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WATER BALANCE – A HYDRO MATHEMATICAL APPROACH TOWARDS WATER MANAGEMENT AT VILLAGE LEVEL

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***Abstract* -** India is one of the few countries having erratic and unevenly distributed rainfall and hence many parts of the country face severe drought conditions which adversely affects the agricultural crop cultivation and ultimately results in the poor socio-economic condition of farmers. Water is a very basic and most valuable resource on this earth which provides life to all living beings and plants hence proper management of water should be our priority, especially in the water-scarce region. Micro watershed management plays a very crucial role in proper water management at the village level but it's not possible without having a proper knowledge regarding water availability, water requirement, and correct data regarding Runoff, Evapotranspiration, Infiltration, and other basic factors. In this paper, we have determined a hydro mathematical approach for water balance at the village level and we have applied this approach to water-scarce Nimkhedi kh. micro watershed region which is situated in the Jalgaon district in Maharashtra. This approach more focused on appropriate monthly calculation of water availability, demand, Runoff, Evapotranspiration, Infiltration, Vapour diffusion and other parameters which gives us detailed dataset for proper water management, after calculation of different factors involved in water balance we come to know that the Nimkhedi kh micro watershed region is a water-stressed region and available rainfall water and groundwater are not sufficient to fulfil the requirement of this region so changes in the cropping pattern and other development is necessary to make this region water sufficient.

Index Terms – Water balance, Runoff, Evapotranspiration, Infiltration, Water requirement

1. Introduction –

Water balance estimation is required for proper micro watershed management and planning related to the use of water but this water balance estimation is not an easy task because we have to consider a lot of factors in calculation. In water balance, runoff plays a very important role in water balance as the decision regarding the new structure for storage in the water-scarce region is mainly dependent on the runoff parameter. There are many empirical formulae to calculate runoff like strange table, Barlow method, SCS curve number method, and Irrigation department method these methods are simple for calculation and also, they are reliable but in village areas, there is a problem of unavailability of data so to overcome this challenge and to get reliable runoff calculation SCS curve method used for calculation which is most widely accepted method for calculation of runoff. Soil Conservation Service Curve Number (SCS-CN) method documented in Section 4 of the National Engineering Handbook (NEH-4) of the US Department of Agriculture in 1956. Evapotranspiration calculation is important to determine crop water requirement, as in village areas, 95% of water demand comes from agriculture, therefore, its calculation plays a crucial role in water balance. There are so many techniques available for calculation of reference evapotranspiration and potential evapotranspiration like Penman Monteith equation, Blaney-Criddle equation, Hargreaves equation, Jensen Haise equation which are widely accepted and reliable among these equations we have used Blaney-Criddle equation for ETo calculation because this method is suitable for missing meteorological data. This method is documented in chapter 3 (Crop Water need) of FAO 56.

Groundwater recharge is an important component of water budget which is very difficult to calculate directly due to uncertainties and complexities in the subsurface. Numerical modeling gives us information regarding indirect estimation of groundwater recharge but its application is limited due to data scarcity. Data scarcity is a major concern at village level for the calculation of hydrological parameters as so many uncertainties are there in meteorological data. There are some numerical formulas which can be used for the calculation of groundwater recharge but these are applicable to the specific region for which it is created Such methods usually estimate GR through a regression equation with precipitation and they offer a reasonable alternative for GR estimation especially in the United States and in India, such as Anderson's formula (1992), Sehgal Method (1973), Waltermayer approach (2001), and Eakin Method (1949) from above approaches Sehgal approach is suitable for India. Soil moisture calculation is also done separately in this study which has significant importance in an area having more agricultural land. After calculating all parameters related to water balance like water demand, availability, and components of water balance equation we can determine the status of a particular village related to water availability and also can give suggestions to reduce water scarcity in that village.

2. Objectives -

1. To determine the monthly total water demand and water availability in selected regions.
2. Planning for water security and balancing.
3. To give suggestions to the village to tackle the problem of water scarcity.

3. Study Area -

Nimkhedi kh, Dhormal, Satod micro watershed region is situated in Muktainagar Taluka, Jalgaon district, India with latitude 20.980 N and 76.0530 E. According to census data this region has a total population of 4833 in which male population is 2465 and the female population is 2368. Average annual rainfall of the region is 577.07mm with a total geographic area of 2146 hect. This region depends on two lakes and some farm ponds having a total combined capacity of 262000 cum and number of wells available in the region.

4. Methodology -

For Water Balance of Nimkhedi kh. micro watershed, we have to collect the data required for the water balance approach in selected regions. The required data for the village is obtained from the Government Authority. By consideration factors required to compute the water balance and formulas to calculate.

