EARTH OBSERVATIONS TO MONITOR WATER BUDGETS FOR RIVER BASIN MANAGEMENT: CASE STUDY IN MURRAY-DARLING BASIN

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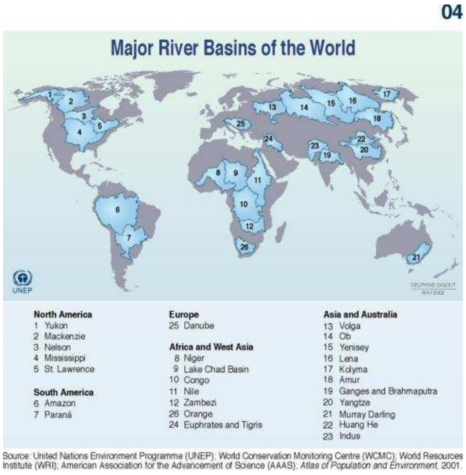
ABSTRACT: Rivers are a major source of freshwater. They support aquatic and terrestrial ecosystems, provide transportation, and generate hydropower. The Murray–Darling Basin is so important to Australia. This paper provides an overview of river basin monitoring and management, focusing on its importance and the approach. Managing river basin watersheds are critical for developing policies for sustainable water allocation and development. The procedure is discussed to finding remote sensing data sources and data access which are relevant to river basin monitoring and management, and demonstrate. This paper addresses using satellite data and Earth system modelling data sources to estimate surface water budgets. Estimate the distributed water balance of the Murray-Darling Basin improve and evaluate hydrological models used in water resource analysis monitor and understand variability in hydrologically complex regions. In this research has so many challenges about In situ data are sparse, In situ data are often politically sensitive, the basin is evaporation dominated and there is considerable meteorological and hydrological complexity. This research includes remotely sensed water balance analysis and wetland mapping and monitoring.

1. INTRODUCTION

A River Basin is an area of land that drains water into a river and its tributaries. So the basin includes areas that drain into tributaries and rivers. A river basin consists of surface water and underlying ground water. This paper uses the word “watershed” or “sub water basins” to talk about the small portion of the basin. These watersheds usually separated by ridges and hills called **Drainage Divide**. All these watersheds collect rain or/and snow water and drains it into common outlets (Stream, tributary, lake or wetland).

Internationally, the Murry Darling Basin (MDB) is recognised one of Importance River Basins in the world. It shows in Figure 1.

Importance of River Basin Management (RBM) is defined as the management of water resources of a basin as part of the natural ecosystem and in relation to their socio-economic setting. MDB is important and crucial because it ensures that the water is properly allocated among states (Queensland, New South Wales, Australian Capital Territory, Victoria and South Australia).



(a) United Environment Programme recognised (b) World Atlas recognised

(https://www.grida.no/resources/5782) (https://www.euratlas.net/geography/world/rivers/murray_darling.html)

(c) Australian Government recognised

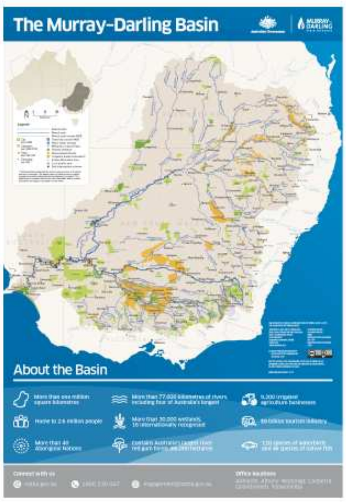


Figure 1: MDB importance for the world

2. METHODOLOGY OF WATER BUDGET ESTIMATION

This research considers the following co elements for the procedures.

2.1. River Basin Network Based on Remote Sensing

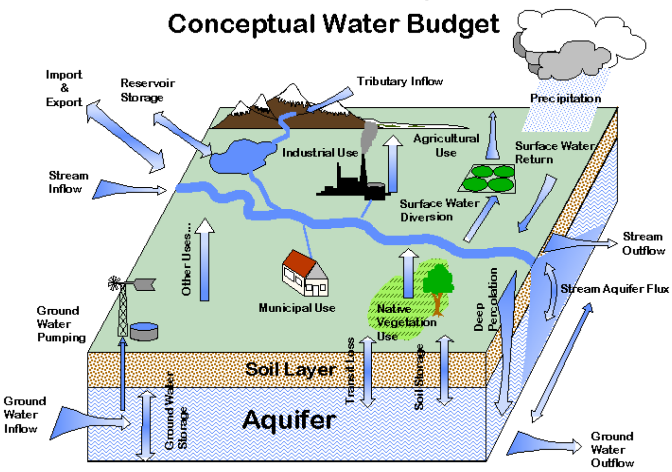


Figure 2: Conceptual Water Budget [1]

