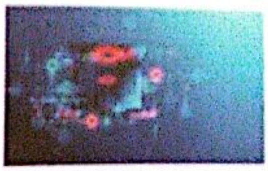
Peer reviewed Journal Impact Factor: 7.265 ISSN-2230-9578

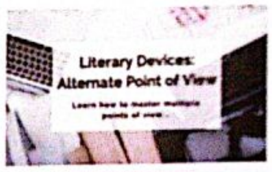
Journal of Research and Development



A Multidisciplinary International Level Referred Journal

June-2021 Volume-11 Issue-19

Changing Perspectives of Language, Literature, Science and Social Science



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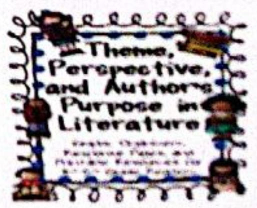

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'Journal of Research & Development' A Multidisciplinary International Level Referred and Peer Reviewed Journal, Impact Factor-7.265, ISSN: 2230-9578, 25June-2021, Volume-11, Issue-19, Changing Perspectives of Language, Literature, Science and Social Science

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Impact Factor-7.265, ISSN: 2230-9578, 25June-2021, Volume-11, Issue-19,
Changing Perspectives of Language, Literature, Science and Social Science

Water Budget of the Indapur Tahsil

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Abstract

Water budgets provide a foundation for evaluating its use in relationship to other important influencing conditions such as other ecological systems and features, as well as social and economic components – how much water is being used by agriculture, industry and residents etc. A water budget commonly provides the info of quantity and place of it. Water budget studies consider the volumes of water within the various reservoirs of the hydrologic cycle and the flow paths from recharge to discharge. The reservoirs of surface and underground water are about 1542.695 MCM; Out of this only 601.38 MCM water is required for use. Water budgets are developed by measuring or estimating the inputs and outputs of a hydrologic system. Inputs are the processes that add water to the system; these include precipitation and inflow from surface water and groundwater. Outputs are the processes that remove water from the system; these include evapotranspiration, the various uses of water by humans, and outflow from surface water and groundwater. General hydrological equation to compute water balance and runoff has been estimated. The average surface water village wise runoff of the study area is estimated. There is great deal of variations in terms of volume of runoff by different villages. The entire tahsil is drought prone and faces the problem of water scarcity throughout the year. Observing these outcomes in the present context, this paper calculates the water budget of the Indapur tahsil. The outcomes of these studies are briefly presented in this paper. It has been observed that the water resources are not uniformly available in the study area.

Key words: *Precipitation, evapotranspiration, runoff, surface water, groundwater* water balance, water budget.

Introduction

A water budget is a basic tool that can be used to evaluate the occurrence and movement of water through the natural environment. Water budgets provide a foundation for evaluating its use in relationship to other important influencing conditions such as other ecological systems and features, as well as social and economic components – how much water is being used by agriculture, industry and residents etc. The water budget process can encompass various levels of assessment which start simple and grow more complex if there are concerns about how much water is available at any level. Water budgets commonly provides the info of quantity and place of it. Water budget studies consider the volumes of water within the various reservoirs of the hydrologic cycle and the flow paths from recharge to discharge. Water budgets need to consider this information on a variety of spatial and temporal scales (Hazel Breton 2010). The maximum water holding capacity of soils, rainfall and potential evapotranspiration are the basic controlling elements of water balance. The distribution of these elements decides droughts or water surplus condition. Therefore rainfall, potential evapotranspiration, aridity, humidity and soil moisture are become primary controlling factors of agriculture (Saikia 1994). In the present study water balance technique is used to estimate the availability of rainwater resource in the study area. The nature and distribution of rainfall of the study area discussed earlier indicates that about 90 percent rainfall takes place during the short period of four months from June to September. There is a great variation in the number of rainy days.

Objectives

1. To identify inputs and outputs of a hydrologic system
2. To identify place and quantity of water.
3. To calculate the runoff of the study area.
4. To make favourable suggestions to low runoff and sufficient water available.

