainfall and NDVI in the kharif season.

iii. The mean manual reference evapotranspiration (ET0) was found 3.44 mmday-1 at Bhojpur and 3.58 mmday-1 at Sasaram. The total crop evapotranspiration (ETc) was found to be maximum for rice crop in kharif season and lowest for maize crop in rabi season.

iv. Net irrigation water requirement was maximum for winter wheat of 133.66 mm at Sasaram and 112.4 mm at Bhojpur and lowest in summer rice of 35.6 and 61.8 mm at Bhojpur and Sasaram respectively. The high correlation of NDVI with rainfall in Sone command can be used as an alternative to understand the requirement of net irrigation requirement (NIR) during the kharif season.

8. Shikha Sachan (2016) "Probability analysis of rainfall and crop water requirement using CROPWAT model for crop planning in a canal command of upper Bhima Basin of Maharashtra"

i. Rainfall is the most important climatic parameters influencing agriculture in Pune district of Maharashtra. Rainfall of this region is highly variable with respect to space and time and about 80-90% of precipitation falls in monsoon period from June to October resulting in drought and flood situation in the upper Bhima basin of Maharashtra.

ii. Therefore, for efficient water resources management, optimal crop planning and also for better understanding of rainfall behavior (i.e., distribution and minimum expected amount during crop growing period) probability analysis of rainfall was conducted. Probability analysis (at 50% and 80%) of monthly rainfall data of 13 raingauge stations of the left bank canal of upper Bhima basin viz., Urali, Loni Karbol, Kasurdi, Tajuproject, Yewat, Dahitane, Bhigwan, Madanwadi, Pondewadi, Kedgaon, Patas, Pimplegaon and Daund for the period from 1975 to 2002 was conducted. Reference evapotranspiration (ETo) has been calculated using climatic parameters like sun shine hour, wind speed, maximum & minimum temperature and rainfall humidity for the period from years 1993-2005 by CROPWAT model.

iii. It was found that ETo is maximum (7.72 mm/day) during April and low in December (3.10 mm/day). Effective rainfall of existing rain gauge stations falling in different sub-basins, BM48, BM49, BM50, BM51 and BM68 have been estimated using the CROPWAT model. Finally net irrigation requirement of crops Kharif Cotton, Summer Cotton, Sugarcane and Rabi Sorghum have been find out for all the sub-basin. From this study it has been concluded that, the crop planning in the area, represented by Pimplegoan and Urali stations should be done keeping in mind maximum deficit of 187 mm and 113 mm of water respectively during July.

iv. Similarly in other stations maximum deficit of water was observed during September which indicate that while selection of crops for the areas represented by these stations the crops requiring less water during September should be selected.

2.2.9 S. Rehana (2013) "Regional impacts of climate change on irrigation water demands"

i. This paper presents an approach to model the expected impacts of climate change on irrigation water demand in a reservoir command area. A statistical downscaling model and an evapotranspiration model are used with a general circulation model (GCM) output to predict the anticipated change in the monthly irrigation water requirement of a crop.

ii. Specifically, we quantify the likely changes in irrigation water demands at a location in the command area, as a response to the projected changes in precipitation and evapotranspiration at that

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location. Statistical downscaling with a canonical correlation analysis is carried out to develop the future scenarios of meteorological variables (rainfall, relative humidity (RH), wind speed (U2), radiation, maximum (Tmax) and minimum (Tmin) temperatures) starting with simulations provided by a GCM for a specified emission scenario.

iii. The medium resolution Model for Interdisciplinary Research on Climate GCM is used with the A1B scenario, to assess the likely changes in irrigation demands for paddy, sugarcane, permanent garden and semidry crops over the command area of Bhadra reservoir, India.

iv. Results from the downscaling model suggest that the monthly rainfall is likely to increase in the reservoir command area. RH, Tmax and Tmin are also projected to increase with small changes in U2. Consequently, the reference evapotranspiration, modeled by the Penman–Monteith equation, is predicted to increase.

v. The irrigation requirements are assessed on monthly scale at nine selected locations encompassing the Bhadra reservoir command area. The irrigation requirements are projected to increase, in most cases, suggesting that the effect of projected increase in rainfall on the irrigation demands is offset by the effect due to projected increase/change in other meteorological variables (viz., Tmax and Tmin, solar radiation, RH and U2). The irrigation demand assessment study carried out at a river basin will be useful for future irrigation management systems.

10 Marinus G. Bos (2009) "Water Requirements for Irrigation and the Environment"

i. Irrigated agriculture produces about 40% of all food and fibre on about 16% of all cropped land. As such, irrigated agriculture is a productive user of resources; both in terms of yield per cropped area and in yield per volume of water consumed.

ii. Many irrigation projects, however, use (divert or withdraw) much more water than consumed by the crop. The non-consumed fraction of the water may cause a variety of undesirable effects ranging from water-logging and salinity within the irrigated area to downstream water pollution.

III PROBLEM STATEMENT

i. The problem statement on irrigation systems can vary depending on the context, but generally it refers to the need to efficiently and effectively distribute water to crops or other plants in order to promote growth and increase crop yields.

ii. Some of the main challenges that need to be addressed in irrigation systems include ensuring a consistent supply of water, delivering water to the right areas at the right time, and minimizing wastage and inefficiency in the distribution process.

iii. Additionally, many irrigation systems also need to take into account factors such as weather patterns, soil conditions, and the specific needs of different types of plants.

iv. Irrigation systems are essential to successful farming, but they are not without their problems. Irrigation systems provide the water needed to grow crops, but they can also cause environmental damage if not managed properly.

v. The problem statement on irrigation systems is twofold: first, how to ensure that water is used efficiently and responsibly; and second, how to ensure that irrigation systems are designed, installed, and managed in a way that minimizes environmental damage. The first part of the problem statement focuses on water efficiency.

IV OBJECTIVES

The concept of sustainable development, including water management, is also referred to in the most important legislative documents at the national level. The purpose of this study is to quantify the potential of harvesting water through assessment of the real possibilities of using rainwater for utility purposes with reference to an effective rainfall on net irrigation water requirement.

The main objectives of this study are as follows:

1. To select the location and collect the topographical data.

2. *To analyze the climate conditions, soil conditions & ground water conditions.*
3. *To study the present cropping pattern of crops.*
4. *Providing the suitable crops.*

V METHODOLOGY

The methodology contains with case study of Raebareli including data collection of site location, Analysis of data, Providing Optimal Solution, Future aspect, Result, Conclusion and Future.

VI ABOUT RAEBARELI DISTRICT & TOPOGRAPHY

Uttar Pradesh is the most populated (199.6 million; 17% of India) state and has distinguished itself as the ‘agricultural hub’ on account of its largest share of rice area (13%, IIIrd in India, 5.95 Mha) and production (13%, IIIrd in India, 14.0 MT). The state also faces tremendous stress on its water resources due to the huge agriculture industry (Mall et al. 2006). Uttar Pradesh is well known for its abundance of water resources, both surface water and ground water.

New agricultural technology has increased groundwater irrigation many fold, with advancement in well-established canal irrigation system. Raebareli lies in the southern part of Uttar Pradesh. The district is irregular in shape, but fairly compact. It forms a part of the Lucknow Division and lies between Latitude 25° 49' North and 26° 36' North and Longitude 100° 41' East and 81° 34' East.

Raebareli district is one of the 74 districts of Uttar Pradesh, that falls in Lucknow division. Southern boundary of the district is naturally demarcated by river Ganga while, Sai river bisects this district in two halves. Administratively the district is divided into 7 sub-division namely Sadar, Unchahar, Dalmau, Tiloi, Maharajganj, Lalganj and Salon and 21 Development Blocks viz Rahi, Harchandpur, Sataon, Amawan, Maharajganj, Bachharawan, Shivgarh, Dalmau, Jagatpur, Unchahar, Lalganj, Khiron, Tiloi, Salon, Deen shah gaura, Rohania, Singhpur, Bahadurpur, Deeh, Chhatoh and Saraini. There are1776 villages in the district.