(https://www.water-research.net/index.php/the-hydrological-cycle-water-budgets)

The hydrologic budget (Figure 2) consists of inflows, outflows, and storage as shown in the following equation:
According the above figure 2:

$$Inflow = Outflow +/- Changes\ in\ Storage \quad (1)$$

Inflows add water to the different parts of the hydrologic system, while outflows remove water. Storage is the retention of water by parts of the system. Because water movement is cyclical, an inflow for one part of the system is an outflow for another.

$$Precipitation = Evapotranspiration + Total\ Runoff \quad (2)$$

Where

Total Runoff = Direct Runoff + Base flow (groundwater component of stream flow)

Water quality monitoring also is an important part of river basin management. This paper focuses on data relevant for monitoring water quantity in MDB.

2.2. Data from HydroBasins database

This research used **Hydro**logical data and maps based on **SH**uttle **E**levation **D**erivatives at multiple Scales (**HydroSHEDS**) provide data sets of stream networks, watershed boundaries, drainage directions, flow accumulations, distances, and river topology information. HydroSHEDS uses digital elevation data from the Shuttle Radar Topography Mission (SRTM)*, a C-band (5.6 cm) radar, carried on-board the Space Shuttle Endeavour. HydroBASINS is a database aiming to provide the shoreline polygons of all global lakes with a surface area of at least 10 ha. Additional attributes for each of the 1.4 million lakes include estimates of the shoreline length, average depth, and water volume and residence time. All lakes are co-registered to the global river network of the HydroSHEDS database via their lake pour points [3]-[6]. Initially, HydroBASINS database used to download Australian hydrological data and processed the data. Finally, the research detected fig. 1(a) data set. It has sub basins boundary as well. The research found 10 hydro sub basins. This data slightly has deference with Basin as defined in Section 4 (1) of the Water Act 2007 in Australia. It is showing fig. 1(b).

(a) Processed by HydroBASINS data of MDB (b) Compare with shoreline polygons with legal boundary of MDB

Figure 3: Compare boundaries of MDB and sub lakes from HydroBASINS database

2.3. Monitoring water availability in River Basins

Water flow in streams within the basin and it depends on the following components [2]. Figure 4 and table 1 show the details of idea behind and sensors of the data capturing.

Precipitation
Evaporation and transpiration
} Can be obtained from the surface based and remote sensing observations

Infiltration: soil characteristics, soil moisture, terrain and slope
Surface water: soil moisture, reservoirs and groundwater storage
} Can be calculated based on other observable geophysical parameters

Runoff } Can be calculated based on a water balance equation

This resource is about how MDB's water is made available and used by people in Australia. Australia has very low rainfall (except seasonally in the tropics); and this rainfall is very variable season-to-season and year-to-year. Most of the runoff bringing water into the MDB river system falls on less than 15% of the land area — except in relatively rare times of flood. Yet MDB is Australia's most important food and fibre growing region.

