INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Estimation of Agricultural Blue and Green Water Use in Upper Manair Catchment, Andhra Pradesh

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Abstract:
An accurate assessment of agricultural blue and green water use is a key to estimate agricultural water demand and to understand human's interference with the ecosystems. Ground water is the primary source for irrigation in Upper Manair catchment, Andhra Pradesh. Due to continuous over-pumping, groundwater resources have been greatly depleted. It is extremely important for a sustainable agricultural water management to explicitly estimate the groundwater consumption for agriculture. Crop water requirements (CWR) of various crops in a catchment are computed using CROPWAT software. The seasonal ETc values for rabi crops were 430 mm, 365 mm and 222.5 mm for paddy, sunflower and maize, respectively, and for kharif crops were 525 mm, 261 mm, 1041 mm and 535 mm for paddy, maize, sugar cane and cotton respectively. However, the amount of ground water applied (MCM) for rice (Kharif), cotton, sugarcane, sunflower, double crop rice and double crop maize are 340.11, 57.94, 114.29, 18.0, 186.75 and 175.43 respectively. The total amount of ground water applied for different agricultural crops is 421.92 MCM more than the required amount of water which leads to depletion of ground water. Hence, immediate measures are required to reduce the blue and green water loss by developing efficient irrigation practices for sustainable ground water resources.

1. Introduction

Water is a limited resource and its scarcity has become one major threat to the sustainable agriculture. Presently, 98.6% of water is being used for irrigation only in Andhra Pradesh. Globally also, agricultural water use accounts for around 70% of the total ''blue" water withdrawn (IWMI, 2000) and over 90% of the total water uses, when ''green" water is also considered. Blue water refers to the water in surface water bodies and groundwater; while green water is essentially the rainfall that (after infiltration in the unsaturated zone) is directly consumed by plants to produce biomass (Falkenmark and Rockstrom, 2006, Liu and Savenije, 2008). However, the allocation of water for agriculture is going to reduce in future with the increasing competition from the other sectors of water use. Further, the demand of water for agriculture increases to meet the food grain requirement of bouncing population. Therefore, the concept of efficient utilization and management is worth considering. Accurate assessment of agricultural water use is a key to identify the demand and thereby efficient water management technologies can be planned to meet the demand.

Hoff *et al.* (2010) assessed the green water use and confirmed that green water use in global crop production is about 4–5 times greater than the consumptive blue water use. Hence, the full green-to-blue spectrum of agricultural water management options needs to be used when tackling the increasing water gap in food production. Junguo Liu and Hong Yang (2010) estimated consumptive water use (CWU) in cropland in a spatially explicit way by taking into account both green and blue water components. Green water contributed to 84% of the global CWU in the crop growing periods and 87% of the global CWU on an annual basis. The high proportion of green water was in part due to the dominance of rainfed agriculture. The important role of green water in crop production gives rise to the need for a better management of this water resource. The maps of irrigation amounts for each growing stage of the winter wheat and summer maize cropping system in China were developed by quantifying the evapotranspiration potential as well as the available soil water. These maps helped in improving irrigation scheduling scheme (Nguyen Thanh Tuan *et al.* 2011) Thimm Gowda *et al.*, (2013) used CROPWAT to evaluate the reference evapotranspiration and crop water requirement of maize at Dharwad. The total water requirement of maize sown at an early date was 116.0 mm and that of sown at late date was 183.8 mm. The water requirement of maize varied with planting dates. This information can be effectively used for proper irrigation scheduling especially under delayed sown condition to get optimum yield. Ground water is the primary source for irrigation in Upper manair catchment. Due to continuous over-pumping, groundwater resources have been greatly depleted. It is extremely important for a sustainable agricultural water management to explicitly estimate the groundwater consumption for agriculture. Hence, assessment of agricultural blue and green water use has been proposed in the catchment of the Upper Manair dam to estimate the agricultural water demand and thereby water management technologies can be identified for the management of green water resource.

2. The Study Area

The Upper Manair Catchment (UMC) of Andhra Pradesh was selected for the study. The UMC is located between the latitudes 17.65^0 and 18.50^0 N and longitudes 78.15^0 and 78.85^0 E which comprises parts of the Medak, Nizamabad and Karimnagar districts of Andhra Pradesh. The catchment area is 2, 20,173.16 ha. Two rivers namely Kudlair river of Medak district and Manair river of Nizamabad are flowing through the catchment and contributing the flows to Upper Manair reservoir. It consists of mainly two types of soils. Clay loam soils occupy an area of 92% in the catchment. Remaining 8% soils are Clay. Climate of the study area is semi-arid with distinct summer, winter and rainy seasons. The average monthly climatic data and rainfall are presented in Table 1, Table 2 and Fig. 1. The average maximum and minimum temperatures ranged between 33 and 19.6^0C and the average relative humidity was 59.3%. The average annual rainfall of 21 years from 1992 to 2012 was 777.8 mm. The highest amount of rainfall was recorded in 1995 as 1143.8 mm and lowest amount of rainfall was recorded during the year 2009 as 536.01mm.