The geographical area of Raebareli district is 4.56 lac ha with a population of 2872204 (2001 census). Though, the district has vast population of cattle, but the productivity in terms of milk is quite low. The net cultivated area of the district is 2.92 lac ha out of which 1.68 lac ha is irrigated. Waste lands occupy 12.57% of the total geographical area of the district. The cropping intensity is 151.6% and fertilizer consumption is 110.10 kg. per hectare (2001-02). Paddy, sorghum, urd, pigeon pea, ground nut and sesamum in Kharif and wheat, gram, toria and mustard in Rabi are the major crops. Sunflower, urd and moong are grown in Zaid on limited scale. There are vast potentialities of exploiting the resource base of district Raebareli.

Humble contribution is being made in a number of areas like organic farming /sustainable crop production, seed production, flower cultivation, spices cultivation, vegetable cultivation, fruit production, mushroom cultivation, kitchen gardening, etc. It has established good collaboration with line departments of the district viz. U.P. Bhumi Sudhar Nigam Limited (UPLDC), District Rural Development Authority (DRDA), State Department of agriculture etc.

VII DATA COLLECTION OF CLIMATES IN RAEBARELI DISTRICT

A. Climate and Average Weather Year-Round in Raebareli

In Raebareli, the wet season is oppressive and mostly cloudy, the dry season is mostly clear, and it is hot year-round. Over the course of the year, the temperature typically varies from 48°F to 105°F and is rarely below 43°F or above 111°F.Based on the beach/pool score, the best times of year to visit Raebareli for hot-weather activities are from mid-March to early May and for the entire month of October as shown in fig. 4.2.

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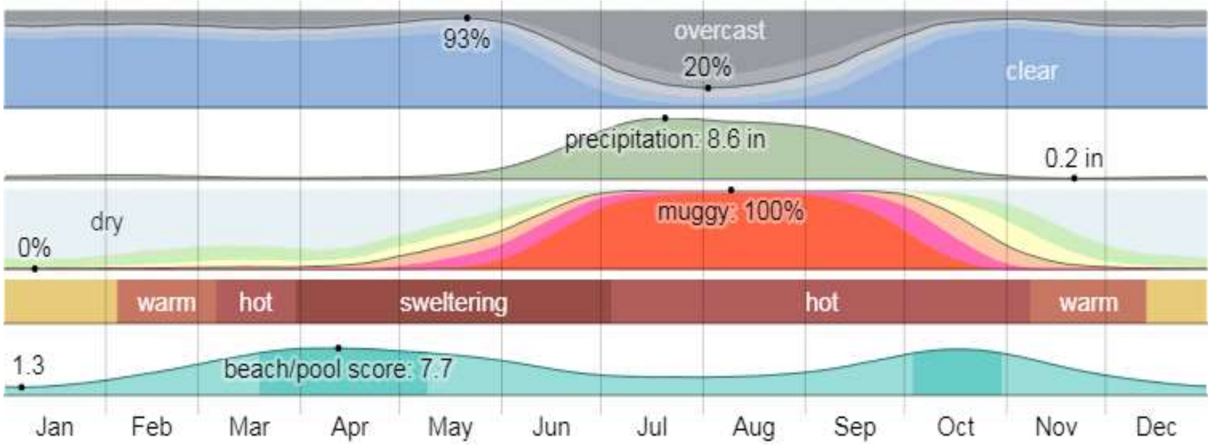

Fig. 4.2 Climate in Raebareli

B. Average Temperature in Raebareli

The hot season lasts for 2.6 months, from April 7 to June 25, with an average daily high temperature above 98°F. The hottest month of the year in Raebareli is May, with an average high of 104°F and low of 80°F (Fig. 4.3)

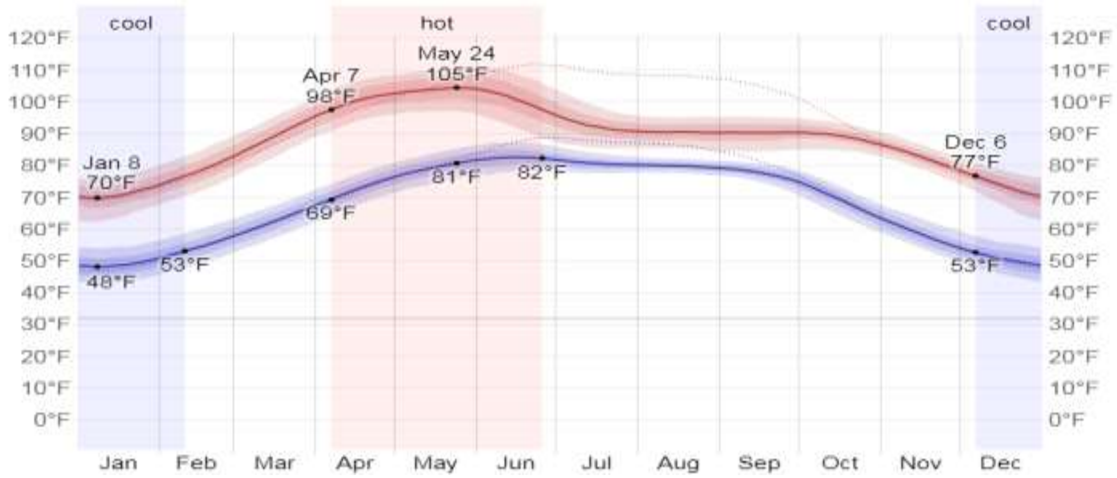

Fig. 4.3 Average High and Low Temperature in Raebareli

The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures. The cool season lasts for 2.1 months, from December 6 to February 10, with an average daily high temperature below 77°F. The coldest month of the year in Raebareli is January, with an average low of 49°F and high of 71°F.

C. Average Hourly Temperature in Raebareli

The figure 4.4 below shows you a compact characterization of the entire year of hourly average temperatures. The horizontal axis is the day of the year, the vertical axis is the hour of the day, and the color is the average temperature for that hour and day.

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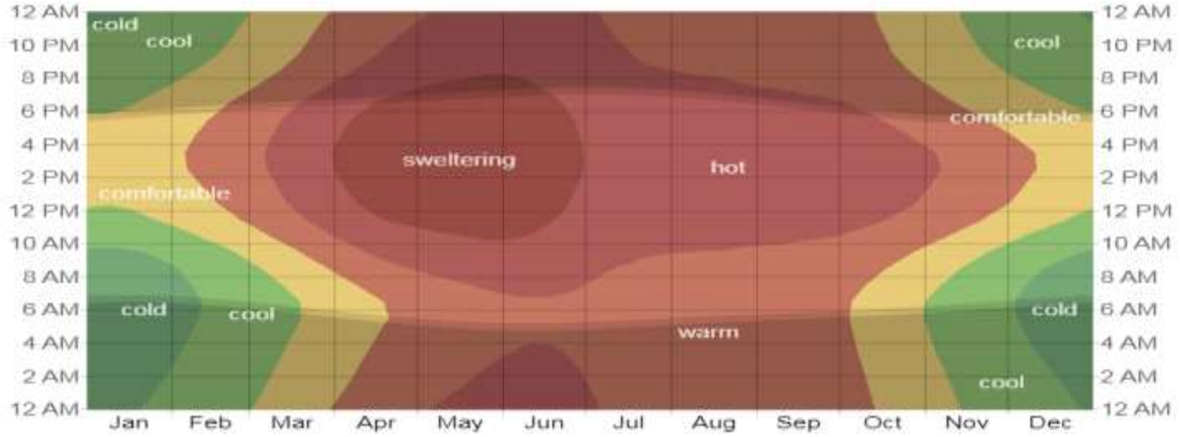

Fig. 4.4 Average Hourly Temperature in Raebareli

The average hourly temperature, color coded into bands. The shaded overlays indicate night and civil twilight.