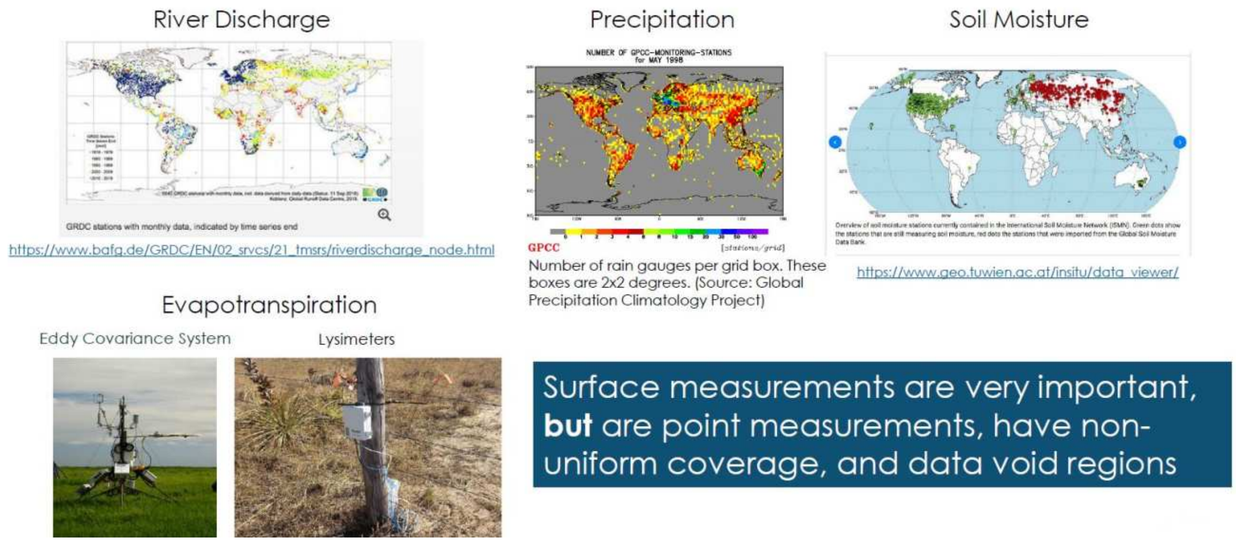


Figure 4: Monitoring Water Budget Components: Surface-Based Observations [2]

Table 1: Satellites and Sensors for Water Budget Components

Satellites	Sensors	Spectral Measurements	Water Budget Component
TRMM & GPM	Microwave Radiometer and RADAR TMI, PR GMI, DPR	TMI: 10-85 GHz GMI: 10-183 GHz PR and DPR (Ku and Ka)	Precipitation
Terra & Aqua	MODIS	Visible, Near IR, Middle IR	Snow Cover, Evapotranspiration
Landsat 7, 8	TM, ETM+, OLI	Visible, Near IR, Middle IR, Thermal IR	Evapotranspiration
SMAP	Microwave Radiometer	L-Band	Soil Moisture
GRACE & GRACE-FO	Microwave Radar	K-Band	Groundwater
Jason 2, 3	Altimeter	C-Band and Ku-Band	Reservoir Height

TMI : TRMM Microwave Imager
PR Precipitation Radar
GMI: GPM Microwave Imager
DPR: Dual-frequency Precipitation Radar

MODIS: MODerate Resolution Imaging Spectroradiometer
TM: Thematic Mapper
ETM+: Enhanced Thematic Mapper
OLI: Operational Land Imager

2.4. Data from IMERG

In this research used IMERG data to find Time average map period of 01.01.2014 to 31.05.2019. GIOVANNI web portal was used for map downloading process. Figure 5 shows the details for the process. Figure 6 shows the visualisation of the data requested area. The boundary box for the data downloading used (138.5684,-37.6821), (152.4885,-24.5856) was defined by Murray-Darling Basin Authority.

