Satellite data use in the WEAP Model as an evaluation of Water Availability in Unda River Basin

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Abstract. Unda river basin is one of the potential river basin in Bali Province of with a perennial river so that water availability is available every year. Even though it has a great potential, the river basin management is not optimal so that during the dry season there is still a lack of water. Water Evaluation and Planning (WEAP) is a model that can combine hydrological processes with management of water allocation in a catchment area. This model can evaluate the water availability in the Unda river basin. WEAP has a tool that is automatic delineation mode that can be used to automatically delineate catchment areas, land cover data and climate data based on satellite data which can make easier to modelling. The results of this study can be used as an evaluation in the water availability in the Unda River Basin so that the potential in the Unda River Basin can be optimal and sustainable.

1. Introduction
Unda river basin is one of the potential river basin in the Bali Province. The Unda River Basin crosses Bangli District in the upstream, Karangasem Regency in the midstream and Klungkung Regency in the downstream. The Unda river basin is a Perennial river with total area of 230,91 km². Unda river basin still has water potential that can still be developed which is proven by the presence of around 91,36 lt/sec in one year of surface water in the Unda river basin that is wasted into the sea [1]. Even though it has a lot of water resources, there are still a lot of Unda irrigation district that is experiencing a water crisis. This happens because there are still many subak that still use non-technical channels that cause water loss that cannot be avoided when draining water on the channel [2].

According to Toban's research [3] the performance of the Unda river basin began to decline, due to various problems in river basin management such as deforestation, siltation of river flow, landslides, erosion and the land use changes that impacted changes towards critical land. Unda river basin is one of the critical river basin which is considered an urgent target for integrated water resources management. During the 2016-2013 period a maximum discharge of 53,4 m³/s was recorded and the lowest discharge was 0,17 m³/s.

To optimize the potential of the Unda river basin and reduce the risks that can occur due to the water use of Unda river basin based on existing conditions that have a large critical area, which indicates rainfall will be easier to flow than stored into the ground, integrated water resources management is needed in the Unda river basin so that the available water potential can be sustainable and there will be no conflict of water access due to competition for access to water use both for drinking water, fulfilment
of domestic water, irrigation and the tourism industry and other sectors that utilize water from the Unda river basin.

Integrated and sustainable water resources management planning is very complex because it is multisectoral. Because of the complexity of water resources planning, it is easier for the model to facilitate it. The water resources management model has been developed both mathematically and in the form of software. One software that has been developed with an integrated water resource management approach is WEAP.

Water Evaluation and Planning (WEAP) is a model of Integrated Water Resources Management (IWRM) which aims to overcome the gap between water allocation management and river basin hydrology process. WEAP can also be used as a forecasting tool to simulate scenarios of changes in water requirements, water availability, flow discharge, water quality, and alternative management of water resources and others that might occur in the future to obtain an optimal management strategy. The availability of accurate data, especially precipitation, is essential for understanding the climate system and hydrological processes since it is a vital element of the water and energy cycles and a key forcing variable for driving hydrological models [4].

WEAP has a tool that is automatic delination mode that can automatically describe water catchments and rivers (using digital elevation data), calculate land area (separated by elevation bands and land cover), and download historical climate data for each catch (with elevation band). This will be a very simple process of setting up and capturing hydrological modelling. WEAP will automatically download global data sets for altitude, land cover and climate as needed.

The HydroSHEDS digital elevation data is based on the high resolution elevation data obtained during the Shuttle flight for NASA's Shuttle Topographic Mission (SRTM). ESA-CCI-LC land cover data comes from the MEdium Resolution Imaging Spectrometer (MERIS) and PROBA-V satellites and a combination of AVHRR and SPOT-VGT data to rank the complete land cover classification covering the period between 1992 and 2015 (24 years) with a resolution spatial 300 m. Princeton's historical climate dataset combines re-analysis data with observations to make global and monthly daily data on temperature, rainfall and wind speed for 1948-2010, at a spatial resolution of 0.25 degrees [5].

Based on this, a water allocation model with WEAP was created, assisted by an automatic delination mode tool to evaluate the availability of water in the Unda river basin for now and in the future as a reference in determining the water resources management planning in the Unda river basin so that the potential in the Unda river basin can be used optimally and sustainably.