Study area

Indapur tahsil is one of the tahsils in the Pune district consisting of 142 villages along with one urban centre in the study area. There are eight revenue circles in the tahsil. The area extends from 17° 53′ 42" to 18° 19′ 58" North latitudes and 74° 39′ 16" to 75° 09′ 39" East longitudes **(Fig. 1)**. The area is drained by the river Bhima on north and east both sides. Nira River flows south of Indapur tahsil. Total geographical area of the tahsil is 1575.38km^2 (Census 2011), out of which Nira river catchment area compress about 586.8 km^2 and Bhima river catchment covers an area of 902.43km^2. Nira River joins the Bhima River at famous tourist place i.e. Narsinhapur village after travelling a course of 209 Kms from origin. The slope of region is towards east. There are three soil types, namely, coarse shallow, medium black and deep black soils occupying 30, 40 and 30 percent respectively.

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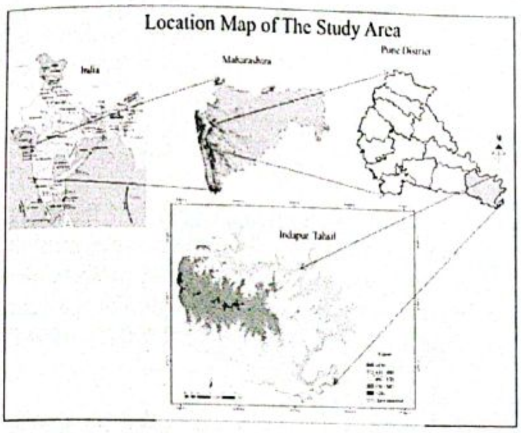
Fig. 1 Location map



Database and methodology

For the present research work secondary data source are used. This work is to develop digital database at large scale using spatial and attribute data. The spatial data comprise of all the thematic and topographic maps and the attribute or non-spatial data is created mainly water details utilities information etc. All the supported data is collected from survey of India, Maharashtra State Gazetteer Pune District, Maharashtra Governments department of irrigation, department of agriculture, department of water conservation. General hydrological equation to compute Water balance used is $P = Q+E+\Delta S$. The Dickens, Inglis and Nawab Ali Jung Bahadur formula was used to estimate the runoff. These data base converted to Microsoft access format to suit to the link up for processing through Arc View 9.3, Surfer version 10, Global Mapper version 11.

Present water Inputs and Outputs of the study area

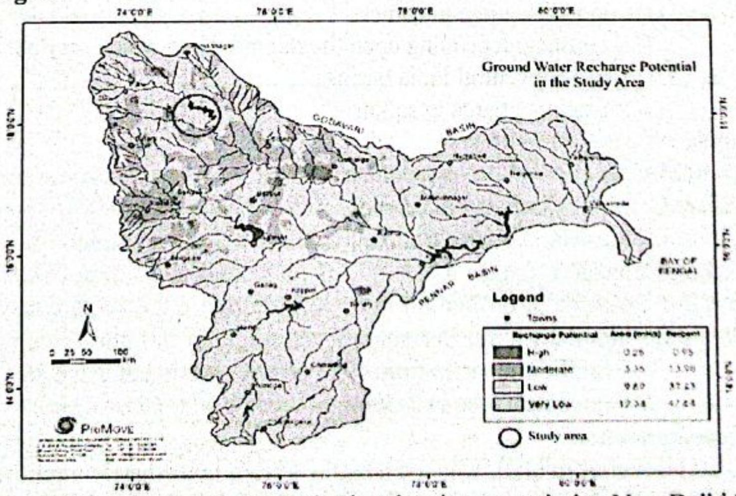
Water budgets are developed by measuring or estimating the inputs and outputs of a hydrologic system. Inputs are the processes that add water to the system; these include precipitation and inflow from surface water and groundwater. Outputs are the processes that remove water from the system; these include evapotranspiration, the various uses of water by humans, and outflow from surface water and groundwater. It is also observed that the critical examination of ground water recharge potential of the study area reveals that infiltration is negligible and hence not considered in the present computation of water budget. The components of a water budget are illustrated in **Table no. 1.** Many inputs and outputs can be measured directly or estimated using various techniques.