D. Clouds

In Raebareli, the average percentage of the sky covered by clouds experiences extreme seasonal variation over the course of the year. The clearer part of the year in Raebareli begins around September 17 and lasts for 9.2 months, ending around June 24.

The clearest month of the year in Raebareli is May, during which on average the sky is clear, mostly clear, or partly cloudy 91% of the time. Raebareli has a warm subtropical climate with very cold and dry winters from December to mid-February and dry, hot summers from April to mid-June.

The cloudier part of the year begins around June 24 and lasts for 2.8 months, ending around September 17. The cloudiest month of the year in Raebareli is August, during which on average the sky is overcast or mostly cloudy 75% of the time as shown in fig. 4.5.

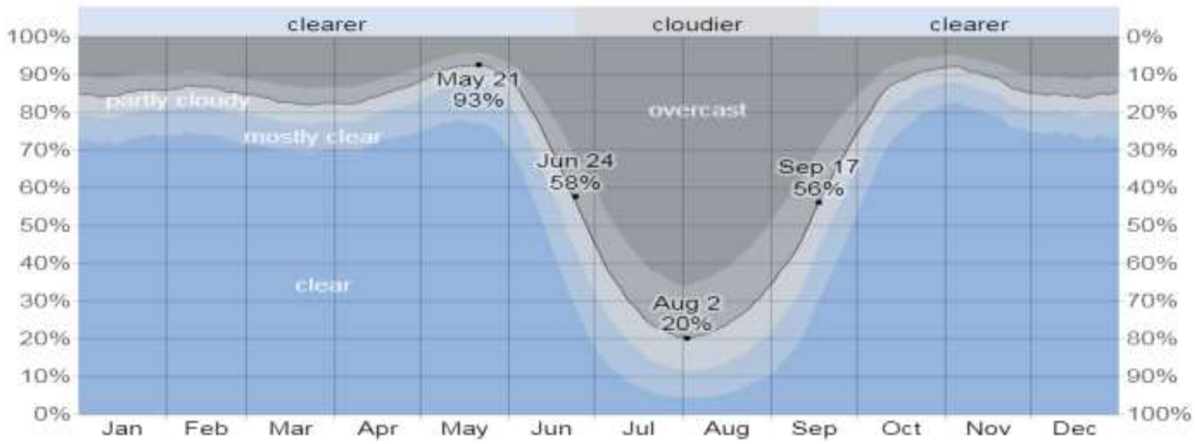

Fig. 4.5 Cloud Cover Categories in Raebareli

The percentage of time spent in each cloud cover band, categorized by the percentage of the sky covered by clouds.

E. Precipitation

A wet day is one with at least 0.04 inches of liquid or liquid-equivalent precipitation. The chance of wet days in Raebareli varies very significantly throughout the year as shown in fig. 4.6.

Fig. 4.6 Daily Chance of Precipitation in Raebareli

The wetter season lasts 3.2 months, from June 15 to September 23, with a greater than 32% chance of a given day being a wet day. The month with the most wet days in Raebareli is July, with an average of 18.3 days with at least 0.04 inches of precipitation. The drier season lasts 8.8 months, from September 23 to June 15. The month with the fewest wet days in Raebareli is November, with an average of 0.7 days with at least 0.04 inches of precipitation.

The percentage of days in which various types of precipitation are observed, excluding trace quantities: rain alone, snow alone, and mixed (both rain and snow fell in the same day).Among wet days, we distinguish between those that experience rain alone, snow alone, or a mixture of the two. The month with the most days of rain alone in Raebareli is July, with an average of 18.3 days. Based on this categorization, the most common form of precipitation throughout the year is rain alone, with a peak probability of 62% on July 19.

F. Rainfall

To show variation within the months and not just the monthly totals, we show the rainfall accumulated over a sliding 31-day period centered around each day of the year. Raebareli experiences extreme seasonal variation in monthly rainfall.

The rainy period of the year lasts for 9.5 months, from January 15 to October 31, with a sliding 31-day rainfall of at least 0.5 inches. The month with the most rain in Raebareli is July, with an average rainfall of 8.5 inches. The rainless period of the year lasts for 2.5 months, from October 31 to January 15. The month with the least rain in Raebareli is November, with an average rainfall of 0.2 inches as shown in fig. 4.7.

The average rainfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average snowfall.

G. Sun

The length of the day in Raebareli varies over the course of the year. In 2023, the shortest day is December 22, with 10 hours, 30 minutes of daylight; the longest day is June 21, with 13 hours, 47 minutes of daylight. The number of hours during which the Sun is visible (black line). From bottom (most yellow) to top (most gray), the color bands indicate: full daylight, twilight (civil, nautical, and astronomical), and full night as shown in fig. 4.8.

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Fig. 4.8 Hours of Daylight and Twilight in Raebareli

The earliest sunrise is at 5:12 AM on June 10, and the latest sunrise is 1 hour, 42 minutes later at 6:54 AM on January 13. The earliest sunset is at 5:12 PM on November 30, and the latest sunset is 1 hour, 49 minutes later at 7:01 PM on July 2.

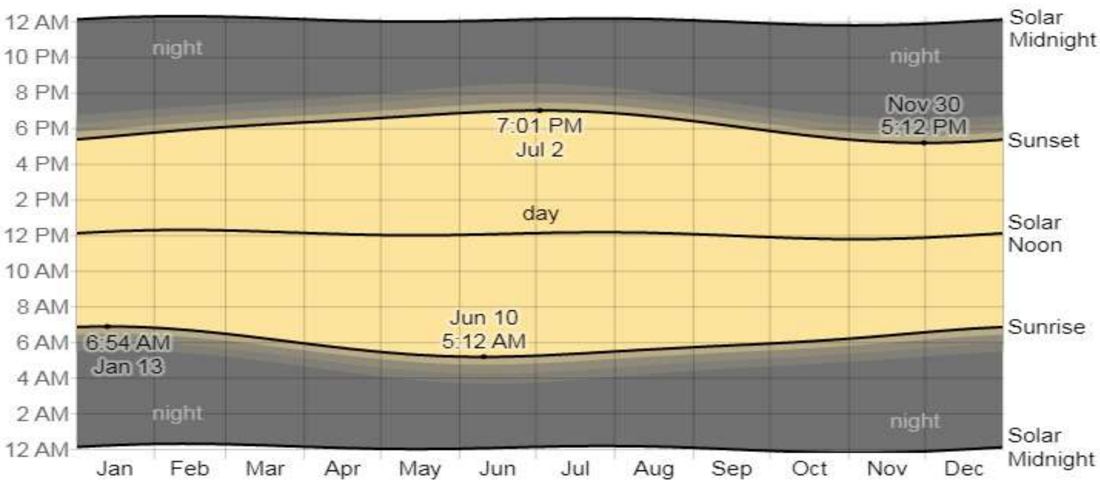

Fig. 4.9 Sunrise & Sunset with Twilight in Raebareli

The solar day over the course of the year 2023. From bottom to top, the black lines are the previous solar midnight, sunrise, solar noon, sunset, and the next solar midnight. The day, twilights (civil, nautical, and astronomical), and night are indicated by the color bands from yellow to gray as shown in fig. 4.9.

VIII DATA COLLECTION OF SOIL IN RAEBARELI DISTRICT

An investigation was carried out to study the micronutrient status in soils of Raebareli district in Uttar Pradesh and their relationship with different physicochemical properties of soils. The soil samples collected from different tehsils of Raebareli district in Uttar Pradesh, during April and May 2020-21. The available Zn, Fe, Cu and Mn were analyzed in the collected soil samples. The results indicated that all the tehsils showed the variation in pH being from 6.8 to 9.4, electrical conductivity ranged from 0.04 to 0.39 dSm-1, organic carbon ranged from 0.11 to 0.77 per cent and calcium carbonate ranged from 1.0 to 3.0 g kg-1. The mean values of available iron, manganese, zinc and copper content were 9.2, 15.35, 1.47 and 1.48 mg kg-1, respectively.