3. Crops and Cropping Pattern of Study area

The major cropping systems followed in the study area are paddy - paddy, maize-maize, paddy-maize, cotton-maize and maize-sunflower. The major crops grown during *kharif* and *rabi* are paddy, maize, sugarcane, sunflower and cotton respectively. The most common sources of water for irrigation include vagus and groundwater. The maximum variation in ground water level (8.84 m) has been observed during the year 2010. The data on application of irrigation water to different crops has been obtained by conducting farmer's survey in the catchment area on different aspects of cultivation. The database had been prepared for the amount of irrigation water applied for the different crops grown in the catchment area.

S. No.	Month	Solar radiation ($MJ\ m^{-1}\ d^{-1}$)	Wind speed ($km\ h^{-1}$)	Mean RH (%)	Mean maximum Temperature (^0C)	Mean minimum Temperature (^0C)
1	January	15.8	2	58	29	14
2	February	18.4	3	54	31.2	15.6
3	March	20.2	3	48	35.1	17.8
4	April	21.4	3	42	35.8	20.1
5	May	21.6	7	40	40.5	23.1
6	June	17.6	9	57	36.6	22.3
7	July	14.7	8	71	31.4	21.2
8	August	14.7	7	75	29.9	20.8
9	September	16.5	5	74	30.8	21
10	October	17.3	2	66	31.4	19.8
11	November	15.8	2	60	30.2	16
12	December	15.2	2	56	28.8	12.7

Table 1: Average Monthly climatic data of Upper Manair Catchment, Andhra Pradesh during 1992-2012

S. No.	Month	Rain fall (mm)
1	January	10.6
2	February	4.8
3	March	17.4
4	April	14.3
5	May	14
6	June	83.2
7	July	183.5
8	August	207.9
9	September	142.7
10	October	79.7
11	November	17.1
12	December	2.5
	Total	**777.7**

Table 2: Average monthly rainfall of Upper Manair Catchment, Andhra Pradesh during 1992-2012

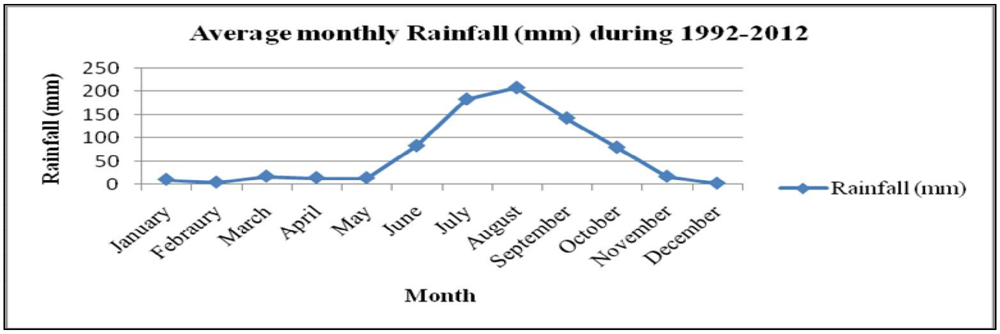

Figure 1: Average monthly Rainfall (mm) during 1992-2012

4. Crop Water Requirement

It is essential to know the water requirement of a crop which is the total quantity of water required from its sowing time to harvest to assess blue and green water use in agriculture. Naturally different crops may have different water requirements at different places depending upon the climate, type of soil, method of cultivation, effective rain etc. The total water required for crop growth is not uniformly distributed over its entire life span which is also called crop period. Actually, the watering stops some time before harvest and the time duration from the first irrigation during sowing up to the last before harvest is called base period. The influence of the climate on crop water needs is given by the reference crop evapotranspiration (ETO). The ETO is usually expressed in millimeters per unit of time, e.g. mm/day, mm/month, or mm/season. The relationship between the reference grass crop and the crop actually grown is given by the crop factor, Kc, as shown in the following formula:

$ETO \times Kc = ET\ crop$

Thus, to determine the crop factor Kc, it is necessary, for each crop, to know the total length of the growing season and the lengths of the various growth stages. It should be kept in mind that the influence of variations in the total growing period on the crop water requirement is very important. Less important is the choice of the various lengths of growth stages. ETO was calculated using Penman-Monteith method and Crop water requirement was calculated using CROPWAT software.