2. Research Methods

2.1. Research Location

The Unda River Basin covers 3 districts, that are Karangasem Regency (208,092 km²), Klungkung Regency (11,701 km²) and Bangli Regency (11,122 km²) with a total watershed area of 230.91 km². Water potential from the Unda River is used mainly for raw water and fulfilment of irrigation water needs with an area of 4542.3 ha of agricultural land, which is mostly located in Karangasem Regency. With an area of 230,91 km², the Unda River also has many tributaries, one of which is the Telagawaja River which has an area of 121,561 km² or 52.6% of the area of the Unda river basin itself. In the Telagawaja River flow, it is widely used for tourism activities, especially rafting tours [6].
2.2. Research Tools and Materials

2.2.1. Research Tools
The tool used in processing data in this research is Microsoft Excel 2013 and WEAP version 2019.1.

2.2.2. Research Material
The data needed in this research are primary data and secondary data. The primary data is in the form of a survey of the existing condition of the Unda river basin for taking assumptions in making models, while secondary data in the form of people population, irrigated land area, climatological data, and GIS maps obtained from relevant agencies and literature studies in determining factors used in scenario analysis.

Table 1. Research Data.

| No. | Data Type                                      | Data Source                        |
|-----|-----------------------------------------------|------------------------------------|
| 1   | The existing condition of the Unda river basin| Survey to the research location    |
| 2   | GIS map river basin water withdrawal points Unda river basin | BWS Bali-Penida                   |
| 3   | Unda river basin water allocation scheme      | BWS Bali-Penida                   |
| 4   | Population data                               | Central Bureau of Statistics       |
| 5   | Irrigated land area                           | BWS Bali-Penida                   |
| 6   | Previous research of the Unda river basin     | Related journals, theses or literature |

2.2.3. WEAP Modelling Process
In WEAP model creation there are several steps that must be carried out as follows.

- Delineating the catchment area uses the automatic delineation mode tool. This catchment is based on HydroSHEDS digital elevation data based on high-resolution elevation data obtained from the Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM). DEM data are available at two spatial resolutions: 500 meters (15 arc seconds) and 90 meters (3 arc seconds). To choose which resolution to use, select "15s" or "3s" from the Resolution dropdown.
in the Options box on the right. The data will produce a more accurate catchment and river delineation, at the expense of time (to initially download the larger data files and create the delineation) and space (DEM data files). However, once the delineation is done, the 90 m delineation will not use any more time or space than the delineation created using the 500 m data, so in general it is better to use the 90 m data.

- In addition to delineating the catchment area, then this tool will also produce land cover from the ESA-CCI-LC land cover data from the Satellite and PROBA-V Electronic Resolution Imaging Spectrometer (MERIS) and a combination of AVHRR and SPOT-VGT data from the period 1992 and 2015 (24 years) with a spatial resolution of 300 m. ESA-CCI-LC land cover data is already used in some project for land cover analysis and soil moisture methods [7,8].
- Climate data will also be obtained when using the automatic delineation mode tool. Where this climate data from the Princeton historical climate dataset blends reanalysis of data with observations to create daily and monthly global data of temperature, precipitation and wind speed for 1948-2010, at a 0.25 degree spatial resolution. Then after the catchment area is created then input GIS map of the water withdrawal points in the Unda river basin (in this research only in the form of irrigation demand and water for domestic). Princeton historical climate dataset is already used in some project for modelling the climate scenarios and for forecasting the climate [9,10,11].
- Then enter GIS map of the location points of the spring as the other supply in the water allocation model.
- After all GIS maps have been inputted in the WEAP interface, then proceed with making a water allocation model based on the Unda river basin water allocation scheme.
- Input data on water demand for each irrigation area and domestic collection.
- After all, then interpretation of the modelling results is done to find out the existing water availability and predicted water availability in the Unda river basin in the future.

3. Result and Discussion

3.1. WEAP Model
To create the water allocation model in accordance with the water allocation scheme obtained from the BWS Bali Penida, it starts with making a catchment area by using automatic delineation mode which will delineate the basin, catchment, river, land cover data and climate data in the research location such as Figure 2.

![Figure 2. Automatic Delineation Mode Unda River Basin.](image)

Then the GIS map is inputted into the location of the weir assumed to be the location for withdrawal of the irrigation water and springs location for other supplies and then demand site points are made. Then after the demand site is created, it is continued to make a transmission link that connects the water
withdrawal point and the reach, which then will form a water allocation scheme in the Unda river basin like Figure 3.

3.2. Climatology Data Based on Satellite Data using Catchment Delineation Mode

When catching delineation modes for each sub basin WEAP will automatically load the climatological data in the form of rain, temperature and wind speed data from 1948-2010 based on Princeton satellite data with raster grid 720 rows x 1440 columns in coordinates 90N 180W - 90S 180E with slope of 0.25 degrees or about 28 km. Figures 4-6 below are climatological data for Nyuling sub basin.

