International Journal For Technological Research In Engineering
Volume 7, Issue 12, August-2020 ISSN (Online): 2347 - 4718

INTEGRATED WATER BALANCE ANALYSIS FOR AN AREA BY UING GIS

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Abstract: The objective of this study is to measure the balance of water demand versus water resource availability in an interfluve ofMallavalli village, Bapulpad Mandal, Krishna District, Andhra Pradesh, India to support water resource planning, particularly of inter-basin transfers. Surface water availability was modelled using the Soil Conservation Service Curve Number (SCS-CN) model, whilst groundwater availability was modelled based on water level fluctuations and the rainfall infiltration method. Water use was modelled separately for the agricultural, industrial, and domestic sectors using a predominantly normative approach and water use to availability ratios calculated for different administrative areas within the interfluves. The process of making an overall water balance for a certain area thus implies that an evaluation is necessary of all inflow, outflow, water storage, components of the flow domain-as bounded by the land surface, by the impermeable base of the underlying groundwater reservoir, and imaginary vertical planes of the area's boundaries. In this water balance analysis we have taken the input data of study area and estimated the water consumption of population, cattle, crops and the output data as the rainfall taken and calculated the deficiency of study area and we have found the 16.89 hector meter of water scarcity and given the preventive measures and alternate solutions for the water storage by water harvesting and storage.

Key Words: water scarcity, surface runoff, ground water, SCS-CN method, GIS, water requirement, water budget

I. INTRODUCTION

In several regions of the world, there is a growing water crisis, precipitating social and political turmoil. One can understand the scarcity of water where nature has withheld its bounties, but there should be none as a result of mismanagement of the available. Humanity is confronting a self-generated environmental crisis. The patterns and ever-accelerating pace of economic development have been in conflict with the environment for quite some time now, stretching well beyond the 20th century. If this trend continues, the cumulative effects of population increase, resource depletion and degradation of the environment will take a heavy toll. Increased human activity and growing demand on the one hand, and limitations in supply on the other, have made it absolutely necessary to pay greater and closer attention to the management aspects of water resources. Water engineers and scientists are confronted with challenges of sustainable development and have the responsibility to meet these challenges, both at the macro-level of overall demand and supply and at the micro-level, by designing, operating and maintaining water resources and water projects in a manner consistent with the objective of local sustainability. The future availability of water for human use depends on how water resources are managed. Especially in water-shortage regions, pressures on management of water resources will become more important. According to an estimate by the World Resources Institute, 1–2.4 billion people (13–20% of the projected world population) will live in water-scarce countries by 2050.

Almost one third of the global population lives under water scarcity conditions (Alcamo et al. 2003, Arnell 2004). Global climate change and rapid population growth coupled with rapidly increasing water demand exacerbate this problem and if present trends continue, by 2025 water scarcity will affect more than half of the world's population (UNESCO 2007). To address water scarcity, metrics are required that demarcate the areas under water stress, and several methods have been developed for this purpose locally, nationally and globally (Kummu et al. 2010). Examples at global and national level include the Falkenmark index, a measure of per capita water resources (Falkenmark et al. 1989), the water vulnerability index, which measures total annual withdrawals as a percentage of available water resources (Raskin et al. 1997), an availability index based on a normalized ratio of water demand to availability (Meigh et al. 1999) and the WATER GAP model (Alcamo et al. 2003, Sullivan et al. 2003, UNWWDR 2003).

Such global assessments may not adequately portray local patterns of water scarcity, since they do not capture small-scale spatial heterogeneity or take advantage of locally available data. Whilst water scarcity is a global concern, it can be addressed through microscale planning (Falkenmark et al. 1989). Validation of water scarcity measures also becomes more feasible at more local levels. Despite this, particularly in lower-, middle- and low-income countries, water resource modelling is constrained by limited data availability, especially where catchments are ungauged or sparsely gauged (Xu and Singh 2004). Under these circumstances, parameterization and validation of models is challenging (Hrachowitz et al. 2013), making local-scale water resource assessment difficult (Xu and Singh 2004).