5. Results and Discussion

Crop water requirements (CWR) of various crops in a catchment are necessary for appropriate utilization of water. Crop coefficients were obtained from the literature for the different crops. The ETc was estimated for both *kharif* and *rabi* seasons considering the period of the crops grown in the study region. The reference ET was estimated using the FAO Penman-Montieth equation and CROPWAT software. The seasonal ETc values for *rabi* crops were 430 mm, 365 mm and 222.5 mm for paddy, sunflower and maize, respectively, and for *kharif* crops were 525 mm, 261 mm, 1041 mm and 535 mm for paddy, maize, sugar cane and cotton respectively (Table 3). The above data can be used for the effective irrigation scheduling of the crops. Vidyavathi (2008) has also computed CWR of Kalyankere watershed in Karnataka and utilized seasonal Etc values in irrigation water management.

Crop	**ETc (mm/month)**												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Rice-rabi	84.5	82.2	11.5							85	86	80.8	429.9
Rice-kharif						120.6	108.2	105.3	107.1	84.1			525.3
Maize-rabi	79.4	80	26.2								5.2	31.6	222.5
Maize-kharif							26.6	81.2	103.3	49.8			261
Cotton	46.2					14.1	38.8	74.1	107.2	108.6	84.8	60.9	534.7
Sugarcane	25.5	44	99	132.5	153.3	133.5	116.3	110.1	109.3	88.2	29.2		1040.9
Sunflower	13.5	40.1	109.5	126.1	75.7								365.1

Table 3: Month wise Evapotranspiration (ETO) of different crops in Upper Manair Catchment

The daily CWR of different crops are depicted in Fig 2 to 8. During the growing and developing period crops need large quantity of water for various physiological functions. Sensitiveness of crop to moisture requirement changes with different growing and developing period (Suman Arya, 2012). Daily evapotranspiration of paddy was computed for paddy growing period. (Fig 2 to 3)

The crop water required for maize, sugar cane and cotton was in increasing order reflecting more water required with increase in days after planting. However, the requirement was reduced in the late season stage of crop. A certain crop grown in a sunny and hot climate needs more water per day as compared to a crop grown in a cooler and cloudy climate. Apart from sunshine and temperature, other climatic factors influence the crop water need. Same crops grown in different climatic zones may have different water needs. The computed CWR of the catchment are in the range established for the region and type of soils.

