# ASSESSMENT OF BENEFICIAL AND NON-BENEFICIAL EVAPOTRANSPIRATION (ET) ACROSS THE MAHANADI RIVER BASIN USING SATELLITE DATA

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## ABSTRACT

Due to high spatial variation of rainfall in Mahanadi basin, drought is dominant in some districts (5 districts of Chhattisgarh and 9 districts of Odisha). Also some districts face water logging problem, which are near to coastal parts. Hence, effective water management strategies require to manage these problems in Mahanadi basin. Water accounting plus (WA+) is a framework which give overall idea about water balance of river basins. WA+ framework consists of eight factsheets. According to the analysis of rainfall data for the periods 2003-2014, the year 2012 has been identified as average year. Thus, this paper shows the evapotranspiration (ET) sheet for a period of 1 year i.e. from June 2012 to May 2013. The results indicate that out of 137.5 $km^3$/year total ET 92.8 $km^3$/year is non-beneficial and 44.7 $km^3$/year is beneficial ET, which is based on whether the ET is meeting the intended purpose or not. It further reports on the separation of ET into evaporation (75 $km^3$/year), transpiration (52.5 $km^3$/year) and interception (10.1 $km^3$/year). All datasets are from satellite data product which are freely available and accessible.
***Keywords:*** *WA+, beneficial and non-beneficial, evapotranspiration, land use, manageable and non-manageable, earth observation data.*

## 1. INTRODUCTION:

Increasing demand for food, biodiversity consumption and bio-energy production can be presumed high competition for water and land resources (Renault et al., 2000). Growing competition for water in many sectors reduce its availability for irrigation. Thus, efficient approaches are require for effective management of water in every sectors. No doubt, lack of processes to collect standard data is the main barrier for effective water management. Generally, there is an inadequacy in interpretation and communication of water related data to researcher, planner, policy maker.

River basin management involves different persons from different educational and cultural backgrounds. Definitely, this create to misconceptions and misinterpretations (Perry, 2007), which are unfavourable for improving water resources availability. Availability of appropriate data and if the management strategies are commonly acceptable, accessible and agreed upon by various stakeholders, it will create an effective investment in water resources management. Water accounting plus (WA+) is a useful platform for operation, planning and monitoring of water resources in river basins. Water accounting plus (WA+) (Karimi et al., 2013) presents water accounts of river basins using four sheets including (i) a resource base sheet, (ii) an evapotranspiration sheet, (iii) a productivity sheet, and (iv) a withdrawal sheet. Information on total quantity of water available, water depletion, water supply is given by resource base sheet. The Beneficial and non-beneficial water depletion are explained by evapotranspiration sheet. The productivity sheet creates links between water depletion and biomass production, carbon sequestration, crop production and water productivity. Idea on quantity of water reuse and withdrawals is given by withdrawal sheet.

This paper shows the evapotranspiration (ET) sheet and describes which parts of evapotranspiration process are managed, manageable or non-manageable. Based on intended purpose further separates the ET into evaporation (E), transpiration (T), and interception (I) and defines which portion of ET is beneficial and which is non-beneficial.

## 1.1 Study area:

Mahanadi basin occupies nearly 4.28% area out of total area of the country. Total catchment area of this basin is 145021 km$^2$. The geographical extent of the basin lies between 80°28’ and 86°43’ east longitudes and 19°8’ and 23°32’ north latitudes. Mahanadi is originating from Dhamtari district of Chhattisgarh and draining into Bay of Bengal. Maximum portion of the basin extend in Chhattisgarh and Odisha and comparatively lesser portions in Jharkhand, Maharashtra and Madhya Pradesh. The Jira, the Ong, the Ib, and the Tel are its main tributaries (http://www.india-wris.nrsc.gov.in/wris.html). The largest dam (Hirakud dam) is constructed across this basin, which irrigates 1556 km$^2$ and 1084 km$^2$ in Kharif and Rabi season respectively. Water demand in the Mahanadi basin indicates a large quantity of water abstraction by the irrigation and experience progressively increasing intensities of flood in September and drought in April (Asokan et al., 2008). Thus proper water management strategies are require for this basin. Evapotranspiration is one of the main influencing factor for effective water management planning. A map showing drainage and gauge-discharge sites of Mahanadi basin is shown in Figure 1.