Table No. 4.1 Soil Micronutrient of Raebareli District

Properties	Dalmau Range	Mean	Raebareli Range	Mean	Mahrajganj Range	Mean	Unchahar Range	Mean
pH (1:20)	6.9-9.4	7.3	7.3-8.0	7.4	6.8-3.9	7.7	7.1-3.7	7.6
EC (dSm^{-1})	0.06-0.26	0.19	0.04-0.19	0.14	0.09-0.19	0.07	0.09-0.39	0.21
Organic Carbon (%)	0.13-0.40	0.20	0.19-0.77	0.31	0.11-0.77	0.24	0.25-0.56	0.44
CaCO3 ($g.kg^{-1}$)	1.0-2.5	1.6	1.0-3.0	1.7	1.0-2.6	1.6	1.0-2 .9	1.8
Coarse sand (%)	0.3-3.4	1.6	0.6-7.6	3.2	0.6-3.6	0.5	0.3-6.6	1.9
Fine sand (%)	2.0-6.9	56.4	60.9-81.5	70.9	12.3-54.4	36.5	14.2-72.3	39.3
Silt (%)	3.8-43.5	21. 1	8.0-16.6	11.1	4.0-53.6	29.0	6.7-52.6	23.4
Clay (%)	9.23- 43.3	18.I	7.1-12.8	14.6	10.5- 48.0	24.4	8.2-43.6	22.6
Iron(mg kg^{-1})	4.5-17.2	8.5	4.5-17.0	8.6	5.5-18.0	10.2	4.5-13.6	9.5
Mn(mg kg^{-1})	12.7-20. 1	6.5	10.6-23.0	17.4	12.6-22.6	16.2	10.5-24.5	19.3
Zn (mg kg^{-1})	0.5-5.0	1.6	0.3-2.7	1.2	0.6-4.7	1.9	0.5-4.3	1.2
Cu (mg kg^{-1})	0.3-7.1	1.3	0.2-5.3	1.2	0.4-7.2	1.6	0.3-5.6	1.8

Negative non-significant correlation with pH and available Fe and Mn, negative significant between pH and Zn, positive non-significant between pH and Cu was found. Nonsignificant positive with EC and Fe, Mn and Cu but non-significant negative between EC and Zn. Positive significant with organic carbon and Fe, Mn and Zn. Negative significant with CaCO3 and Mn and Zn, negative nonsignificant between CaCO3 and Fe while positive non-significant correlation between CaCO3 and Cu was recorded as shown in table no. 4.1. Different types of microbes play a significant role in the soil for managing both macronutrients and micronutrients for the plant. Soil microbes help to improve the soil quality and maintain the soil profile, texture, and structure.

4.4.1 Description of Agro-Climatic Zone & Major Agro Ecological Situations

Agro-climatic conditions mainly refer to soil types, rainfall, temperature and water availability which influence the type of vegetations. An agro-ecological zone is the land unit carved out of agro-climatic zone superimposed on landform which acts as modifier to climate and length of growing period. In order to maximize the production from the available resources and prevailing climatic conditions, need-based, location specific technology needs to be generated. Delineation of agro-climatic zones based on soil, water, rainfall, temperature etc. is the first essential step for sustainable production.

An "Agro-climatic zone" is a land unit in terms of major climates, suitable for a certain range of crops and cultivars. The planning aims at scientific management of regional resources to meet the food, fiber, fodder and fuel wood without adversely affecting the status of natural resources and environment. Crop yield is (FAO, 1983). Agro-climatic conditions mainly refer to soil types, rainfall, temperature and water availability which influence the type of vegetations. An agro-ecological zone is the land unit carved out of agro-climatic zone superimposed on landform which acts as modifier to climate and length of growing period.

The main objective was to integrate plans of the agro-climatic regions with the state and national plans to enable policy development based on techno-agro-climatic considerations. In the agro-climatic regional planning, further sub-regionalization was possible based on agro-ecological parameters as shown in table no. 4.2.

Several attempts have been made to delineate major agro-ecological regions in respect to soils, climate, physiographic and natural vegetation for macro-level planning on a more scientific basis. They are as follows.

Agro-climatic regions by the erstwhile Planning Commission
Agro-climatic zones under National Agricultural Research Project (NARP)
Agro-ecological regions by the National Bureau of Soil Survey & Land Use Planning (NBSS & LUP)

Table No. 4.2 Description of Agro-Climatic Zone & Major Agro Ecological Situations (based on soil and topography)

S.No.	Agro Ecological Situation	Characteristics
1	AES-I	Light brown sandy loam to sandy, generally structure less, poor in water holding capacity and organic matter, moderately alkaline, restricted drainage, surface soils poor in lime content but the middle layer is calcareous, medium in soluble salts. Carbonates & sulphates practically absent.
2	AES-II	Light grey brown at surface to pale brown at lower depth, poor to average water holding capacity neutral in reaction and poor in organic matter. Generally, non-calcareous with fair drainage, medium in soluble salt contents with predominance of bicarbonates and chlorides.
3	AES-III	Light grey to light brownish grey, sandy loam, average water holding capacity, neutral in reaction, slightly calcareous, low in organic matter content, impeded drainage and prone to salinity in the water-logged areas, average in soluble salts but injurious carbonates are absent.
4	AES-IV	Brown at surface and lighter brown, sandy loam, average water holding capacity, neutral non-calcareous, fair drainage, low in soluble salts mainly comprising of bicarbonates and chlorides of sodium.
5	AES-V	The colour varies from gray to greyish brown at the surface to slightly light at lower depths. Light texture at surface but becoming heavier below, average water holding capacity, neutral in reaction but lower layers moderately calcareous. High soluble salts that increase with depth.
6	AES-VI	Surface soil gray in colour which darkens below, becoming gray again in the third horizon. Texture is clay loam at surface and heavier below, average water holding capacity, neutral in reaction and medium water-soluble salts comprising mainly bicarbonates and chlorides of sodium.

4.4.2 Description of Soil in Raebareli District

Soil is the loose surface material that covers most land. It consists of inorganic particles and organic matter. Soil provides the structural support to plants used in agriculture and is also their source of water and nutrients. Major part of Raebareli soils is sodic and in these soils crop cultivation without any modification, becomes very difficult. Under these conditions rice-wheat cropping system immerged as predominant one. Rice is the most important crop of the district followed by moong and urd that are grown during Kharif season.

Dhaincha is a major green manuring crop. During winter wheat with its salt tolerant varieties is the most important Rabi crop. Other important crops of Rabi season are Bengal gram, pea, mustard etc. During Zaid fields usually remain vacant due to unavailability of irrigation water.

Geographical, climatic and edaphic characteristics of the district determine the type of the farming system to be followed. The district comprises a flat gently undulating tract and is characterised by six

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physiographic tracts namely Ganga khadars, Ganga Recent Alluviams, Ganga flats, Sai uplands Sai low lands and Sai flats.

These physiographic divisions have contributed to the development of six specific soils association in the district. Climate is semi-arid and is characterized by average rainfall of 923 mm with mean maximum and minimum temperature of 44.2 0C and 2.30C, respectively.

Loamy sand, sandy loam, clay loam and silt loam soils are found in the district. Loamy sand and sandy loam soils are generally light shallow, low water retentive and deficient in nutrients whereas silt loam and clay loam soils are deep, highly water retentive and medium to highly productive the clay bed is overlain by a white salt efflorescence which is due to capillary action within close distance to surface, unsuitable for cultivations.

There are four major farming systems in the district based on nature of soil and degree of assured irrigation. The major crops of this district are paddy, wheat, sorghum, pigeon pea, gram, pea and mustard. Soils in the district exhibits wide variance in composition and appearance as shown in table no. 4.3.