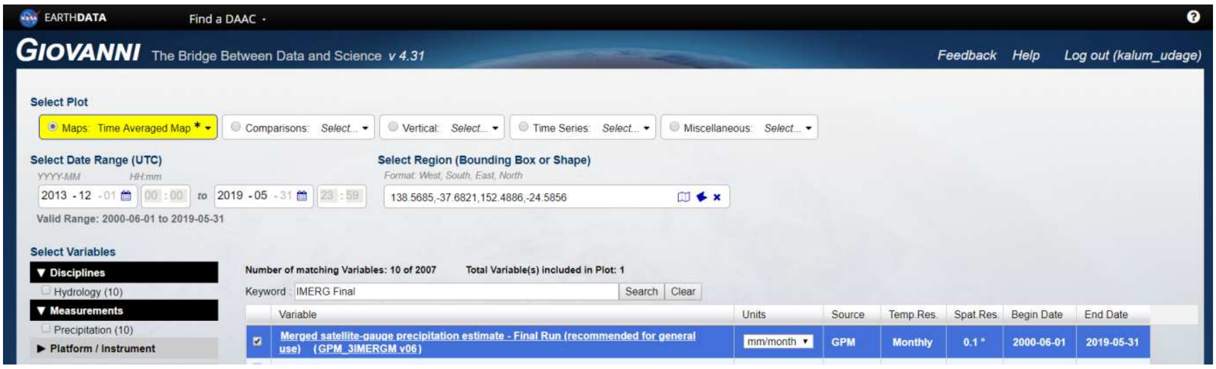


Figure 5: GIOVANNI web portal screen shot of Time average map

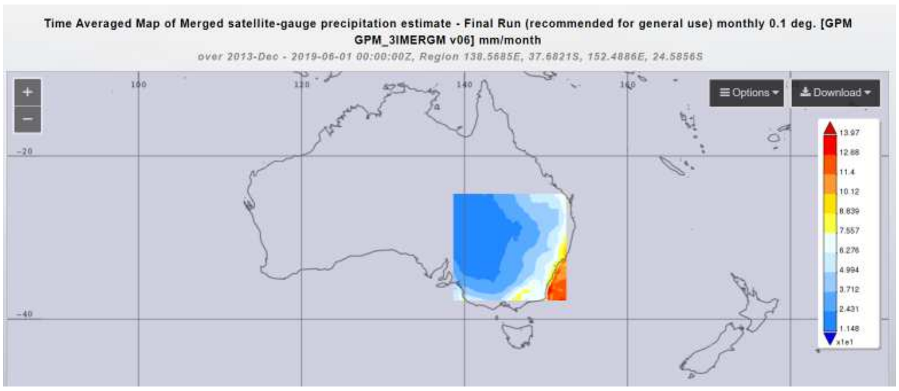


Figure 6: Result of the request for the data

If the data consider average time series the figure shows the graph to decide which year to account for this research. The research was found for the period 2016-2018 is good because it has significant dropping hydrological perception estimation.

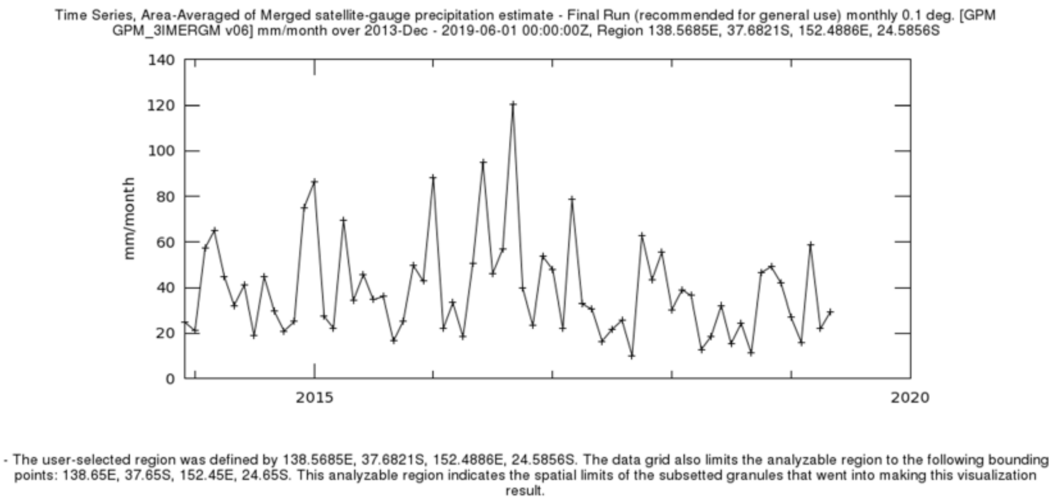


Figure 7: Result of the request for the data

2.5. Global Land Data Assimilation System (GLDAS) for Water Budget Data

According Water Budgets: Foundations for Effective Water-Resources and Environmental Management [7], [8] can be used a water and energy balance model with assimilation of remote sensing data. GLDAS make output the above our four required variables the following table 2.

Table 2: GLDAS inputs and Outputs

Inputs	Integrated outputs include
➢ Rainfall: TRMM and multi-satellite base data ➢ Meteorological data: global reanalysis and observations-based data from Princeton University ➢ Vegetation mask, Land/Water mask, Leaf Area Index (LAI): MODIS (GLDAS-2) ➢ Clouds and Snow (for surface radiation): NOAA and DMSP satellites	✓ Soil Moisture ✓ Evapotranspiration ✓ Surface/Sub-surface runoff ✓ Snow water equivalent

2.6. Estimation of Water Budgets

The equation 3 is considering that there is no surface, sub-surface, or groundwater net inflow/outflow in the watershed, surface RO and base flow contribute to discharge.

The water-budget equation for a small watershed can be expressed as:

$$Pr = ET + DS + RO + Base\ Flow \quad (3)$$

Where
Pr = Precipitation
ET = Evapotranspiration
DS = Change in water storage in the watershed can include surface (snow, soil moisture), and sub-surface (root zone moisture, groundwater components)
RO = Surface Runoff
Base Flow = Sub-Surface Runoff

The required data availability is showing the following table 3. In this research used GLDAS data sources to find the estimation.