Table no. 1 The components of a water budget

Sr. No.	Inputs	Water in MCM	Outputs	Water in MCM
1	Rainfall	1052.468	Runoff	327.716
2	Canal and Reservoir	214.587	Actual evapotranspiration	771.212
3	Recharging of groundwater	275.64	Infiltration	*
	Total	1542.695		1098.918

Source: Tahsil office and agriculture office Indapur, Irrigation offices, Baramati and Daund, GSDA office, Pune, 2018.

* *Being too low ground water recharge potential Infiltration has not been considered in the present component.* Ref. **Fig. 2.**



Source: National rain fed area authority planning commission New Delhi 2011

Fig. 2.

Water budget estimation using hydrological equation

General hydrological equation to compute Water balance used is

$P = Q + E + \Delta S$

Where,

P is precipitation, Q is runoff,

E is evapotranspiration and ΔS is the change in storage in soil or the bedrock.

Inputs

1. Rainfall

One of the fact that need to be emphasized here, is that the mean annual rainfall of the eight stations in the study area is above 362 mm for all of the stations receive more or less same rainfall throughout the year. The lowest rainfall in the study area, during the last 15 years period of time, the minimum value was around 128.12 mm in the year 2003 and maximum value was 817.99 mm in the year 2009 with this rainfall the volume of rainfall that is received is 188.06 MCM and 1200.73 MCM, respectively.

2. Canal and reservoir

The Nira left canal and Mutha (Khadakwasala) canal runs through the study area, hence the higher level of contribution to the irrigation. On the basis of the hydraulic data total 93.963 MCM water available from these two canals this is ultimately recharge the groundwater by canal through seepage and increase the level of groundwater. Dam and reservoirs may largely regulate the hydrological regime of a catchment since they temporarily store surface water and hence, reduce storm water runoff downstream of structure. In terms of water budget, overall surface runoff may be significantly reduced due to evaporative losses from the reservoir and abstraction of stored water.Irrigation tank, percolation tank, K. T. Weir etc. near the Ujani dam are the water resources for the area.

3. Recharging of ground water

In the study area the total rechargeable fresh groundwater is computed as 275.64 MCM and the net ground water availability is to the tune of 261.86 MCM. The present gross groundwater draft for all purposes is 221.15MCM. The Stage of groundwater development for the study area, as whole, is 84.45%. This indicates that on an average 84.45% of yearly replenishable groundwater is being used in the study area. Considering the domestic and industrial requirement the allocation of groundwater for next 25 years comes out to be 18.79 MCM. Leaving this allocation, the groundwater available for irrigation in future is around 53.33 MCM. The canals and reservoirs are other main sources of groundwater recharge in the study area.

Outputs

1. Runoff

A. Runoff estimation and computation of its volume

There are several rainfall-runoff models available in the study of hydrological field. In this study, the following empirical formulae have been used and runoff has been estimated by the three methods. Design flood for Indapur tahsil has been worked out by empirical formulae are given below;

1. Dickens formula

   $Q = CA^{3/4}$

   Where Q = flood discharge in cumecs

   C = constant depending upon the rainfall depth which may be taken as 13.9 to 19.5 for central India basins

   A = catchment area in sq.km.

2. Inglis formula

   $Q = 124A / (A+10.4)^{0.5}$

   Where Q = flood discharge in cumecs

   A = catchment area in sq.km.

3. Nawab Ali Jung Bahadur formula

   $Q = C\,(0.386A)^{(0.925 - (1/14)\log 0.386A)}$

   Where Q = flood discharge in cumecs

   C = coefficient varies from 49 to 60 with maximum value 86

   A = catchment area in sq.km.

B. Distribution of surface runoff

Runoff is that portion of rainfall, which enters the stream immediately after the rainfall. It occurs when all losses are satisfied and if rain is still continued, with the rate greater than in-filtration rate, at this stage water starts flowing over the land as overland flow. For the design of any soil and water conservation

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structures and waterways or channels, runoff volume and peak rate of runoff are required to be estimated. Runoff rate is expressed in cubic meter per seconds and runoff volume or water yield from watershed is generally expressed as m^3 **Fig. 3a** The study area is characterised by undulating terrain land in western part and eastern part is a plain area.