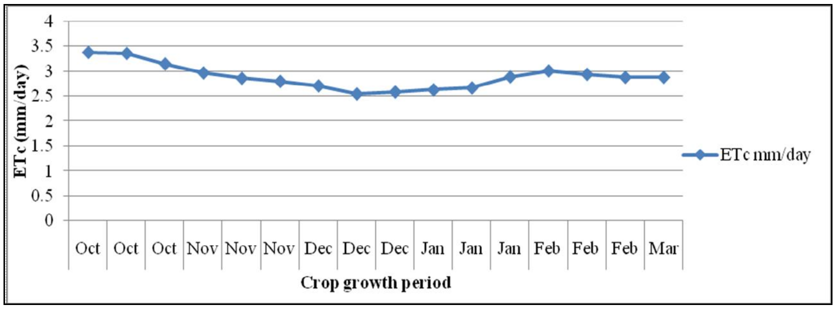

Figure 2: Evapotranspiration of Rice-rabi

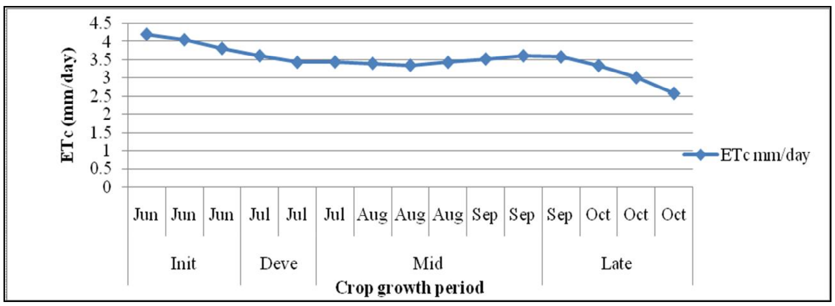

Figure 3: Evapotranspiration of Rice-kharif

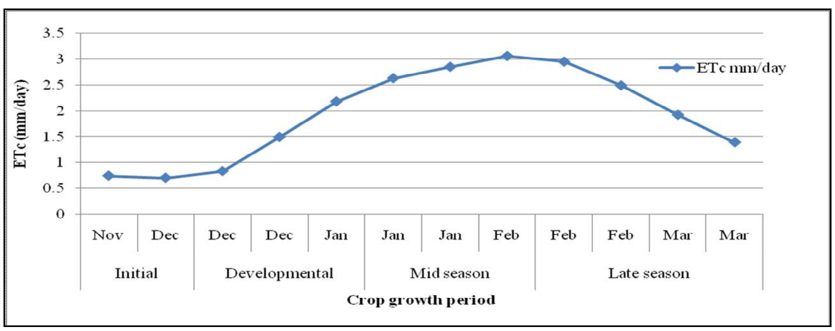

Figure 4: Evapotranspiration of Maize-rabi

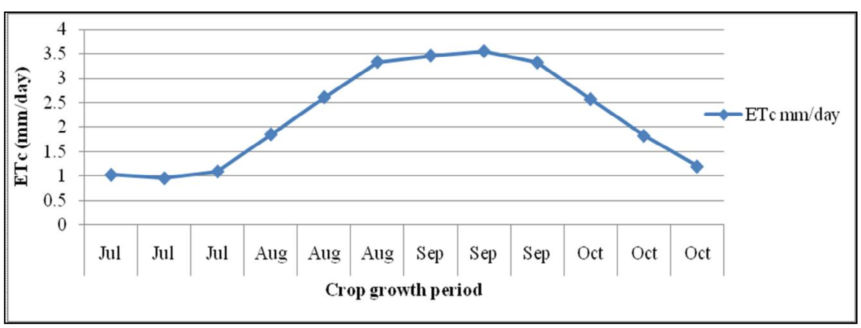

Figure 5: Evapotranspiration of Maize-kharif

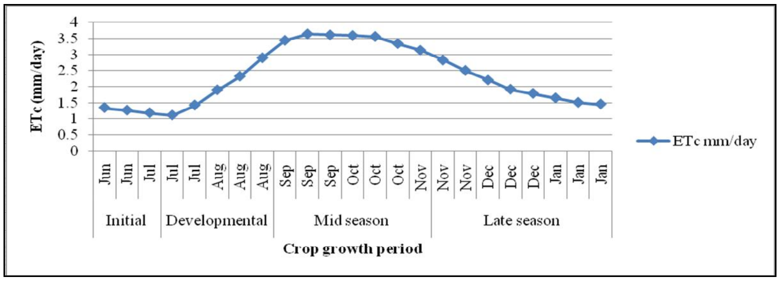

Figure 6: Evapotranspiration of Cotton

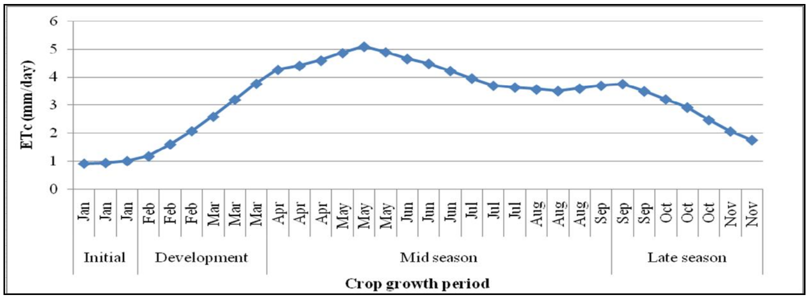

Figure 7: Evapotranspiration of Sugarcane

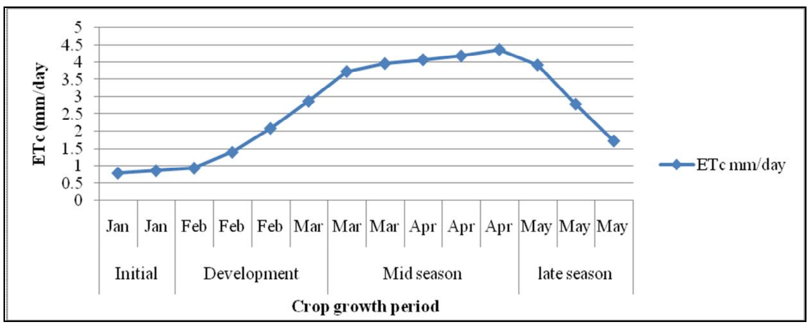

Figure 8: Evapotranspiration of Sunflower

The gross irrigation requirement and actual irrigation requirement of different crops are presented in Table 4. The gross irrigation requirement (GIR) has been estimated based on effective rainfall and crop water use. It is more for paddy, followed by sugarcane, sunflower, cotton and maize respectively. Actual irrigation water requirement is less than GIR, which clearly indicated the losses that are occurring in the application of water. The agricultural water demands of the different crops that are grown in the catchment are presented in the Table 5. The irrigation water demand for rice was more since it occupies an area of 24.37% (Rice *Kharif*, 20.06% and Rice *Rabi*, 4.31%) in the watershed. In addition to that, the actual evapotranspiration from rice fields was more due to ET from rice and evaporation from the stagnant water. The irrigation requirement for Cotton and Maize was less with more water use efficiency due