They can be classified into following categories.

Bhur or Silty Sand
Matial or Clay
Dumat or Loam
Usar / Alkaline Soils

Table No. 4.3 Soil Types

S.N.	Soil Type	Characteristics	Area (ha)
1	Ganga Khadar	Light brown sandy loam to sandy, generally structure less, poor in water holding capacity and organic matter, moderately alkaline, restricted drainage, surface soils poor in lime content but the middle layer is calcareous, medium in soluble salts. Carbonates & sulphates practically absent.	14935
2	Ganga Recent Alluvium	Light gray brown at surface to pale brown at lower depth, poor to average water holding capacity neutral in reaction and poor in organic matter. Generally, non-calcareous with fair drainage, medium in soluble salt contents with predominance of bicarbonates and chlorides.	14548
3	Ganga Flat	Light gray to light brownish gray, sandy loam, average water holding capacity, neutral in reaction, slightly calcareous, low in organic matter content, impeded drainage and prone to salinity in the water-logged areas, average in soluble salts but injurious carbonates are absent.	108593
4	Sai Upland	Brown at surface and lighter brown, sandy loam, average water holding capacity, neutral non-calcareous, fair drainage, low in soluble salts mainly comprising of bicarbonates and chlorides of sodium.	5986

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5	Sai Low Land	The colour varies from gray to greyish brown at the surface to slightly light at lower depths. Light texture at surface but becoming heavier below, average water holding capacity, neutral in reaction but lower layers moderately calcareous. High soluble salts that increase with depth.	126597
6	Sai Flat	Surface soil gray in colour which darkens below, becoming gray again in the third horizon. Texture is clay loam at surface and heavier below, average water holding capacity, neutral in reaction and medium water-soluble salts comprising mainly bicarbonates and chlorides of sodium.	193175

4.5 DATA COLLECTION OF GROUND WATER IN RAEBARELI DISTRICT

4.5.1 Hydrogeology:

Rae Bareli district is underlain by alluvial sediments of quaternary age. The upper layer of alluvium is composed of sandy loam, silty clays and clays in varying proportions. Minor sand beds are also seen. The thickness of this zone ranges from 5 to 16 m on an average. Kankar is interspersed in clay. Kankar beds at times forming thick layers are also presents at different depths. The kankar beds can be seen in the ravinous area of Ganga and Sai rivers. Older alluvium occupies a large part of the district in topographic high which do not get flooded, whereas the younger alluvium occupies the area along the river courses forming their food plain and terraces. The thickness of alluvium is more than 600 m in the northern part as per C.G.W.B. exploratory drilling data, whereas in southern part the thickness of alluvial sediment is about 487.00 mbgl, where bed rock (Bundelkhand Granite) was encountered at 487.80 mbgl at Sultanpur Janaul. Based on ground water exploration by C.G.W.B. in the area, a four-tier aquifer system has been established down to the depth of 600 m bgl.

4.5.2 First Aquifer Group:

This comprises clay sediments and sand beds in different proportions having kankar bed at different depth and occurs generally down to 100 m bgl sometimes occasionally down to 166.00 mbgl as found close to Unchahar village. The average depth to bottom of this group can be taken as 100 mbgl. Two or three fine grained sand beds are prevalent and variable in their regional extension. They have been harnessed in shallow tube wells. The discharge of the wells ranges from 500 to 1500 lpm.

4.5.3 Second Aquifer Group:

This group exists between the depth of 100-250 m bgl. The formation encountered is isolated sand beds, dominantly fine grained, clays and kankar. The formation water is brackish to saline and not suitable for domestic and agriculture purposes. At places thickness of this zone become too thin and aquifer containing brackish water is not discernable down to drilled depth.

4.5.4 Third Aquifer Group:

This group exists below 140 / 250 m bgl and extends down to 410 / 420 mbgl. The sediments are intercalated sequence of sand and clay beds. Sand is medium to coarse grained with occasional gravel beds. The sand beds are regionally extensive and forms the potential aquifer. Piezometric head varies between 8-15 mbgl and yield varies between 1500-3000 lpm. Quality is good and suitable for drinking / irrigation purposes.

4.5.5 Fourth Aquifer Group:

This group exists below 410 / 420 m and continues down to 550 / 600 mbgl. In this group intercalated sequence of arenaceous to argillaceous sediment exists all over the area. Kankar is practically absent. The quality of water is comparatively poor as compared to IIIrd aquifer.

4.5.6 Ground Water Condition:

Ground water occurs in pore spaces and interstices of unconsolidated alluvial sediments under phreatic to semi confined to confined condition in shallow aquifers. The near surface aquifer is under unconfined / water table condition. The shallow phreatic aquifer is harnessed by dug wells. The depth to water levels ranges from 3.15 to 23.00 mbgl in pre-monsoon period whereas it ranges from 1.50 to 21 m bgl in post monsoon period. The water level fluctuation varies from 1.50 m to 5.62 m.

4.5.7 Ground Water Quality:

Ground water quality is generally potable in phreatic aquifer except in certain areas where high fluoride content makes it unsuitable for drinking purposes. The total hardness as calcium carbonate is in range of 110 to 590 ppm. Fluoride is under permissible limit i.e. 0.15 to 1.30 except at few places while nitrate is high in some areas and is in range of 0.00 to 128.00. Phosphate is not present. The Arsenic content in the district has been found maximum to 30 micro g/ litre.

4.6 USE OF FERTILIZERS IN RAEBARELI

Earlier the farmer practice of producing food grains was based on his traditional knowledge. Farmers were convinced to select crop varieties on need based as time of sowing whether it is timely or late situation, soil condition whether it is normal soil or soil affected by salts. Balanced use of fertilizer with use organic manures and biofertilizer viz. Rhizobium culture in pulse crop and Azotobactor & PSB culture in cereal and oilseed crops, use of zypsum in oilseeds and pulse crops. Timely use of herbicides and plant protection chemicals so as to give crops favorable condition and finally to get higher yield. With all these farmers introduced cucurbits and Mentha crop in his crop rotation. Now he is growing crops scientifically keeping in mind all suitable agronomic practices and getting higher returns comparing to previous practices as shown in fig. 4.10.

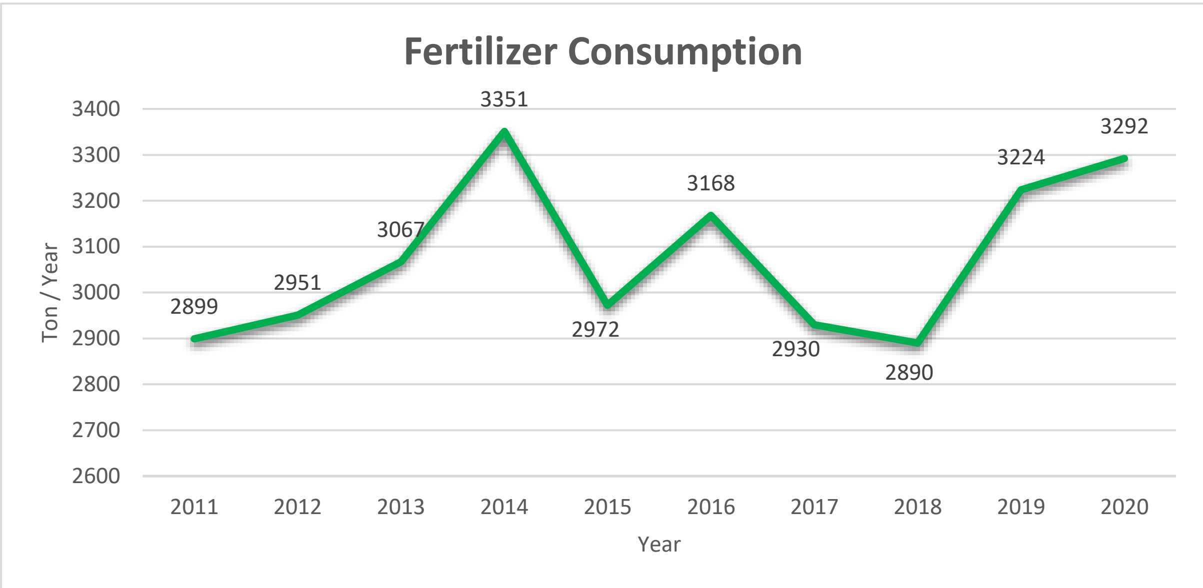

Fig. 4.10 Fertilizer Consumption in Raebareli district

Nitrogen data was reported at 3964 Ton in 2021. This records an increase from the previous number of 3292 Ton for 2020. Chemical Fertilizers: NPK Consumption: Uttar Pradesh: Nitrogen data is updated yearly, averaging 2,914.420 Ton from Mar 2001 to 2021, with 20 observations.