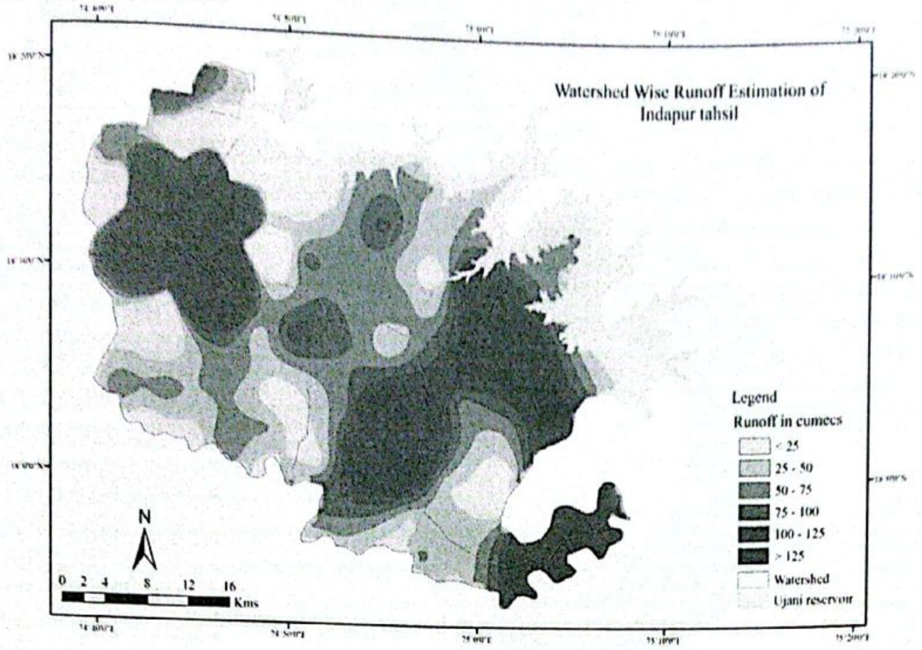

Fig. 3a

In the study area it is observed that the maximum 402.25 km^2 (25.57 %) area under more than 125 cumecs runoff and 235.51 km^2 (14.95%) area under less than 25 cumecs. More than 125 cumecs area found western high altitudinal area, eastern side strip between river Bhima and Nira and two patches are found at around Nimgaon Ketki and Indapur settlement. Low runoff (< 25) has found in the Northern area, besides this it found around in patches in the middle and Eastern part of the study area. Besides this 25-50, 50-75, 75-100 and 100-125 cumecs runoff found in patches all over in the study area **(Fig 3a & Fig 3b).**

Table 2 watershed wise runoff

Sr. No.	Runoff in cumecs	Area Km^2	Area %	Description
1	< 25	235.51	14.95	Very low
2	25-50	334.86	21.25	Low
3	50-75	357.76	22.71	Medium
4	75-100	149.32	9.48	High
5	100-125	95.08	6.04	Very high
6	> 125	402.25	25.57	
	Total	1575.38	100.00	

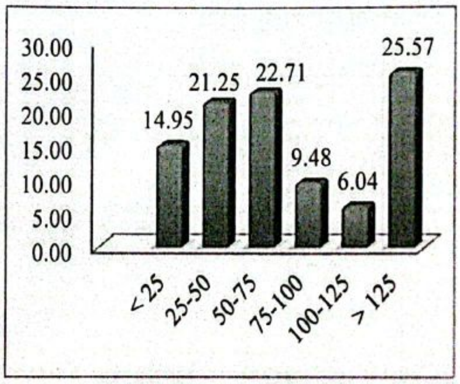

Fig 3b Average surface water runoff **(% area)**

The average surface water runoff of the catchment is estimated to 327.72 MCM/year **(Table 3 & Fig. 4)**. This is about 31.14% of the total volume of rainfall for the entire study area. There is great deal of variations in terms of volume of runoff by different watersheds. The maximum contribution of runoff in the watershed no. BM67 area that is amounting 46.08% and lowest contribution can obviously be expected from BM61 Bhigwan area which is only 0.37%. From the following **table no. 5.2** it becomes clear that, due to variation in rainfall and size of considerable amount of rainfall volume does not get converted in to runoff.