Government authority has provided us data regarding rainfall, Cropping pattern, average monthly temperature, and soil type. Selected regions received an average of 585 mm of rainfall yearly.

A simple equation for water balance is given by hydrologist is as follows,

$P = R + ET + F + SM$

Where,

P is precipitation

R is runoff

ET is evapotranspiration

SM is soil moisture

4.1 Runoff (R):

Runoff is a very important factor in water balance because it plays a crucial role in determining the potential of the water storage. In this study we have decided to use the Soil Conservation Service Curve Number (SCS-CN) method for runoff calculation. The formulas used to calculate are (Equation is valid for P>=i for =0.2)

$R=(P-0.2S)2P+0.8S$

Where $S=25400CN-254$

S= potential maximum retention or Infiltration

CN= curve number

Total runoff value for this region is 1662920 cum which is nearly 12% of total rainfall, from runoff generated only 565968 cum of runoff available for further storage.

4.2 Infiltration (F):

Infiltration is the downward movement of water into the land surface, which helps to enhance the groundwater recharge condition of the zone, more the infiltration rate of the soil more the groundwater recharge. As the soil in the zone is mostly clayey the rate of infiltration is found out to be lesser than the sandy soil. Here we done the calculation for the infiltration by Philip Method (Cumulative method)

$F(t)=St0.5+kt$

Where, S= Sorptivity (cm/hr)

K= the hydraulic conductivity (cm/hr)

T= time from the beginning of rainfall (hr)

Total infiltration is found out to be 8.19% of the total rainfall, which is less to increase the ground water recharge for the zone.

4.3 Crop water requirement:

Crop water requirement calculation can be done in two ways, first by considering delta for a particular crop and second by considering the evapotranspiration approach. In evapotranspiration approach we have to calculate reference evapotranspiration which depends on various environmental factors for calculation of evapotranspiration we have decided to use Blaney-Criddle formula which is easy and accurate as some other methods available but these methods are not suitable for rural areas having less environmental data available. Blaney- Criddle formula is given below,

$ETo = p(0.46Tmean +8.13)$

Where, T mean = mean daily temperature (c)

P = mean daily percentage of annual daytime hours

After calculation of reference evapotranspiration, we can determine potential evapotranspiration by simply multiplying it by crop factor which changes according to crop and its age, with the help of potential evapotranspiration we can determine monthly crop water demand. Average yearly crop water demand is 15250580 cum which is around 97.34% of total water requirement therefore calculation of crop water requirement is very important in water balance at village level.

4.4 Soil Moisture (SM):

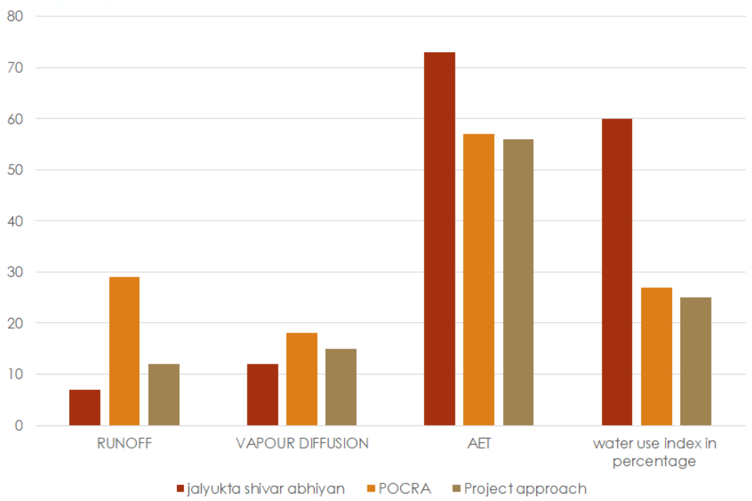
Soil Moisture is the volume of water held by soil in its active layer typically for 1-2 m. Soil moisture is important for crop growth as this will help in plant growth and reduces the external water requirement by irrigation. Soil moisture depends on the amount of precipitation (rainfall), water consumption by crops, air temperature, etc. Adequate moisture levels are of high importance to yield, soil moisture available after kharif will be used by rabi crops and therefore calculation of soil moisture is important in computation of accurate water balance. According to calculation 15% of total rainfall gets converted into soil moisture in this region.

4.5 Water Requirement:

Domestic water requirement in villages is calculated by considering water demand for humans, livestock and schools. As standard values are given as per the Central Public Health and Environmental Engineering Organisation. per day water requirement of humans and different livestock therefore by simple calculation, we can determine domestic water requirement and by adding above crop water requirement we get total water requirement for a particular region. Most of the water requirement in rural areas comes from agriculture hence water demand in April and May is very low because of less activities in agriculture. For calculation of water requirement, we have considered monthly variation in consumption of water which gives us more accurate data to analyse results and for further improvements.