4.7 PRESENT CROPPING PATTERN

The soils in the region falling under Agro-climatic zone IV are alluvium-derived soils mostly khaddar (recent alluvium) and hangar (old alluvium). In some area the soil is highly calcareous. The soils are loamy and high in organic matter content. Rice, maize, pigeon pea, moong bean crops are common in kharif season. In post-rainy (rabi) season wheat, lentil, Bengal gram, pea, and sesame and at some places groundnut is grown on residual soil moisture with one or two supplemental irrigation. The important cash crops of the region are sugarcane, potato, tobacco, chillies, turmeric and coriander with supplemental irrigation. Rice–wheat cropping system is more predominant.

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The dominant soil landscapes, representing the northern plains, constitute gently to very gently sloping lands. In some area the soil is highly calcareous. The soils in general are neutral in reaction and have moderate clay and low organic carbon content. Traditionally rain fed and irrigated agriculture is common as shown in table no.4.4. The main crops grown are rice, maize, pigeon pea, sorghum, pearl millet, moong beans during kharif and wheat, Bengal gram, green peas, rapeseed and mustard and lentil during rabi season. Sugarcane is the main cash crop. Rice–wheat cropping system is more predominant.

Table No. 4.4 Area, Production and Productivity of Major Crops Cultivated in The District (2021-22)

Field Crops Including Oil Seeds and Pulses

S.No.	Crop	Area (ha)	Production (Qtl)	Productivity (Qtl /ha)
1	Wheat	183484	39447500	21.7
2	Rice	136362	27970901	20.41
3	Gram	6684	695910	10.39
4	Pea	4041	365720	9.15
5	Arhar	10320	1084801	10.4
6	Lentil	302	23110	7.61
7	Urd	19674	739110	4.71
8	Moong	1291	38000	4.51
9	Mustard	10146	928600	9.14
10	Til	1910	31100	1.62
11	Ground nut	2281	182000	8.01
12	Potato	5073	12264800	241.51

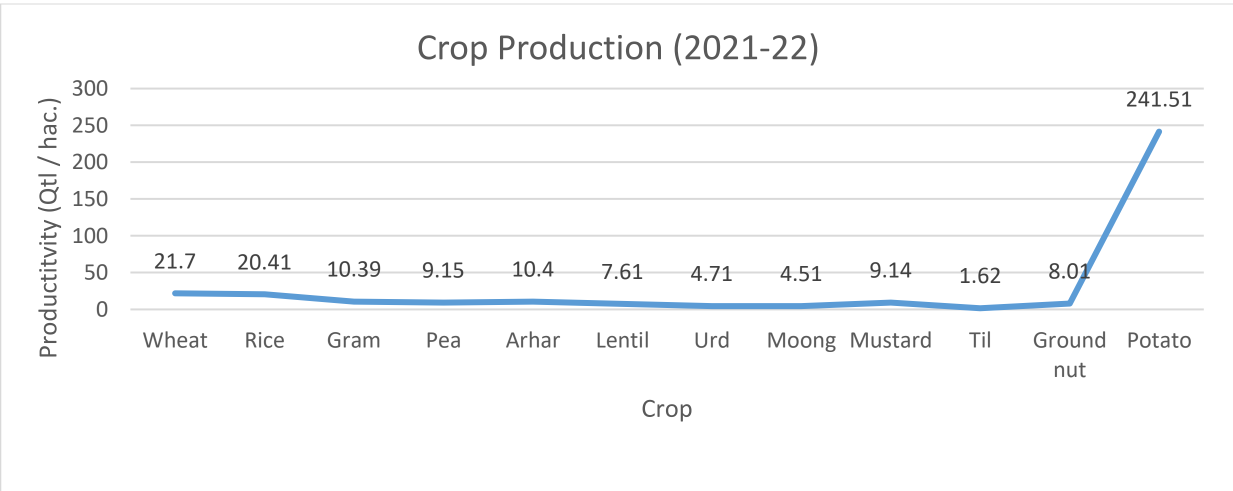

Fig. 4.11 Area, Production and Productivity of Major Crops Cultivated in The District (2022-23)

There are two main harvests, the kharif in autumn and the rabi in spring. As in other areas, the intermediate zaid harvest that takes place during the summer is far less significant. In general, kharif crops are sown over a wider area than rabi crops, but the latter are economically more valuable.

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During the 1970s, there was a significant increase in the area under rabi crops so that by 1981 it covered a larger area than kharif cropland.

4.7.1 Kharif Crops

Rice is by far the most important kharif crop. The district is well-suited to rice cultivation: the northern part of the district is situated in a belt of clayey soil ideal for growing rice, and in the south, the lake-studded area between Dalmau, Raebareli, and Salon is also a major rice-growing region. There are two types of rice known as early (dhan or kuari) and late (jarhan). Late rice produces a higher yield per acre, but is more cost-intensive to produce. It involves transplanting the rice plants once they reach a height of 5 or 6 inches into special enclosures called jhatas that are reclaimed from lakes or marshes, or alternatively into adjoining land well-suited for irrigation. Late rice is sown after the onset of the monsoon rains and harvested in November. Its land is usually not used to grow rabi crops. Early rice, meanwhile, is more dependent on rainfall. It is sown in July and then weeding begins two weeks later. It is harvested in mid-September, and then in October the fields are prepared for rabi crops such as peas, barley, or wheat.

The other main kharif crop is juwar, which is the largest of the millets. It does best in loamy soils and is most extensively grown in the area around Dalmau. Juwar can do fairly well on its own without much intervention, and many farmworkers will mostly leave it alone between sowing and harvesting and devote their attention to other crops instead. Kodon, a smaller millet, is also grown widely in the district. Like juwar, it can succeed with minimal intervention.

The two are often grown along with arhar, Urd, along with other pulses like moth and mung, is generally grown in outlying fields or mixed in with groves. Sown in August and harvested in November, these crops are generally not irrigated and depend on good rains late in the season. Bajra is generally not very widely grown in the district, but it makes for an important crop in certain localities, particularly along the Sai.

It is only grown in lighter soils, often mixed with arhar, and requires less rainfall than juwar — as long as the rain doesn't fail altogether, bajra typically provides a good harvest. Another fairly widespread crop is mandua, which is grown more in Raebareli district than in most parts of Awadh. Other crops grown during the kharif season include oilseeds, groundnuts, onions, garlic, potatoes, and miscellaneous fruits and vegetables. The potato in particular is the main vegetable crop in the district.

4.7.2 Rabi Crops

Among the rabi crops, the most important are wheat and barley. Wheat is economically more important than barley, although it is less extensively grown. It does best in light, loamy soil and is usually irrigated. Preparation of wheat fields begins before the monsoon rains come, when they are treated with manure, and then in late September they are cleared of weeds. The wheat is sown in early October, then given a first watering in early November once the plants reach 2 or 3 inches in height. The fields are again irrigated in December, and often also a third time in late January, and then the crop is harvested in late March and early April. As for barley, it is usually grown mixed with gram, although sometimes it's mixed with wheat instead, or grown alone. It is grown in all types of soil and usually is not irrigated, instead relying on good rains during the winter.