Table 3 and Fig. 4 Watershed wise area and runoff of Indapur tahsil

Sr. No.	Name of Watershed Area	Surface Area in Km^2	Surface Area in %	Runoff in MCM	Runoff in %
1	Bhigwan-BM61	24.53	1.56	1.20	0.37

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2	Loni-BM66	194.93	12.37	12.07	3.68
3	Palasdev-BM67	238.97	15.17	150.99	46.08
4	Akole-BM68	125.67	7.98	50.57	15.43
5	Sansar-BM76	337.88	21.45	49.33	15.05
6	Nimgaon-BM77	281.63	17.88	29.98	9.15
7	Indapur-BM78	371.77	23.59	33.57	10.24
	Total	1575.38	100.00	327.71	100.00

Source: Author.

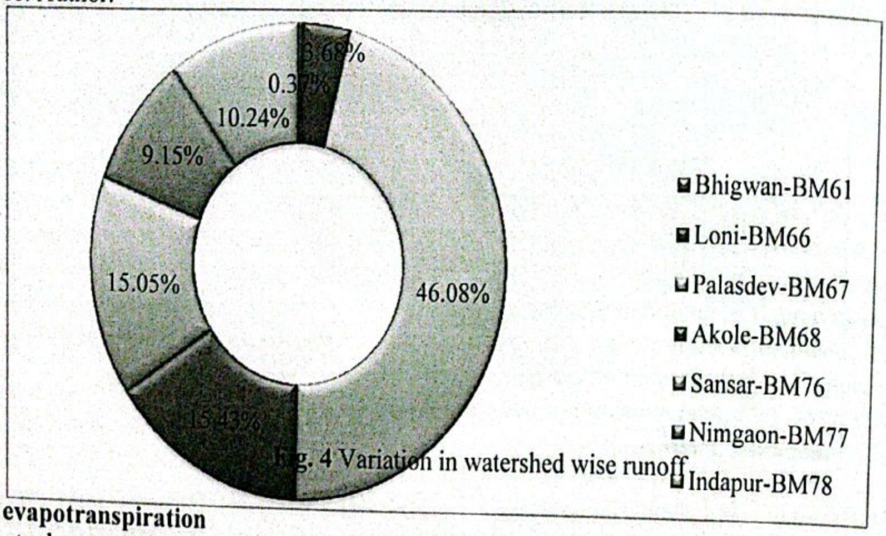
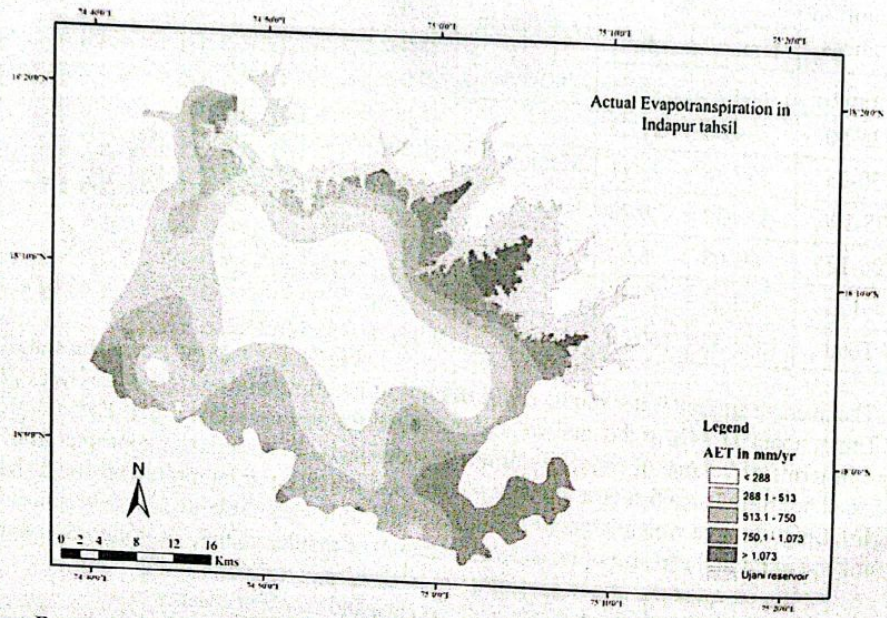


