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Demand Simulation for Water, Food Irrigation, and Energy from Micro Hydro Power Plant in Sungai Bayang, Bayang Utara, Pesisir Selatan West Sumatra

Siti Nurlaila Indriani[1,*], *Ahmad Agus* Setiawan[2], and *Rachmawan* Budiarto[1]

[1]Dept. of Nuclear Engineering and Engineering Physics, Gadjah Mada University, Yogyakarta, Indonesia

Abstract. Clean water or fresh water, food and energy are basic human needs. The three basic needs are dependent to one another. The relationship between the three is called the "The nexus of Water, Energy, and Food". It requires good governance on watershed which will be implemented for example to manage water resources to fulfil demand of clean or drinking water, irrigation in food area and energy sources in hydro power plant. This study conducted analysis and simulation to prepare projection of electricity produced by Micro hydro Power Plant (MHP) It integrates a climate change scenarios to forecast its influence on electricity demand and response of river. In addition, the study also presented projections of influence on irrigated food production scenario in irrigation for rice paddy fields. Projection of The MHP electricity and the water demand including for the food sector is conducted by using the WEAP (Water Evaluation and Planning) software, while electricity demand forecast is conducted by applying the LEAP (Long-Range Energy Alternatives Planning) software. The case studies in this study conducted in river flows Bayang's River. On the river there are three operating MHPs: The Muaro Aie MHP (ity30 kW of installed capac), The Koto Ranah MHP (30 kW) and The Pancuang Taba MHP (40 kW). The LEAP simulation projected electricity demand for Pesisir Selatan until 2025. Demand for South Pesisir Regency up to 2025 is predicted to reach 226.4 GWh with growth of 11.2% per year in BAU scenario, while reach 113.7 GWh with a 5% annual growth in efficiency scenario. The WEAP provided projected electricity production of MHP, basic water needs and irrigation needs for paddy fields in District IV Nagari Bayang Utara until 2025. The MHP electricity production in final year of projection with BAU scenario reaches 0.88 GWh, while with a climate change scenario of 0.63 GWh. The electricity demand fulfilled by MHP is predicted to be 0.39% in the BAU scenario, 0.28% in climate change scenarios, and 0.55% in the electricity savings scenario. Of the three MHP, the MHP Pancuang Taba is the most vulnerable to climate change, while MHP Koto Ranah shows relatively lower fluctuation. The highest staple water requirement is for Pancuang Taba which is 3643.4 thousand m3. The growth of staple water needs until 2025 tends to be constant. and most rice irrigation needs are in agriculture 2 of 976 thousand m3. The growth of irrigation needs of Bayang watershed until 2025 tends to be constant. Most irrigation needs for paddy fields are in irrigation area of "Agriculture 2" reaching 976,000 m3. The growth of irrigation needs in Bayang watershed tends to be constant.

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1 Problem Statement

Clean water or fresh water, food and energy are basic human needs. Without all of it, people will not be able to live properly. The three basic needs are also interdependent with each other. In a certain situation, the scarcity of energy will affect water supply. This is because to produce water (with desalination) requires large amounts of energy, for example for desalination, wastewater treatment, water distribution (pumps), and others. Conversely, to produce energy is also needed water, for example MHP (Micro Hydro Power Plant). On the other hand, water scarcity will obviously cause food scarcity. Similarly, food scarcity will cause the standard of human life to decline, thus affecting the quality of work, for example in the energy industry sector. The relationship between these three is called "The nexus of Water, Energy, and Food" (red: water relations, energy / electricity, food). [1]

The rapid growth of the world's population causes the world's water resources to become one of the most

* Corresponding author: sn.indriani@gmail.com

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important assets. Water is essential for human consumption and sanitation, for the production of various industrial goods as well as for the production of food and fibre fabrics. Water demand for irrigation is increasing to meet the needs of human food. Care-based design and careful management are essential to achieve water utilization efficiency. [2] The water source of the river is not only to meet basic needs of basic water and food needs in the form of irrigated rice fields and fields, but also used as a source of MHP use. Ultimately this led to the need for governance management of watershed use to be used for basic water needs, food irrigation, and MHP power sources.

Water cannot escape from a water source, one of the water sources is a river. Rivers exist in different regions of the hemisphere. Water from various places flows into the river that will be forwarded to the sea. Watershed is a region on the surface of the earth where there is a water system consisting of the main river and some of its subsidiaries (Ritter 2003). Watershed geometry that affects runoff is the size, shape, slope, orientation, elevation and river density (Shelton 2009). Meanwhile, several physical properties of watersheds that also affect the use of land and land cover, surface infiltration, soil type, permeability, water capacity and the presence or absence of lakes and swamps. River properties such as size, shape, stroke and length affect the capacity of river stores and determine peak discharge times (Shelton 2009). [2]

Climate change is a threat to the earth, because it can affect all aspects of life that will affect the balance of life of the earth. Climate change is the occurrence of changes in atmospheric conditions, such as temperature, and weather that causes an uncertain condition. [3] The rise in temperature will cause the expansion of water masses and sea levels. Climate change will also affect hydrological systems such as watersheds and river flows.

Irrigation has been done by farmers in Indonesia since time immemorial by using streams of creeks. These small irrigation networks are built by using watersheds to irrigate fields and fields that will meet food needs. Food demand is influenced by the ability of the regions to provide food resources, because from the graph, rice imports from time to time increase. So that water, energy, and food needs can be obtained from one resource, that is river water resource.