Figure 3. Schematic Model in WEAP.

Figure 4. Satellite Precipitation Data with Catchment Delineation Mode.

Figure 5. Satellite Temperature Data with Catchment Delineation Mode.

Figure 6. Satellite Wind Data with Catchment Delineation Mode.

Because the data available only until 2010 to extend the data for the following year to be used in the current account data can be cycled as shown in Figure 7. To get results that are closer to the field
conditions, first year to use has a trend that is almost resembling the trend of climate data in the field. Then first year to use was chosen in 1979 with a base year in accordance with the current account year, 2014.

Figure 7. Cycle Data of Precipitation Data with Catchment Delineation Mode.

3.3. Water Demand Data of Unda River Basin

Water requirements that will be modelled here are only domestic water demand and irrigation water demand, because indeed the Unda river basin is widely used for raw water and irrigation. Irrigation water demand for each irrigation area are calculated based on the cropping pattern of each irrigation area and the area of each irrigation area is then input into WEAP such as Figure 8.

Figure 8. Data Input of Irrigation Water Demand

Where as for domestic water demand, it is calculated based on service coverage, water requirements per person per day and population in each sub-district such as Figure 9.

Figure 9. Data Input of Domestic Water Demand

Because there is a supply of several springs in the Unda river basin water allocation, for the spring discharge input data according to the Unda river basin water allocation scheme such as Figure 10.
3.4. The simulation results of WEAP for the water availability in Unda River Basin are in Future

Based on the results of the simulation using WEAP, there are still some irrigation areas that are experiencing water shortages. The most irrigated areas experienced unmet demand that is Unda Irrigation Area which reached 1,904 m$^3$/s in May 2014. Then based on the simulation results it can be seen that water shortages occurred in May to August (as Figure 11). This may occur because there are still many irrigated areas with large areas that still use the paddy-paddy-palawija cropping pattern, so that in May-August it requires considerable water while the rainfall pattern in the Unda river basin tends to decline in that month.

Whereas for the domestic water demand of each sub-district experiencing the largest water shortage is the Karangasem sub-district which is equal to 0.138 m$^3$/s in May 2024 as shown in Figure 12.
3.5. Demand Site Coverage
Besides being able to find out the unmet demand of each demand site, from the WEAP simulation it can also find out the demand site coverage of each demand site such as Figure 13.

Figure 13. Irrigation Demand Coverage

The average water needs of each irrigation area have been fulfilled 70% -100% but there are some irrigation areas that have not met their water demand such as DI Gambalan, DI Padangaji, DI Umadesa and DI Yeh Masin.

Figure 14. Domestic Demand Coverage

Whereas the domestic demand site, for Bebandem Sub district, Sidemen and Rendang has been fulfilled ranging from 70% -100%, for Selat and Karangasem Sub districts it has only been fulfilled 12%- 40% and for Abang, Manggis and Kubu Districts, their needs cannot be fulfilled as seen in Figure 14.

3.6. Streamflow
For the 2014 streamflow at the outlet, which is at the Telagawaja runoff node, there is still a significant amount of discharge, which ranges from 0.11-6.75 m³/s which is wasted wastefully which still can be optimized and used to meet irrigation water needs and unmet domestic like Figure 15.

4. Conclusion
Based on the WEAP simulation, the catchment delineation mode can be summarized as follows.

- With a catchment delineation mode, climate data with 0.25 degree resolution can be produced which can facilitate the evaluation of water availability in a river basin when the availability of field data is insufficient.
- Based on the simulation results using WEAP, for demand sites in the form of irrigated areas, there are still some irrigation areas that are experiencing water shortages, the most irrigated areas of water are Unda Irrigation Area which reached 1,904 m³/s in May 2014 and water shortages common occur in May to August.
- The average water requirement for each irrigation area has been fulfilled 70% -100% but there are some irrigation areas that have not met their water needs such as DI Gambalan, Padangaji, DI Umadesa and DI Yeh Masin. Whereas the domestic demand site, for Bebandem, Sidemen and Rendang Sub district has been fulfilled ranging from 70% -100%, for Selat and Karangasem Sub districts it has only been met 12% - 40% and for Abang, Manggis and Kubu Sub districts, their needs cannot be fulfilled.
- For the 2014 stream flow at the outlet, which is at the Telagawaja runoff node, there is still a significant amount of discharge, which ranges from 0.11-6.75 m³/s which is wasted wastefully which still can be optimized and used to meet irrigation water needs and unmet domestic.

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