Table 3: Obtain Water Budget Components

Water Budget Component	Data Sources
Pr	GPM-IMERG, GLDAS
ET	ALEXI, MODI 6, GLDAS
DS	SMAP, GLDAS
RO, Base Flow	GLDAS

The water budget components data was obtained from GIOVANNI web portal. The paper highly gives credibility to them and read acknowledgement to fins more details.

The figures 8 and 9 show the data from the Giovanni time average maps for 2016 to 2018 under the above four water budget components for the process. Table 4 shows each data meta data information.

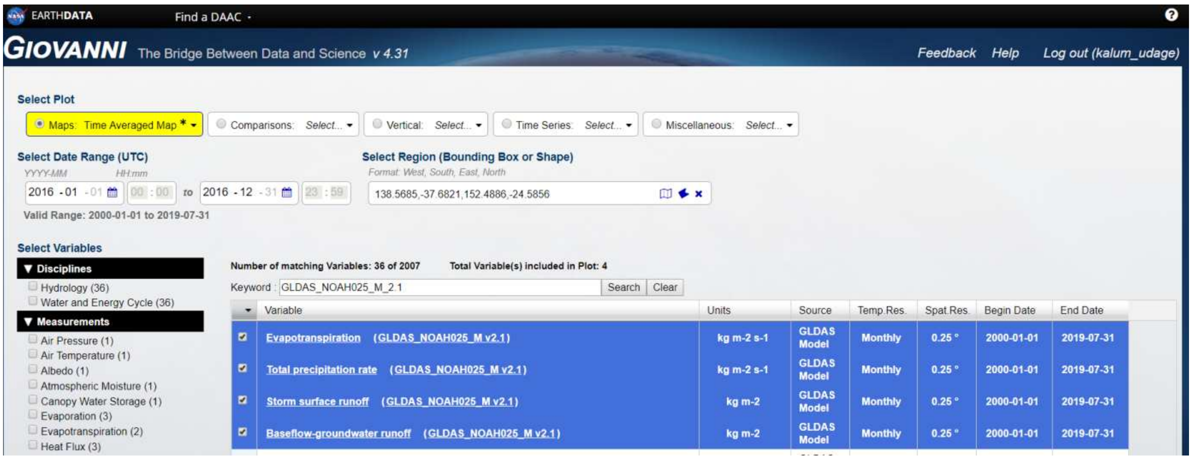


Figure 8: GIOVANNI web portal screen shot of Time average map selection for Pre, ET, RO and Base flow.

Table 4: Data selection information

Variable	Units	Source	Temp Res	Spatial Res
ET	kg m^{-2} s^{-1}	GLDAS Model	Monthly	0.25°
Pre	kg m^{-2} s^{-1}	GLDAS Model	Monthly	0.25°
RO	kg m^{-2}	GLDAS Model	Monthly	0.25°
Baseflow	kg m^{-2}	GLDAS Model	Monthly	0.25°

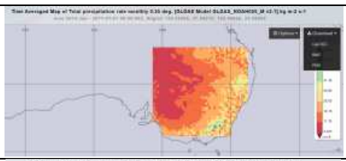
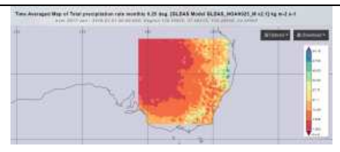
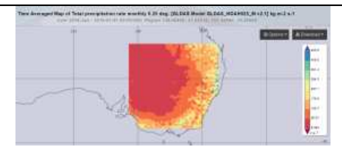
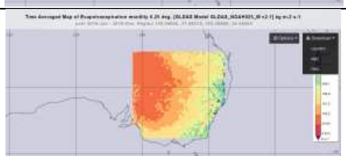
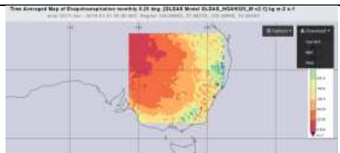
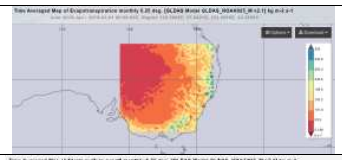
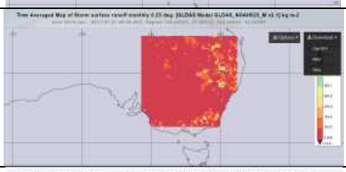
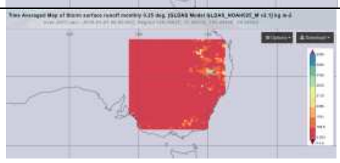
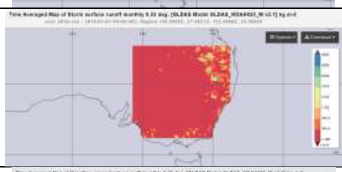
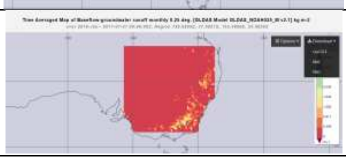
	2016	2017	2018
Pre			
ET			
RO			
Base Flow			