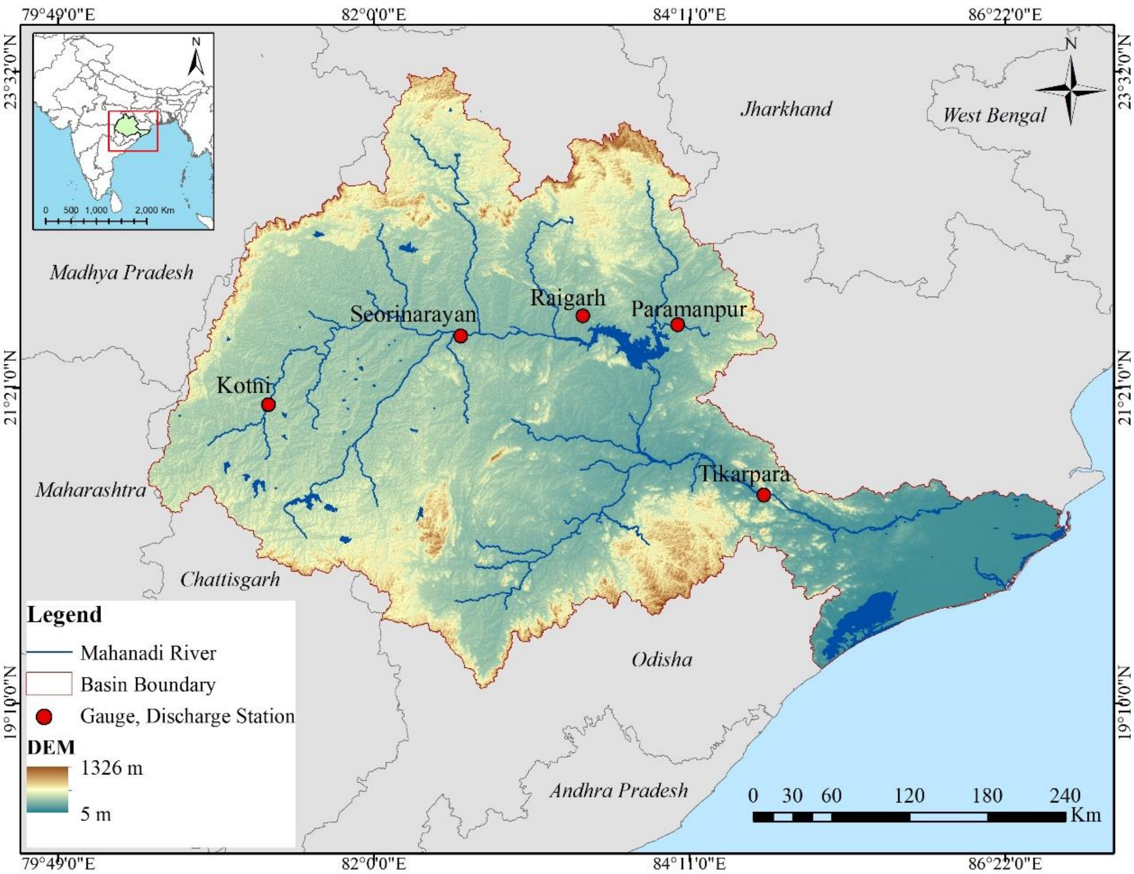


**Figure 1**. Location map of Mahanadi river basin

## 2. MATERIAL AND METHODS

### 2.1 Land use and land cover

Land use and land cover (LULC) is a main parameter, which affect the hydrological cycle, as well as the services and benefits for society and for the environment. Thus, spatially distributed information on LULC is the key component required by WA+. Based on remotely sensed data and by using different algorithm there are number of regional and global land cover databases (Bontemps et al., 2010; Friedl et al., 2010). There are different data products like globcover, global map of irrigation area (GMIA), moderate resolution imaging spectro radiometer (MODIS), international water management institute (IWMI) crop maps, monthly irrigated and rainfed crop area (MIRCA), world database on protected area (WDPA), world population data were used to prepare WA+ based LULC. In terms of water management, the LULC classes have been classified into four major clusters: protected land use (PLU), utilized land use (ULU), modified land use (MLU), managed water use (MWU). The area under PLU is 982 km$^2$, ULU is 57359km$^2$, MLU is 62410 km$^2$, MWU is 24263 km$^2$. LULC map of Mahanadi basin is shown in Figure 2.