Global assessments suggest that many states within India are considered water stressed (Kumar et al. 2005). Dakshinamurthy (1973) estimated water resources in India in relation to agricultural utilization, whilst the National Institute of Hydrology of India quantified national Indian water resources in 1996 (Kumar et al. 1996). Climate–water resource interactions in India have also been investigated at national level for 2000 (Ramesh and Yadava 2005). Despite the extensive literature on water availability in India, water demand relative to availability remains under-studied. All these studies show there is considerable local variation in water resource availability and use.

STUDY OBJECTIVES

1. To Know Population Data and Calculation of Consumptive Use
2. Consumptive use of cattle data and agriculture data
3. Calculation of runoff by using soil conservation service curve number (SCS-CN) method.
4. To analyse water balance to an area by using GIS

II. STUDY AREA

Mallavalli village, Bapulpad Mandal, Krishna district, Andhra Pradesh, India. The village lies between north latitudes 16.6367549 and east latitudes 80.9636105.
The total number of population inMallavalli = 6507. Total area ofMallavalli =31.82 km2

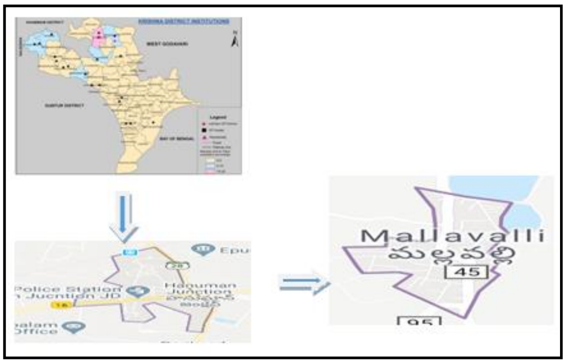

Fig.1.Study area

III. METHODOLOGY

Methodology is mainly consists of locating the drought (study) area and collecting the data of rainfall, population, crops and cattle data and there after calculating the consumption of water by population, cattle, and crops taken as input and estimated the water deficiency for the study area and giving the preventive measures and conclusion for the given study area.

Data Collection
2001 population data of Mallavalli village.
2011 population data of Mallavalli village.
Ground water data of piezometers of Bapulpad mandal.
Agriculture data of Mallavalli village.
Cattle data of Mallavalli village.

Population Estimation
Mallavalli Population
Area = 31.7 km2
2001 Census = 3969
2011 Census = 5082
For 2021 =?

1. Arithmetic Mean Method
P2021= P2011 + n (change in population)
Change in population = 5082 - 3969 = 1113
n = no. of decades = 1 (2021-2011)
P2021 = 5082 + 1 (1113)
P2021= 6195.

2. Geometric Mean Method
P2021 = P2011 (1+ i/100) N
i = % change in population

Table 1: Population data

Year	Population	Change in population	% change in population
2001	3969	1113	28.04 %
2011	5082	1113	21.90 %

P2021 = P2011 (1+i/100) N
= 5082 (1+28.04/100) 1
= 6506.99 = 6507
Consumption of water per human per day = 6507 × 135
= 8,78,445 lit/day.
Annual consumption = 6507 x 135x 365x 10-3
= 11842990.34 m3

Cattle Data Estimation:
Ministry of agricultural, Food and rural areas.
1. Cows = 87-102 lit/day.
Average typical water use = 115 lit/day.
2. Buffaloes = 43-07 lit/day.
Average = 55 lit/day.
3. Poultry
Winter = 230.1/1000 birds/day.
Summer = 450.1/1000 birds/day.
Average = 250.1/1000 birds/day
4. Sheep = 5528
= 9.0 – 10.5 lit/day.
Average = 10 lit/day.
5. Goats = average 9 lit/day.