Gram is commonly grown either with barley or linseed. It does best in clayey soil and often is planted in fields that are also used to grow rice. It is planted in October and then nipped while young, before flowering, in order to improve growth. It ripens by March and the harvest is usually finished by the second week in April.

Among other rabi crops, peas are usually sown together with other crops such as barley or oilseeds. They are widely cultivated, and in drier seasons they provide an important source of income for farmers. Tobacco is not widely grown, although several villages have a reputation for producing it due to the brackish water in their wells. Kandrawan, Pirhi, and Oil are a few examples. As with the kharif season, the rabi also has cultivation of sunn hemp, oilseeds, groundnuts, onions, garlic, and potatoes, along with miscellaneous fruits and vegetables.

Although now banned, poppy was historically one of the most important crops grown in Raebareli district. Raebareli was one of the main poppy-producing districts in the region, and poppy was "the great rent-paying crop" in the district — on multiple occasions, income from poppy production was enough to pay the entire government revenue. Like wheat, poppy thrives best in lighter soils and was extensively irrigated; it was planted in late October and weeded soon after sprouting. The weeding, as well as irrigation, was repeated 3 or 4 times before the harvest in February and March. There was a dramatic increase in poppy cultivation in the late 19th century, peaking in 1884 and declining somewhat after that.

4.7.3 Zaid Crops

The zaid harvest is a comparatively minor one — in 1980–1981, zaid croplands covered an area of just 8,223 hectares, compared to almost 200,000 hectares for the kharif and rabi crops. The main zaid crop is sanwan (Panicum miliaceum), a small-grained millet that grows fast and prefers stiffer soils. Melons are not widely grown; most melon production is along the course of the Sai. Hot-weather rice is also grown along the edges of lakes, swamps, and drainage channels. It is typically grown by making an embankment in a jhil when there is still plenty of water, and then emptying it of water and using that area to sow the rice. Irrigation is then brought in from outside.

4.8 IRRIGATION SYSTEM IN RAEBARLI DISTRICT

Raebareli district has plenty of irrigation sources, both natural and artificial. Although typically shallow, the extensive lakes and jhils sprinkled across the district provide plenty of water to irrigate rice when the monsoon rains let up, and they also provide enough water for at least one or two waterings during the winter months. These natural sources are supplemented by a variety of artificial sources: wells, canals, tube wells, and lift irrigation. As of 2021, 92% of the total farmland in Raebareli district is irrigated. Of this, 56% is by canals, 43.6% is by tube wells, and 0.4% comes from other sources. As of 2011, 82.2% of the total farmland in Raebareli district is irrigated. Of this, 51.2% is by canals, 48.3% is by tube wells, and 0.5% comes from other sources. As of 1998, the district had a canal network of 2,775 km along with 56,019 pumping stations, 382 government-owned and 9,460 privately owned tube wells, and 2,436 masonry wells.

4.9 DECADAL CROP PRODUCTION IN RAEBARELI

During last three years (2012-13, 2013-14 and 2014-15) in Plant Protection Use of Bio-agents viz. Trichoderma virdae, buveria bassiana, Trichogramma card to control insect pests & diseases through biological means & to reduce use of chemicals. Seed treatment were popularized among the farmer to protect the crop from different diseases. Different herbicides for controlling weed in crops were popularize among the farmer to reduce loses during crop production.

Together with latest crop production technology viz. Integrated plant nutrient, Use of Biofertilizer, line sowing of wheat through seed drill, selection of crop varieties on the basis of areas salt affected, under timely sown condition, late or very late sown condition, direct sowing of paddy through drum seeder, Use of fertilizer on the basis of soil testing etc. were introduced between the farmers for better crop production as shown in table no. 4.5. The data is collected from **Krishi Vigyan Kendra, Raebareli.**

Crop	Decadal Production (Qtl/ha)										
	2011-12	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**Avg.**
Wheat	190	189	188	182	184	184	190	185	182	187	186.10
Rice	340	322	370	310	290	345	330	380	395	315	339.70
Gram	165	160	172	160	165	161	172	171	163	163	165.20
Pea	171	164	162	152	167	165	169	159	168	163	164.00

Arhar	154	142	150	152	153	153	148	147	147	140	148.60
Lentil	164	170	165	164	162	170	161	168	166	171	166.10
Urd	207	215	193	194	205	191	230	205	204	209	205.30
Moong	250	264	284	271	245	248	278	269	272	256	263.70
Mustard	146	132	136	133	155	125	146	130	140	118	136.10
Til	122	138	127	102	137	140	146	100	104	116	123.20
Ground nut	146	107	101	109	145	118	133	131	149	121	126.00
Potato	180	193	199	204	181	198	205	185	202	242	198.85

Table No. 4.5 Decadal Crop Production

Major part of Raebareli soils is sodic and in these soils crop cultivation without any modification, becomes very difficult. Under these conditions rice-wheat cropping system immerged as predominant one as shown in fig. no. 4.12.

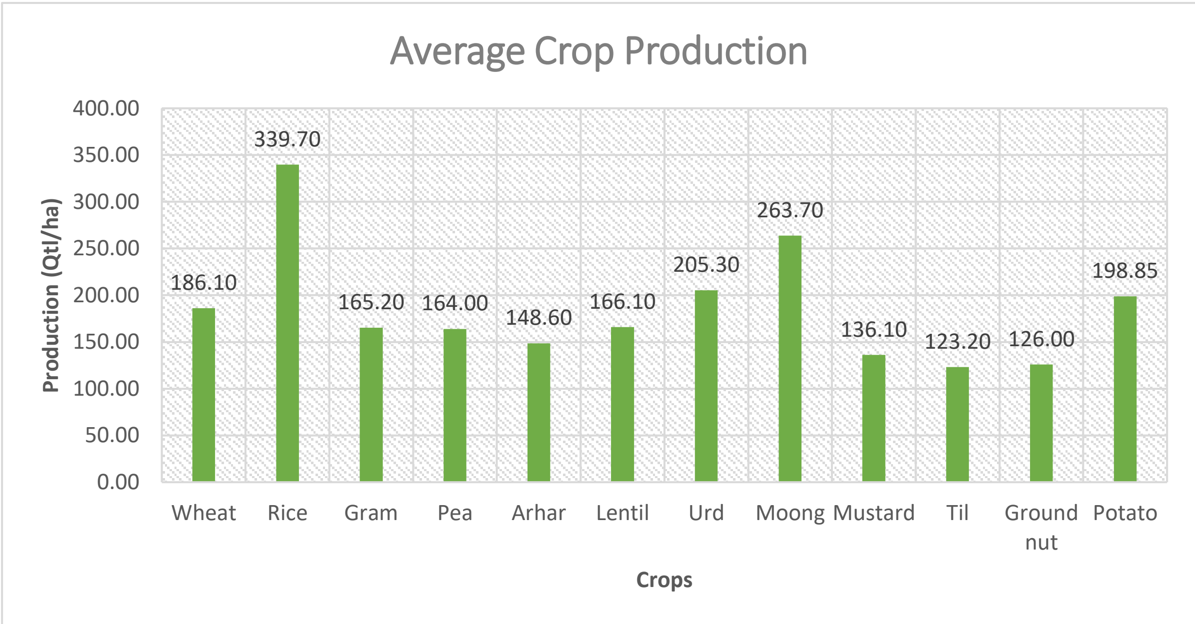

Fig. 4.12 Average Crop Production

As per the data shared by the Krishi Vigyan Kendra it is found that in last ten decades rice is the most important crop of the district followed by moong and urd that are grown. These crops can be altered year to year from other crops. Alteration of crops maintains and increases the soil fertility.