Fig. 4 Variation in watershed wise runoff

2. Actual evapotranspiration

Actual evaporation is a major component in the water balance of a catchment, reservoir or lake, irrigated area. Compared with precipitation and stream flow, the magnitude of actual evaporation over the long term is more difficult to estimate than either precipitation or stream flow. The actual evapotranspiration data obtained from 2006 year has been used for the present study. The spatial distribution pattern of actual evapotranspiration (AE) is shown in the **Fig. 5**. It has distinct to that of PE distribution. But in this case, highest values are observed in the eastern side area and decreasing from east to middle portion of the study area.



Source: Remote Sensing and Hydrological Modeling of the Upper Bhima Catchment (2006) **Fig. 5**

The highest value of 1500 mm is at the village Ganjewalan, Ajoti and Kandalgaon; where the area experiences very heavy rainfall comparatively rest of the study area and in the area of Ujani dam. An increasing trend towards east has been observed in actual evapotranspiration, this is seen in the case of

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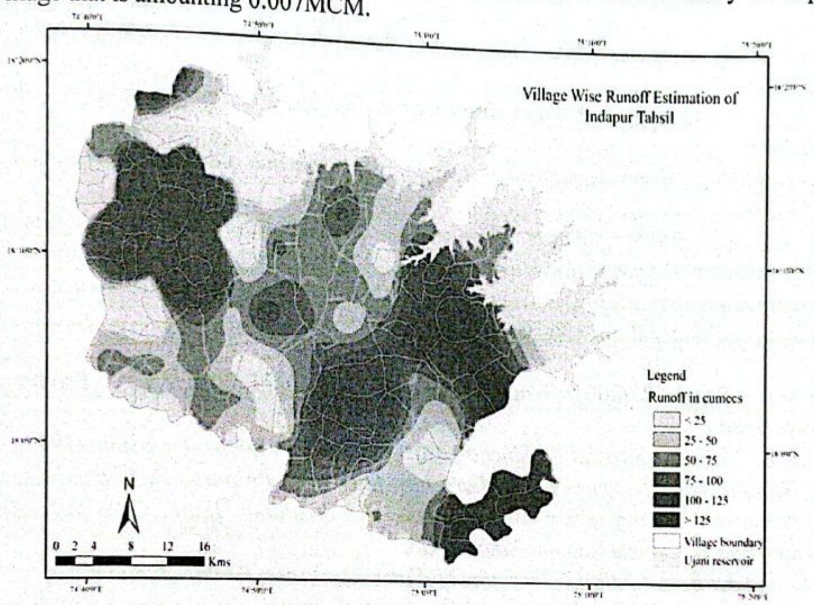
annual potential evapotranspiration. This is because of the dependence of actual evapotranspiration on rainfall. The lowest values of actual evapotranspiration are over the places Nirgude, Mhasobachiwadi, Lakdi, Vyahali, Kauthali, Karewadi, Nimgaon-ketki, Tarangwadi, Zagadewadi, Gokhali, Vadapuri and Galandwadi No.2, which is already discussed, is the lowest rainfall part of the study area. In this area actual evapotranspiration has been observed between 56 mm to 113mm.