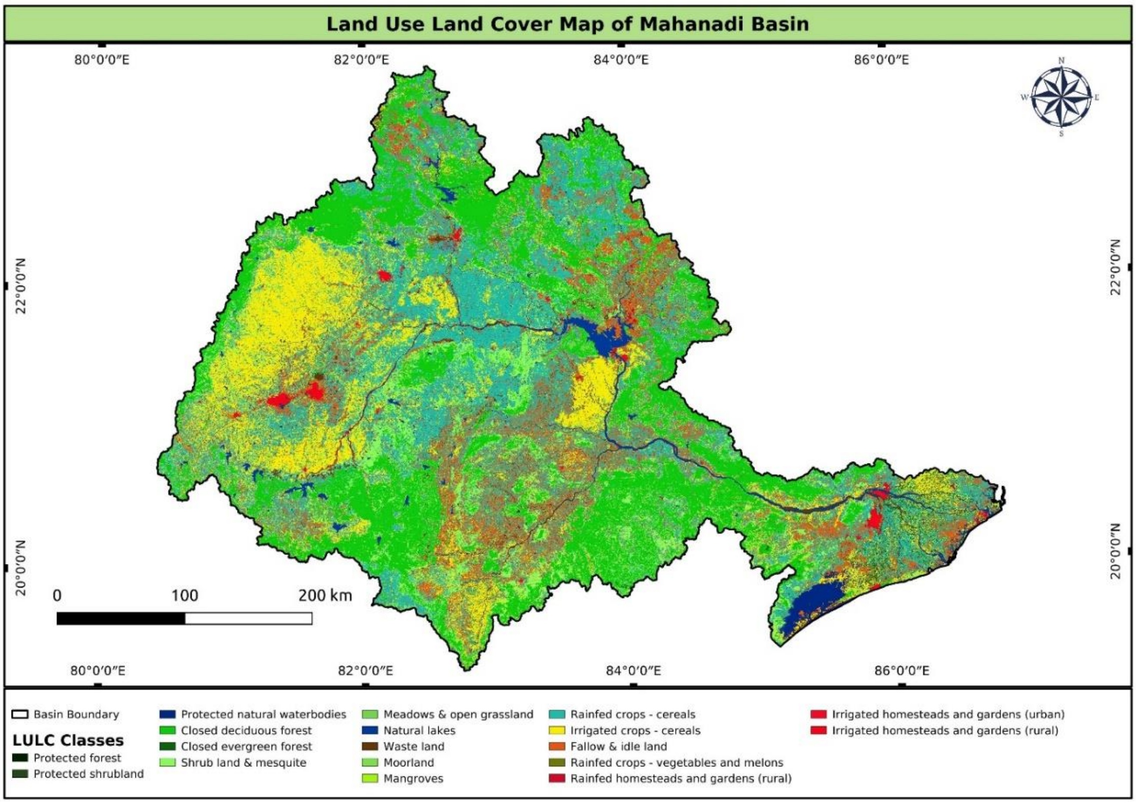


**Figure 2.** LULC map of Mahanadi river basin generated using WALU

### 2.2 Precipitation, evapotranspiration (ET), leaf area index (LAI), net dry matter (NDM)

Gross precipitation is a primary input for WA+. Climate hazards group infrared precipitation with station data (CHIRPS) rainfall product was used for this accounting procedure. The annual rainfall in the basin was 1520 mm/year for 2012.

Over the past decades there are various methods and algorithms to calculate actual evapo-transpiration (ET). ET data of Mahanadi basin for 2012-13 was taken from ETensemble product which was created by linear averaging of seven individual ET products: (1) Modis Global Terrestrial Evapotranspiration Algorithm (MOD16), (2) Atmosphere-Land Exchange Inverse Model (MOD16), (3) Global Land Evaporation Amsterdam Model (GLEAM), (4) Operational Simplified Surface Energy Balance (SSEBop), (5) CSIRO MODIS Reflectance-based Evapotranspiration (CMRSET), and (6) Surface Energy Balance System (SEBS), (7) ETmonitoer and subsequently downscaled to 0.0025° using the MODIS-based, normalized difference vegetation index (NDVI) data. The period of analysis was from 2003-01-01 to 2014-12-31 (Da Motta et al., 2019).

Leaf area index (LAI), and net dry matter (NDM), which give information on leaf area per unit ground surface area and mass of carbon per unit area, also were used for this sheet preparation. NDM was created from gross primary production (GPP) and net primary production (NPP), which are MODIS datasets. From June 2012 to May 2013 LAI and NDM in Mahanadi basin were 12.6 $m^2/m^2$ and 8893 kg/ha respectively.

For this accounting evaporation from wetlands, rivers, natural lakes were assumed beneficial and from other sources it was assumed 100% non-beneficial. Transpiration from all the sources was assumed to be 100% beneficial expect the transpiration from waste lands and floating vegetation in reservoir. Although interception has certain benefits for crops all interceptions from different sources was assumed non-beneficial. It can be modified by users to define their beneficial and non-beneficial E and T fractions.