Consumption
1. Cows – 134 =134 × 115= 1,410 lit/day.
2. Buffaloes = 1138 × 55 = 62,590 lit/day.
3. Poultry – 1733 = 433.52 lit/day.
4. Sheep – 5528 = 5528 × 10 = 55280 lit/day.
5. Goats -46 = 465 × 9 = 4185 lit/day.
Annual consumption = 137898.25 x 365 x10^{-3}
= **320632.425 m^3**

Consumptive Use of Crops
Calculation of water requirement for crops at kharif season (2014-2015):

1. Black gram:
Area =1861.72 acres
1 Acre =4047 m 2
Delta= 70cm=0.70m
Water requirement =1861.72 x4047x0.70
=5.27x106m3
=5.27x109lits
2. Cotton:
Area =1850/0.405

=4567.90 acres
1 ACRE = 4047 m2
DELTA =50cm=0.50m
Water requirement= 4567.90*4047*0.5
=9.24*106 m3
=92.4*109 lits

3. Sugar cane:
AREA = 89400/0.405
=220470.74 acres
1ACRE = 4047 m2
DELTA =120 cm =1.2m
Water requirement =220470.74*4047*1.2
=1.07*109 m3 = 10.7*1011lits

Table 2: MAJOR CROPS IN KHARIF SEASON: (2014-15)

S.no	Name of the crop	Total area irrigated in acres	Water requirements(lit)
1.	Maize	1861.72	5.27x109
2.	Cotton	4567.90	92.4*109
3.	Sugar cane	220470.74	10.7*1011

WATER BUDGET:
Water budgets provide a means for evaluating availability and sustainability of a water supply. A water budget simply states that the rate of change in water stored in an area, such as a watershed, is balanced by the rate at which water flows into and out of the area. Water budget can be defined as the relationship between the inflow and outflow of water through a specified region. It gives a comparison between the supply and demand of water, making it possible to identify periods of excess and deficit precipitation. Availability of water depends on various factors such as the water cycle itself, availability of surface water in lakes, rivers, aquifers, wetlands and other water bodies and the usage of water in a region.
Knowledge of the water budget of an area is important for the planning of trenchless projects that involve the distribution of waste within a community and for other services such as supply and demand.
METHODS OF WATER BUDGET
1. Water-budget method,
2. Energy-balance method, and
3. Mass-transfer method.

1Water-Budget Method
The water-budget method is the simplest of the three analytical methods and is also the least reliable. It involves writing the hydrological continuity equation for the lake and determining the evaporation from a knowledge or estimation of other variables. Thus considering the daily average values for a lake, the continuity equation is written as
P + Vi, + Vig = Vos + Vig + EL + DS + TL (3.11)
where P = daily precipitation,
Vis = daily surface inflow into the lake
Vig = daily groundwater inflow
Vos = daily surface outflow from the take
Vog = daily seepage outflow
EL = daily lake evaporation
DS = increase in lake storage in a day
TL = daily transpiration loss
All quantities are in units of volume (m3) or depth (mm) over a reference area. Equation (3.11) can be written as
EL = P + (Vis - Vos) + (Vig - Vog) - TL - DS
In this equation, the terms P, Vis , Vos and DS can be measured. However, it is not possible to measure Vig, Vog and TL and therefore these quantities can only be estimated. Transpiration losses can be considered to be insignificant in some reservoirs. If the unit of time is kept large, say weeks or months, better accuracy in the estimate of EL is possible. In view of the various uncertainties in the estimated values and the possibilities of errors in the measured variables, the water-budget method cannot be expected to give very accurate results. However, controlled studies such as over Lake Hefner in USA have given fairly accurate results by this method.