3. Infiltration capacity of the soil

The study area is in the rain shadow and semi-arid climatic condition. In this climatic condition the direct infiltration is relatively ineffective because of the rarity of rainfalls, low mean average precipitation and high potential evaporation. Furthermore, the high potential evaporation compared to precipitation in semi-arid environment results the low deep infiltration of rainwater. The entire tahsil is the basement of Deccan trap basaltic lava. Typically these rocks form the 'Hard rock terrain' and their physical properties such as porosity and permeability play an important role in the movement and accumulation of groundwater.Therefore, in the study area, ground water of acceptable quality and quantity usually lies very low. There are more than 95% area of the study area shows very low ground water recharge, along the Ujani back water and near the confluence of river Bhima and Nira low recharge the ground water. There are only 74.67 km^2 (4.74%) area recommended for groundwater development in the study area. These are found in the patches in SW and NE part of the study area. Another 1500.71 km^2 (95.26%) area is notable for groundwater development.

Village wise computation of runoff volume

The average surface water village wise runoff of the study area is estimated to 327.72 MCM/year **(Fig. 6)**, this is about 31.14% of the total volume of rainfall for the entire study area. There is great deal of variations in terms of volume of runoff by different villages. The maximum contribution of runoff in the Akole area that is amounting 79.889 MCM and lowest contribution can obviously be expected from Lamjewadi village that is amounting 0.007MCM.



Source: Author **Fig.6**

Classification of villages based on hydrological equation

It can be deduced from the figure no. 5.5 that, hydrological equation implied for water budget assessment clearly demonstrates that, the entire tahsil is drought prone and faces the problem of water scarcity throughout the year. In order to make the differences again to find out the villages facing very high shortage of water. By adopting the grid operation, reclassification has been achieved and two classes have been determined. One class below '0' indicates more severity covered 566.92 km^2 (35.99%) area (50 villages) and 0-1 shows less severity 1008.46 km^2 (64.01%) area covered (93 villages).

Conclusions

It has been one of the challenging studies for quantifying the climate change impact wherein the water balance simulation modelling approach has been used to maintain the dynamics of hydrology and thereby make assessments of vulnerability which are more authentic and reliable. The average annual volume of rainfall is 1052.46 MCM. The very low rainfall volume is observed to the northern side sub basin of the

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tahsil (BM-61) accounts 16.43 MCM i.e. 1.56% and very high rainfall volume is observed to the eastern side sub basins of Indapur tahsil (BM-78) accounts 247.95 MCM which covers around 23.56% of the total study area. After the study of empirical formula, it is noticed that, around 49.08 % area (65 villages) facing very high water scarcity and rest of the villages (78 villages), 50.92% area comparatively show low degree of water scarcity. In an attempt to find out the present villages which are dependent on water supply through water tankers especially in summer months. This overall statistics generated from the raster analysis through the principles of map algebra, clearly indicates that entire tahsil is in water deficit zone, within which different levels of priority have been delineated. The average annual volume of rainfall is 1052.46 MCM. The very low rainfall volume is observed to the northern side sub basin of the tahsil (BM-61) accounts 16.43 MCM i.e. 1.56% and very high rainfall volume is observed to the eastern side sub basins of Indapur tahsil (BM-78) accounts 247.95 MCM which covers around 23.56% of the total study area. The 'High' ground water potential areas are those having ground water table less than 5 m bgl, admeasures about 394.79 km^2 (25.06%). The 'Medium' areas are those having water table in the range of 5 to 15 m bgl this groundwater potential zone covers 553.12 km^2 (35.11%) of the total study area and the 'Low' ground water potential areas are those having water table more than 15 m bgl and under these having maximum area i.e. 627.47 km^2 (39.83%) of the total study area. In the study area it is observed that, the maximum 402.25 km^2 (25.57 %) area under more than 125 cumecs runoff and 235.51 km^2 (14.95%) area under less than 25 cumecs. More than 125 cumecs area estimated for western high altitudinal area, eastern side strip between river Bhima and Nira and two patches are found at around Nimgaon Ketki and Indapur settlement. Low runoff (< 25) has estimated for Northern area, besides this it found around in patches in the middle and Eastern part. Besides this 25-50, 50-75, 75-100 and 100-125 cumecs runoff found in patches all over. The average surface water runoff of the catchment is estimated to 327.72 MCM/year.

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