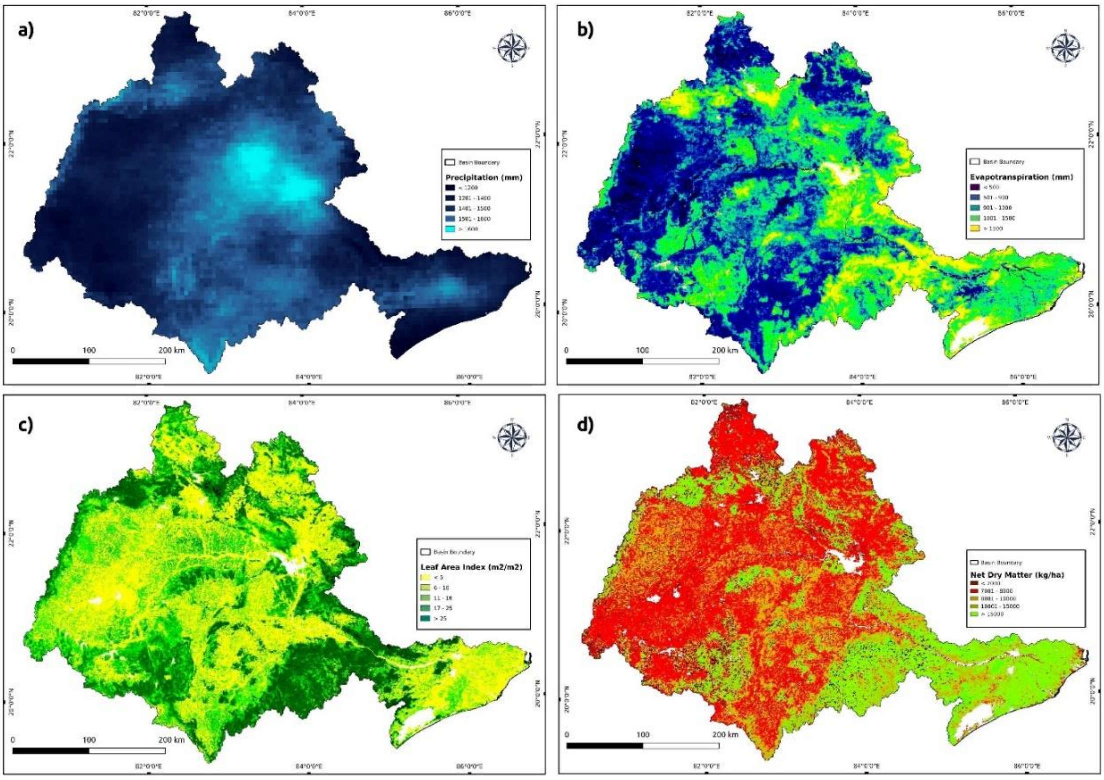


**Figure 3.** (a) precipitation (b) evapotranspiration (c) leaf area index (d) net dry matter maps in the Mahanadi basin in (June 2012 – May 2013)

## 3. RESULTS AND ANALYSIS

This section discusses about the results obtained from application of WA+ tool. An assessment of total water consumptions by evapotranspiration (ET) process in the basin have been estimated as shown in Figure 4. As per WA+ standards, it is also named as sheet-2 (ET sheet) which informs details about beneficial and non-beneficial ET as per prevailing LULC. Table 1 shows the beneficial non-beneficial ET fraction for different LULC classes. Evapotranspiration sheet (Figure 4) also shows the separation of ET into evaporation (E), transpiration (T), interception (I) for each LULC class. Sheet 2 shows that the total water consumptions in the basin for 2012-13 is 137.5 km$^3$/year from different LULC classes. we can also infer that the non-beneficial consumptions are 92.8 km$^3$/year, which is greater than the beneficial consumptions, i.e., 44.7 km$^3$/year. If we look at the irrigated crops under Managed Water Use (MWU) class, then ET is approximately more than twice as compared to T and hence the irrigated water needs to applied more judiciously to reduce the non-beneficial consumptions mainly in the form of E. Similarly, for rainfed crops under Modified Land Use (MLU) class, the E component is higher than T and this evaporation can be reduced through proper management of soil moisture through various agronomical practices and improved cropping patterns.