Energy-Budget Method
The energy-budget method is an application of the law of conservation of energy. The energy available for evaporation is determined by considering the incoming energy, outgoing energy and energy stored in the water body over a known time interval.
Considering the water body as in Figure 3.4, the energy balance to the evaporating surface in a period of one day is give by
Hn = Ha + He + Hg + Hs + Hi
where
Hn = net heat energy received by the water surface = Hc (1 - r) - Hb in which Hc (1 - r) = incoming solar radiation into a surface of reflection coefficient (albedo) r
Hb = back radiation (long wave) from water body
Ha = sensible heat transfer from water surface to air
He = heat energy used up in evaporation
= r L EL where r = density of water, L = latent heat of evaporation and EL = evaporation in mm
Hg = heat flux into the ground
Hs = heat stored in water body
Hi = net heat conducted out of the system by water flow (adverted energy)

All the energy terms are in calories per square mm per day. If the time periods are short, the terms Hs, and Hi can be neglected as negligibly small. All the terms except Ha can either be measured or evaluated indirectly. The sensible heat term Ha which cannot be readily measured is estimated using Bowen's ratio b given by the expression.

Mass Transfer Method:
The mass-transfer method used to compute evaporation in this study was outlined by Harbeck (1962)where
Emt = E~vaporCltioncomputed by the mass-transfer method, in inches per day;
N = mass-transfer coefficient; and
U2 = mean w'lndspeed at 2 meters above the water surface, in miles per hour.

The mass-transfer coefficient (N) is a function of several factors such as wind dirl~ction, length of fetch, stability of air, wind and vapor pressure profiles, and physiographic setting of the lake. The best method to determine N is to calibrate N against an independent measure of evaporation because these factors can vary from lake to lake. The independent measure of evaporation can be a technique such as eddy correlation, a water budget, or an energy budget (Brutsaert, 1982). An alternative method for determining N is given by Harbeck (1962) as follows: N 0.00338 = AO.OS' where A = surface area, in acres. N is assumed to be a constant.

SCS-CN Method
For year 2019
Q = (P-0.3S)2/P+0.7S for p >0.2s
AMC 2: average conditions
Soils group B: moderately low runoff potential – sandy loam, red loamy soil, and red sandy loam
Cultivated – contoured: B
Poor -79
S = 25400/CN – 254
CN = 79
S = 25400/79 – 254
S = 67.51 mm
Rainfall, p = 450.8 mm (2019)
Q = [450.8 – 0.3 x 67, 51]2 / 450.8 + 0.7 x 67.51 for p >0.2s
Q = [430.54]2/ 498.057
2019, Q = 372.187 mm.
For 1999, Q = 877.55 mm.
2000, Q = 1037,33 mm.
2001, Q = 881.93 mm.
2002, Q = 541.04 mm.
2003, Q =970.97 mm.
2004, Q = 724.572 mm.
2005, Q = 997.376 mm.
2006, Q = 1020.19 mm.
2007, Q = 751.408 mm.
2008, Q = 1127.45 mm.
2009, Q = 707.91 mm.
2010, Q = 1552.94 mm.
2011, Q = 806.91 mm.
2012, Q = 1505.61 mm.
2013, Q = 1208.33 mm.
2014, Q = 399. 70 mm.
2015, Q = 399.70 mm.
2016, Q = 399.70 mm.
2017, Q = 575.90 mm.
2018, Q = 674.80 mm.

Total geographical area = 31.82833 km2
Total runoff volume over the
catchment Vr = 31.82 x 106 x 372.187/(1000)
= 11.84 X 10^6 Mm.