S. No.	Crop	Effective rainfall (mm)	Actual crop water use (mm)	Actual irrigation requirement (mm)	Gross irrigation requirement (mm)
1	Rice-rabi	40.4	427.1	386.7	543.6
2	Rice-kharif	204	522.7	318.7	450.9
3	Maize-rabi	27.3	221.1	193.8	137.4
4	Maize-kharif	257.5	259.8	2.4	0
5	Cotton	329.8	533.3	203.5	231.6
6	Sugarcane	665.9	1039.1	373.2	479.8
7	Sunflower	49.7	363.3	313.7	293.7

Table 4: Irrigation water requirement of different crops in Upper Manair Catchment

S. No.	Crop	Area (ha)	Gross irrigation requirement (mm)	Volume of water required (MCM)	Volume of water applied (MCM)
1	Rice-*kharif*	44170.6	450.9	199.17	340.11
2	Cotton	21069.9	231.6	48.80	57.94
3	Sugarcane	7619.6	479.8	36.56	114.29
4	Sunflower	6000.0	293.7	17.62	18.0
5	Double crop rice	9479.8	994.5	94.28	186.75
6	Double crop maize	53978.3	137.4	74.17	175.43
	Total			470.59	892.52

Table 5: Agricultural water demand in the Upper Manair Catchment

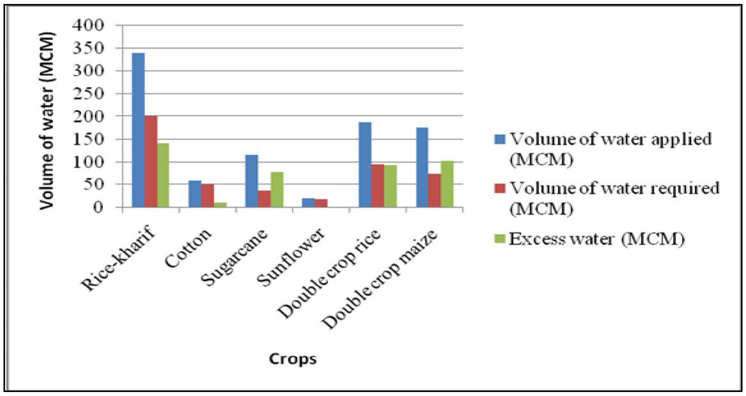

Figure 9: Volume of water required and applied for different crops in Upper Manair Catchment

to deep rooted system. The green water use (Evapotranspiration) is less for maize and cotton. The volume of water applied is more than requirement in all the crops. The total volume of water required is 470.59 MCM. However, the ground water applied for irrigation is 892.52 MCM, which is 421.92 MCM more than the requirement. The excess amount of water applied for different crops in the catchment are shown in Fig. 9. An excess 140.94 MCM volume of ground water has been applied to Kharif rice over and above the irrigation water requirement. Similarly, 101.26 MCM of water has been applied additionally for double crop maize. If appropriate irrigation practices are adopted, the excess with drawn ground water of 421.92 MCM can be used to cultivate 3.08 lakh ha under maize or 1.43 lakh ha under sunflower. The study explicitly estimated the irrigation requirement to meet the deficit between crop water requirement and that which is supplied by rainfall. The renewal of surface and groundwater resources is dependent on the difference between precipitation and evapotranspiration in the catchment. Hence, the estimation of agricultural water and groundwater irrigation net consumption will provide scientific information for developing efficient irrigation practices to improve crop water productivity and lead to sustainable agriculture.

6. Conclusion

Assessment of agricultural blue and green water use in a catchment is important for water resources planning. The assessment of green water use in crop production gives rise to the need for a better management of this water resource. Agricultural Water Management options were focused on blue water and irrigation infrastructure in the past. Given the increasing overexploitation or other limitations of blue water resources in many regions, green water management deserves more attention. Appropriate water management technologies like water saving production systems and efficient irrigation practices need to be adopted to reduce the green water loss.

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