Figure 9: Annual Data for each category

3. RESULT/ANALYSIS

3.1. Annual Pre, ET, and RO over MDB

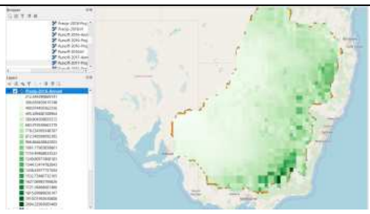
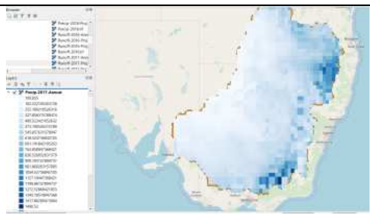
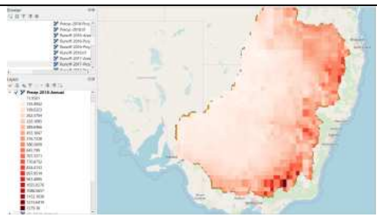
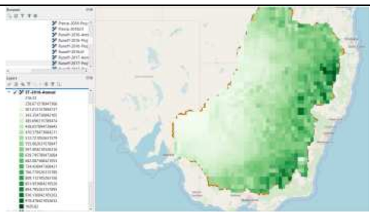
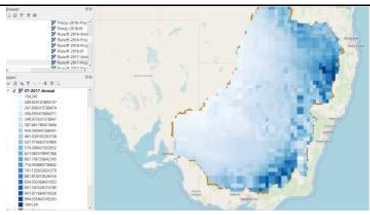
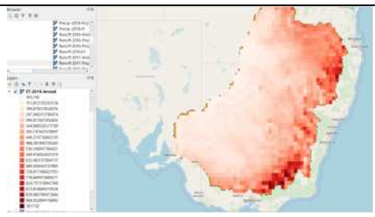
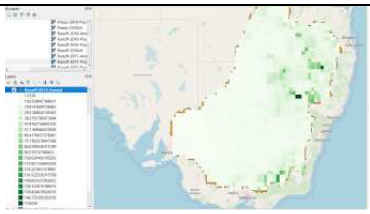
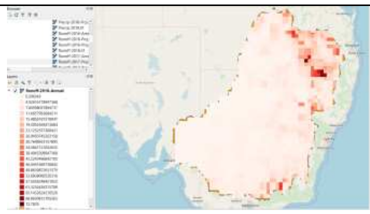
	2016	2017	2018
Pre	 Min 212 Max 2004	 Min 109 Max 1490	 Min 71 Max 1279
ET	 Min 216 Max 1020	 Min 154 Max 1041	 Min 103 Max 1017
RO	 Min 1.3 Max 178	 Min 0.4 Max 185	 Min 0.2 Max 73

Figure 10: Annual Data for each category with MDB

The above precipitation data (fig. 10) is depicting 2016 is a large estimate annual rainfall at MDB comparing with 2017 and 2018. It is illustrating significantly dropping after that. It is same manner are showing ET and RO as well.

4. CONCLUSION

This research focused on the application of remote sensing-based data for access to river networks and assessing surface water budget components in river basins. River Basin Management also requires accurate identification and delineation of watersheds and stream channels within a basin based on terrain and slope. Identification of characteristics of the basin - soil and vegetation, lakes and reservoirs, aquifer/groundwater storage are necessary. Information requires about water demand -residential, agricultural, and industrial in the basin. All freshwater components were based on remote sensing and/or Earth system models and all data are open source. This research demonstrated Remote sensing-based data together with GIS analysis help in assessing the water budget in river basins. Monthly/seasonal and inter-annual variations can be used in water resources and river basin management. In addition to the water budget component, information about socio-economic characteristics and In Situ data (e.g. river discharge, ecosystems) are required for sustainable river basin management.

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