2.6 Rainfall Data Shows in Graphs

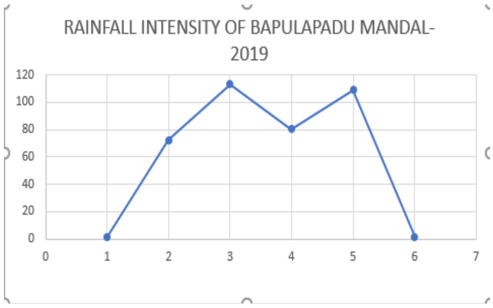

Fig 2: Rainfall intensity of Bapulpad mandal 2019

Table 3: Ground water details of 2013

S.NO.	MONTHS	VILL-1	VILL-2	VILL-3
1.	MARCH	1.17	7.07	-
2.	APRIL	1.45	9.75	9.54
3.	MAY	1.50	11.65	11.39
4.	JUNE	1.41	11.28	10.81
5.	JULY	1.33	7.00	7.24
6.	AUGUST	1.15	6.17	5.78
7.	SEPTEMBER	1.03	5.50	5.80
8.	OCTOBER	0.25	1.65	1.74
9.	NOVEMBER	0.78	1.89	1.29
10.	DECEMBER	0.94	2.26	2.50

VILLAGE – 1:RANGANNAGUDEM
VILLAGE -2 SINGANNAGUDEM
VILLAGE – 3 VEERAVALLI

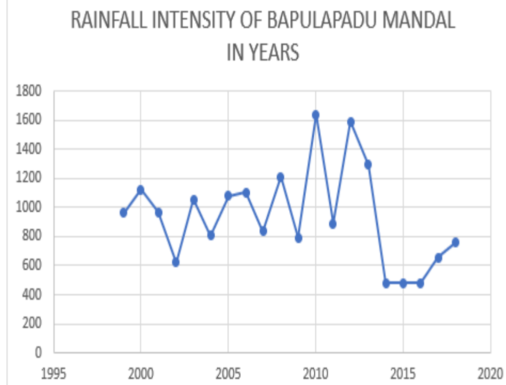

Fig 3: Rainfall intensity of Bapulpad over years

Graph Showing the Piezometer Water Level Data of Bapulpad Mandal Of Krishna District Name of the mandal: Bapulpadu is given below:
Ground water level for: 2013

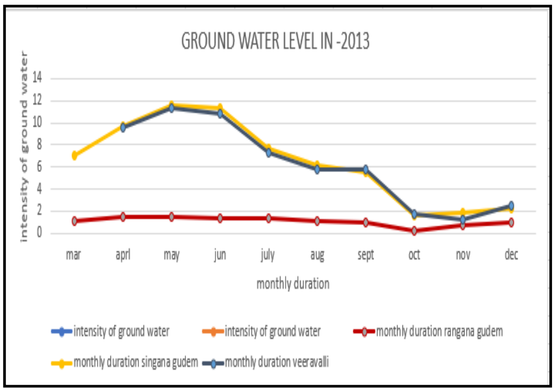

Fig 4: ground water level in 2013

Creation of Thematic Maps by GIS

A thematic map is a map that emphasizes a particular theme or special topic such as the average distribution of rainfall in an area. They are different form general reference maps because they do not just show natural features like rivers, cities, political subdivisions and highways.

By using the software arc maps we developed the base map and thematic maps

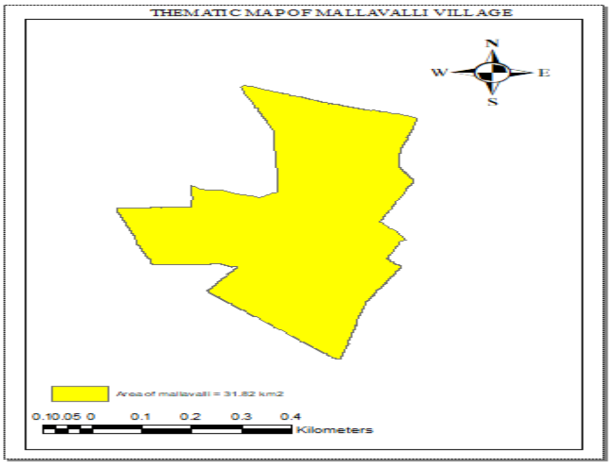

Fig 5: Thematic map of Mallavalli village

IV. RESULTS

Based on the input data collected (Rainfall data, groundwater data, soil data and crop data)and deducted from the losses like evaporation, Evapo-transpiration and infiltration and also domestic water supply and livestock requirement were deducted from the inputs.