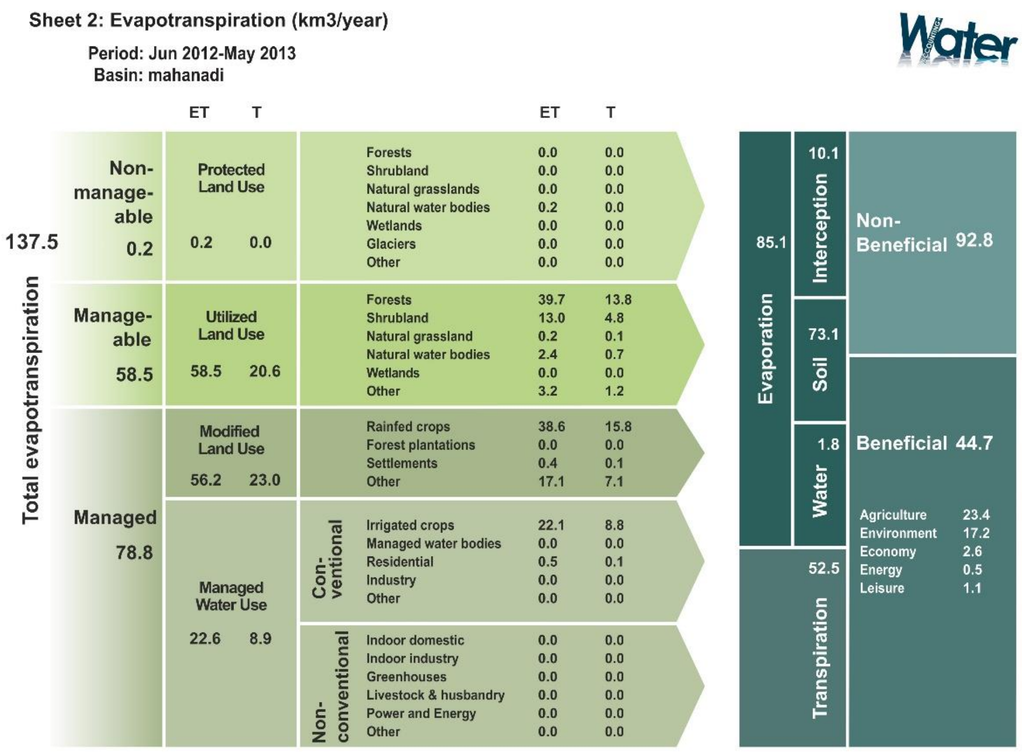


**Figure 4.** Sheet 2: Estimates of evapotranspiration and its separation into evaporation, transpiration, beneficial and non-beneficial consumptions for different LULC classes during year 2012-13.

Table 1 informs for all LULC classes non-beneficial ET is more than beneficial ET. Thus it requires proper management strategies for both land and water.

**Table 1.** Estimates beneficial and non-beneficial ET over different LULC classes

| Land use class | Land use group | Beneficial ET (MCM) | Non beneficial ET (MCM) | Total ET (MCM) | Beneficial ET fraction | Non-beneficial ET fraction |
|---|---|---|---|---|---|---|
| Protected natural waterbodies | PLU | 200 | 0 | 200 | 1.00 | 0.00 |
| Natural grassland | ULU | 100 | 100 | 200 | 0.50 | 0.50 |
| Shrubland | ULU | 4800 | 8200 | 13000 | 0.37 | 0.63 |
| Natural waterbodies | ULU | 850 | 1550 | 2400 | 0.35 | 0.65 |
| Forest | ULU | 13800 | 25900 | 39700 | 0.35 | 0.65 |
| Others (Waste land, Moorland, Mangroves) | ULU | 200 | 3000 | 3200 | 0.06 | 0.94 |
| Settlements (Rainfed) | MLU | 100 | 300 | 400 | 0.25 | 0.75 |
| Rainfed crops | MLU | 15800 | 22800 | 38600 | 0.41 | 0.59 |
| Fallow land | MLU | 0 | 17100 | 17100 | 0.00 | 1.00 |
| Irrigated crops | MWU | 8800 | 13300 | 22100 | 0.40 | 0.60 |
| Settlements (Irrigated) | MWU | 100 | 400 | 500 | 0.20 | 0.80 |

(MCM=Million cubic meter)

## 4. CONCLUSIONS

A clear understanding of evapotranspiration (ET) is important for preparing an effective water management strategy for the future. In this study we assessed the beneficial and non-beneficial evapotranspiration using WA+ tool for Mahanadi basin during June 2012 to May 2013. The results suggest that out of total ET the modified land use group, chiefly dominated by rainfed agriculture accounts for 29.2% of non-beneficial ET. It is followed by the utilized land use group (28.3%), managed water use group (9.9%). Out of total ET 67.4% ET is non beneficial and 32.6% ET is beneficial.

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