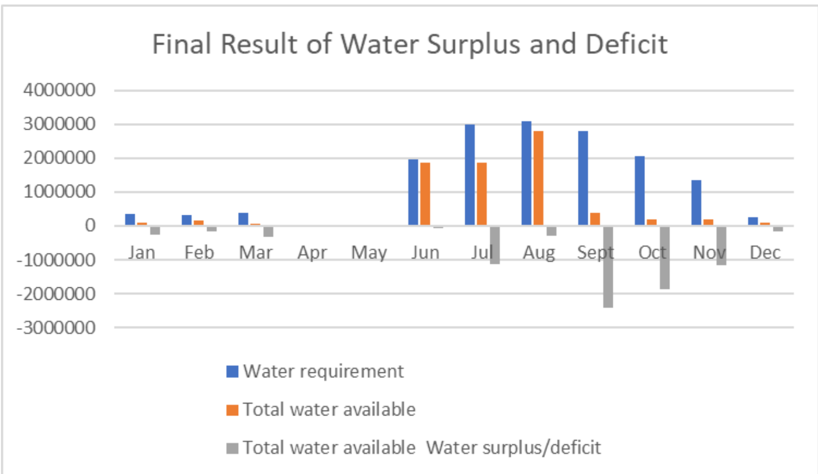
5. Results -

Jalyukta shivar abhiyan and POCRA approach are two important approaches in water balance calculation and they are widely used in Maharashtra for water budgeting. In graph no. 1 We have compared our study and important parameters of the hydrological cycle with the above approaches. Some changes in result arise due to utilization of different formulas and assumptions in the micro watershed region in different approaches. In this study our focus was on more accuracy, simplicity and reliability because less data is available in villages for computing different parameters in hydrology.



Graph no. 1 Water balance parameter comparison with other method

In Nimkhedi kh micro watershed region Rainfall is observed in June, July, August and September, October month and about 12661400 cum volume of water generated by rainfall. This region mostly depends on groundwater for irrigation and domestic water requirement, Total existing groundwater draft for all purposes is 801747 cum, and only 15 % of agricultural land is irrigated. According to the study and calculation we made, we found this region has water deficiency every month except April, as the water requirement for crops in April month is very less. In Nimkhedi kh micro watershed region Rainfall is observed in June, July, August and September, October month and about 12661400 cum volume of water generated by rainfall. This region mostly depends on groundwater for irrigation and domestic water requirement, Total existing groundwater draft for all purposes is 801747 cum, and only 15 % of agricultural land is irrigated. According to the study and calculation we made, we found this region has water deficiency every month except April, as the water requirement for crops in April month.



Graph no.2 Final result of water balance

In Nimkhedi kh micro watershed region is a water deficit region having a total yearly water deficit of 7836153 cum which is about 50% deficiency. Therefore, some steps are required to achieve water security in this region. Available runoff for storage is less because of intermittent rainfall and availability of black cotton soil which has more water holding capacity, therefore available runoff is insufficient to fulfil the water requirement, hence some changes in cropping pattern and structural changes are required to achieve water security in the micro watershed region is very less.

6. Conclusion:

In this current study we had an approach towards meeting the water requirement of Nimkhedi Kh micro watershed.This is a simple way of approach by using various methods and previously developed hydrological empirical formulae for calculating water balance parameters which will give amount of requirement and availability of water at small scale. The proposed calculation approach is for monthly water balance components which helps to plan uses of water correctly and this approach is most suitable at village level as the dataset required for this approach is less and it is also accurate and reliable.

In this region Rainfall is less which gives Runoff value after calculation is 12% of rainfall which is quite less to fulfil the storage requirement. Infiltration is about 8.19% of rainfall, the maximum water requirement is from agricultural areas. To meet this requirement, we have to take correct decisions and action in the form of structural changes in storage as well as cropping patterns. We found that there is good improvement in irrigation methodology as drip irrigation is used in 70 to 75% of agricultural areas which will save ample amounts of water. Nimkhedi kh micro watershed region is a water deficit region having a total yearly water deficit of 7836153 cum. We have 296646 m3 of groundwater available for future scope but it is also not sufficient to solve the problem of water scarcity of this region hence some structural changes and proper micro watershed planning required for this region to solve the problem of water scarcity.

As groundwater and available storage is not sufficient to tackle the problem of water scarcity we have to consider some other options. Purna River is near to this micro watershed region so there is scope of studying water availability in this river; We can take decisions about transfer of water in the lake, so that water availability can be increased. With this method we can easily calculate water balance parameters and find the solutions to tackle water scarcity problems. This method can be applied to any other micro watershed to find out different hydrological parameters.

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