Rainfall Deficiency:

Area ofMallavalli = 3166 hectors

Average rainfall (2019) = 450.8 mm

Village rain water = 3166 x (450.8/1000)
= 1427.2328 h.m

1. Ground water (9%) = 1427.23 x (9/100) = 128.45 h.m
2. Surface water (40%) = 1427.23 x (40/100) = 585.165 h.m
3. Evaporation and Evapo transpiration (41%) = 1427.23 x (41/100) =
4. Earth's moisture (10%) = 1427.23 x (10/100) = 142.723 h.m

Water storage in the village = 5 hectors meter

Ground water in the village = 5 x (20/1000 = 1 h.m

Actual water available = surface water – water storage
= 585.165 – 5 = 580.165

Total water available = 128.45 +5 = 133.45 h.m

Table 4: Rain fall deficiency

s. no.	Source	Quantity	Unit (h.m)	Water (h.m)
1.	People	5082	3.20/1000	16.26
2.	Buffaloes &cows	1272	4.80/1000	6.10
3.	Poultry	1733	0.20/1000	0.34
4.	Sheep/goat	5993	0.40/1000	2.39
5.	Sugar cane	65	8/10	52
6.	Tobacco	73	3/10	21.9
7.	Maize	128	2/10	25.6
8.	Pulses	20	2.8/10	5.6
9.	cotton	20	2.8/10	5.6
				135.79

Water budget = water available – water usage

For 2019 =133.45 -135.79 = - 2.34 h.m = - 2340000 litres

Water budget(average) = average water available – average usage of water

= 152.58 – 135.79 = 16.89 hector meter

By the above calculations and from the given rainfall over the years , 16.89 hector meters of water is less according to usages.

Table 5: Rainfall Deficiency Results For Years (2013-19)

S.NO.	YEARS	DEFICIENCY IN (lit)
1.	2013-2014	2135100000
2.	2014-2015	-168900000
3.	2015-2016	-168900000
4.	2016-2017	-168900000
5.	2017-2018	296400000
6.	2018-2019	-23400000

Too often, minimal or no account is taken of uncertainty when estimates are made and presented. Therefore quality assurance and control of the estimates should always be built into a water balance.

From 2014 -15 onwards the less rainfall is observed in this region , and also usage of water increases often leads to drought.

The scope for further development of ground water in the district varies widely from place to place and from Mandal to Mandal. Hence scientific and judicious development and management of available water resource will contribute to the overall planned development and improving the economy of district. There is huge scope for further development of groundwater resources in order to bring more areas under irrigation in the district.

V. CONCLUSIONS

In an average throughout a year 16.89 hector meters of water is less inMallavalli village , suggesting the water harvesting techniques and crop rotation which will give the optimum utilization of water resources available in that region.

Ground water should be judiciously exploited in shallow fresh water aquifers of deltaic area without disturbing the fresh /saline water interface.

In the limited fresh ground water potential areas, modern irrigation methods like drip and sprinkler irrigation should be adopted to increase the command area of the well.

Conjunctive use of surface and groundwater needs to be planned in the command area, to prevent adverse effects of the water logging conditions and to improve or to avoid further deterioration of quality of ground water.

Artificial recharge measures should be adopted in the urban areas , in the deltaic area and areas with considerable exploitation of ground water for improving the ground water situation.

A multi -sectorial approach is needed to study the ground water development, augmentation and management perspective. Therefore, all the aspects related to ground water, involvement of NGOs and mass awareness campaigns will play an important role in conserving and developing the precious fresh ground water resources.

Water Conservation and Artificial Recharge

Construction of artificial recharge structures like check-dams, contour trenches, percolation tanks and water conservation structures like sub-surface dykes are feasible in the areas where water levels are declining and considerable exploitation of ground water resources is taking place in mallavalli, Bapulpad Mandal. Roof top rainwater harvestings is to be implemented in the urban areas wherever deepening of water levels is taking place.

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