4.10 INTERNATIONAL YEAR OF MILLETS 2023

For centuries, millets were the staples in India but gradually were relegated to the background and got marginalized post green revolution [GR] as the emphasis shifted to increased food grain production & productivity using high yielding varieties of wheat & rice in the identified GR geographies.

Millets are small-grained, annual, warm-weather cereals belonging to the grass family. Jowar (Sorghum), Bajra (Pearl Millet) and Ragi (Finger millet) are the important millets cultivated in India. Small Millets such as Proso (Cheena), Kodo (Kodra, Arikelu), Fox tail (Kangni/Korra), Barnyard (Varai, Sawa), Little millet (Kutki) are also grown in our country as shown in table no. 4.6.

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Table No. 4.6 List of Positive Millets

Nutritional content in 100 grams of dry grains (Source: Dr. Khadar Valli, Mysore)												
Nutritional facts / Name of the Grain	Niacin mg (B3)	Riboflavin mg (B2)	Thiamine mg (B1)	Carotene ug	Iron mg	Calcium g	Phosphorous g	Protein g	Minerals g	Carbohydrate g	Fiber g	Carbohydrate / Fiber Ratio
Positive Grains												
Foxtail Millet	0.7	0.11	0.59	32	6.3	0.03	0.29	12.3	3.3	60.6	8	7.57
Barnyard Millet	1.5	0.08	0.31	0	2.9	0.02	0.28	6.2	4.4	65.5	10	6.55
Kodo Millet	2.0	0.09	0.33	0	2.9	0.04	0.24	6.2	2.6	65.6	9.0	7.28
Little Millet	1.5	0.07	0.30	0	2.8	0.02	0.28	7.7	1.5	65.5	9.8	6.68
Browntop Millet	18.5	0.027	3.2	0	0.65	0.01	0.47	11.5	4.21	69.37	12.5	5.54
Neutral Grains												
Pearl Millet	2.3	0.25	0.33	132	8.0	0.05	0.35	11.6	2.3	67.1	1.2	65.91
Finger Millet	1.1	0.19	0.42	42	5.4	0.33	0.27	7.1	2.7	72.7	3.6	20.19
Proso Millet	2.3	0.18	0.20	0	5.9	0.01	0.33	12.5	1.9	68.9	2.2	31.31
Great Millet	1.8	0.13	0.37	47	4.1	0.03	0.28	10.4	1.6	72.4	1.3	55.69
Desi Corn	1.4	0.10	0.42	90	2.1	0.01	0.33	11.1	-	66.2	2.7	24.51
Negative Grains												
Wheat	5.0	0.17	0.35	64	5.3	0.05	0.32	11.8	1.5	76.2	1.2	63.50
Paddy Rice	1.2	0.06	0.06	0	1.0	0.01	0.11	6.9	0.6	79.0	0.2	395.0

To create domestic and global demand and to provide nutritional food to the people, Government of India had proposed to the United Nations for declaring 2023 as International Year of Millets (IYoM-2023).

RESULT & DISCUSSION

This case study shows that millet is a good source of protein, fiber, key vitamins, and minerals. The potential health benefits of millet include protecting cardiovascular health, preventing the onset of diabetes, helping people achieve and maintain a healthy weight, and managing inflammation in the gut. Millet is an adaptable grain.

Millet is an ancient grain that people have enjoyed for thousands of years. Millet is also food for livestock and birds. It is becoming increasingly popular as it is fast-growing, drought-resistant, and requires low input.

5.1 CONCLUSION

This case study shows that millets conventional crops require more water (as shown in fig. 5.1), fertilizers and pesticide.

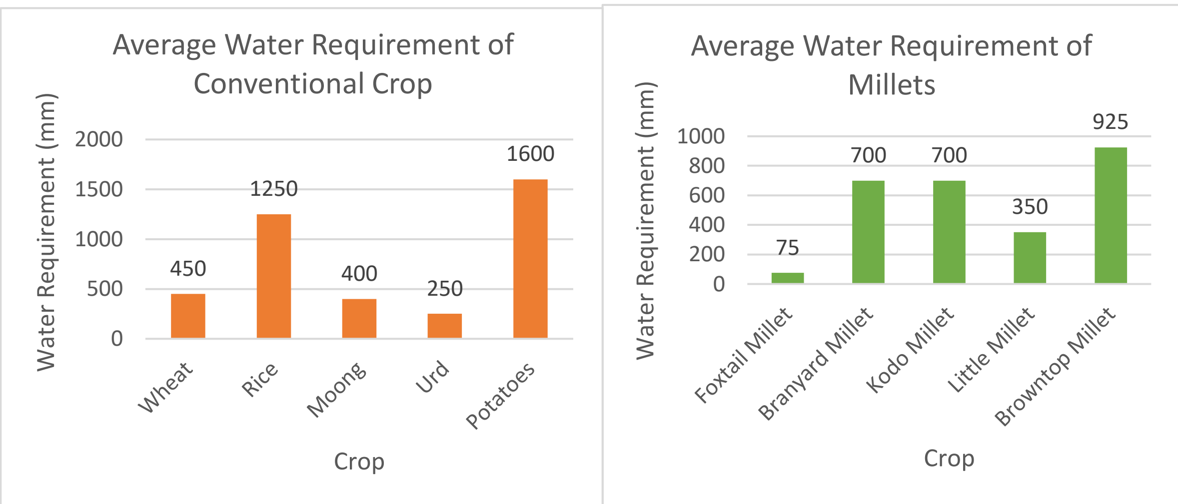

Fig. No. 5.1 Water Requirement Comparison

5.2 FUTURE SCOPE

This study can be done in other districts for crop study and their alternatives so that soil quality can be maintained easily without any fertilizers.

References

[1] Feilong Jie (2022) "Effects on Net Irrigation Water Requirement of Joint Distribution of Precipitation and Reference Evapotranspiration",Agriculture 2022, 12, 801. https:// doi.org/10.3390/agriculture12060801

[2] Wanqi Luo (2022) "Analysis of crop water requirements and irrigation demands for rice: Implications for increasing effective rainfall", agriculture water management, Volume 260, 107285

[3] Yaling Zhang (2022) "Encounter risk analysis of crop water requirements and effective precipitation based on the copula method in the Hilly Area of Southwest China", Agricultural Water Management, Volume 266, 31 May 2022, 107571

[4] Madhusudhan M S (2021) "Crop Water and Net Irrigation Requirement of Major Crops Grown in Mandya City using Cropwat 8.0", International Journal of Engineering Research & Technology, Vol. 10, ISSN: 2278-0181, pp.45-50

[5] Andualem Shigute Bokke (2020) "Impact of effective rainfall on net irrigation water requirement: The case of Ethiopia", water science, vol. 34, no. 1, pp. 155–163

[6] G. Sai Krishna (2020) "Determination of Water Requirements of Principal Crops Grown In Krishna District of Andhra Pradesh State, India", International Journal of Advances in Engineering and Management Volume 2, Issue 6, pp. 109-114.

[7] S. Kumar (2019) "NDVI-rainfall correlation and irrigation water requirement of different crops in the Sone river-command, Bihar", MAUSAM, 70, 2 (April 2019), pp. 339-346

[8] Shikha Sachan (2016) "Probability analysis of rainfall and crop water requirement using CROPWAT model for crop planning in a canal command of upper Bhīma Basin of Maharashtra", International Journal of Agriculture, Environment and Biotechnology, IJAEB: 9(1): pp. 123-135

[9] Salas, J. D., 1993, "Analysis and modeling of hydrologic time series", Handbook of Hydrology, 19, 1-72

[10] Khandelwal, S. S. and Dhiman, S. D., 2015, "Irrigation water requirements of different crops in Limbasi branch canal command area of Gujarat", J. Agrometeorol., 17, 1, pp. 114-117.