In the National Energy Policy Presidential Regulation no. 5 of 2006 with the aim to direct efforts to realize the security of supply (energy of supply) to support sustainable development, which is expected by the year 2025 will be achieved target energy elasticity. The elasticity of energy is the ratio between the growth rate of energy consumption and the rate of economic growth. Therefore, the energy conservation program to obtain economic growth, poverty reduction, environmental sustainability, energy security with the basic pattern of energy efficiency supported by the regulation in the field of energy conservation. Water energy is included in the category of Natural Resources that can be renewable. Development of Renewable Power Generators is a priority because renewable energy can be available throughout the ages.

The analysis study of how the river relates to energy generation, about how water resources management, about the nexus of water, energy, food on a macro scale, and on the prediction of electricity needs, general energy needs using Long-range Energy Alternative Planning (LEAP) applications and on the prediction of the production of solar and electric power plants using LEAP.

In a micro-scale review, one or more watersheds covering an area can be managed to be potential water resources to meet the community's need for water resources. Needs that can be managed are basic water needs, water needs for irrigation fields as food sources and energy needs that can be obtained from micro hydro power plants. Furthermore, predictions of electricity demand, basic water sources and water for food irrigation can be obtained. Projection of the demand for electricity, water source and water for irrigation will also be obtained. Similarly, climate change scenarios that will affect the fulfilment of any need will be obtained. So, it is expected that the management of water resources maximally to meet the nexus of water, food, and energy in an area can be done.

Sub-district IV Nagari Bayang Utara is located in Pesisir Selatan Regency, West Sumatera Province. River Basin Batang is located in District IV Nagari Bayang Utara. This research is a follow up study on MHP and the integrated water-energy management scenario in Pesisir Selatan Regency, West Sumatera. This area is chosen because there is one flow that has more than one MHP, also the availability of data, because there are rain gauge stations in the river and in Tarusan River which is adjacent to Bayang River which can be used as data, and then easy access to the location. This location can be said to be quite remote, plus the local people use direct river water to meet water needs, so the watershed is a vital source of life for the surrounding community. Thus, good watershed management is an important issue for this region. [4].

2 Figures and tables

This study projected the MHP electricity production under climate change scenarios and integrated the demand for electricity demand. In addition, projection of food production with irrigation and irrigation field scenarios is predicted with demand for food and basic water needs. MHP projection and food irrigation needs are carried out using WEAP (Water Evaluation and Planning) software, whereas electricity demand prediction is done using LEAP (Long-range Energy Alternatives Planning) software.

The location of this research is Sub district IV Nagari Bayang Utara located in Pesisir Selatan Regency, West Sumatera Province. River Basin Batang is located in District IV Nagari Bayang Utara. This research is a follow up study on MHP and the integrated water-energy management scenario in Pesisir Selatan Regency, West Sumatera. This area is chosen because there is one flow that has more than one MHP, also the availability of data, because there are rain gauge stations in the river and in Tarusan River which is adjacent to Bayang River which can be used as data, and then easy access to the location. This location can be said to be quite remote, plus the local people use direct river water to meet water needs, so the watershed is a vital source of life for the surrounding community. Thus, good watershed management is an important issue for this region. Flowchart research steps can be seen in Figure 1 below.

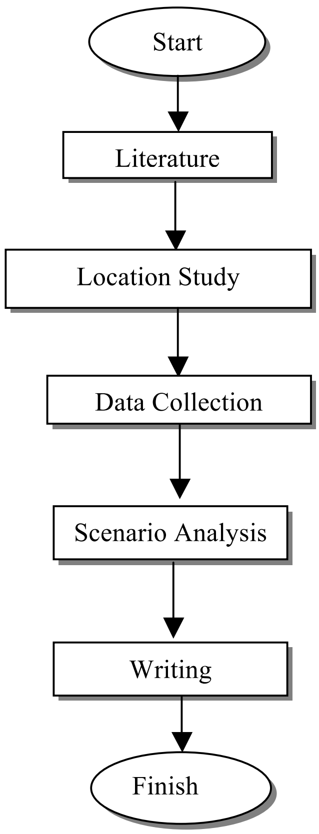

Fig. 1. Research flowchart.

3 Results

3.1 LEAP-WEAP Simulation

Energy demand simulation is done by using LEAP software. The method used in this simulation is based on the end-use model. The equation used as the analysis with the energy intensity variables and the number of consumers as unit activity level.

LEAP modelling steps generally consist of five stages: problem definition, system conceptualization, model representation, model evaluation, and policy analysis.

The simulation of water availability is done by using WEAP software. The method used in this simulation is based on the trend approach. Hydrological modelling is done by incorporating climatological data over the last 20 years to see the trend of climate factors.

Before carrying out the simulation of water availability using WEAP, firstly analyse the mainstay discharge. Calculation of reliable debit is done using Mock Method By following the following stages: Potential Evapotranspiration Calculation (ETo), Calculation of Basic Water Requirement, Calculation of Irrigation Water Requirement.

In this research, WEAP calculation of debit is done by using soil moisture method. This method uses data of rainfall and monthly climatology as input data. The data is then processed to produce the output of evapotranspiration, discharge, and storage of ground water. Water availability calculation scheme by WEAP is shown in Figure 2 below:

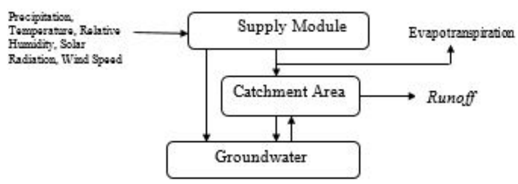

Fig. 2. WEAP calculation scheme.

The implementation phase of water availability simulation with WEAP is as follows:

3.1.1 Basic parameters

The first step in the simulation is to set and determine the basic parameters of the simulation. In the basic parameters, the scope of work is determined on the catchment and the MHP (resource). The next step is to determine the base year of simulation. In this study used as the base year is 2013, based on the data held as the basis for calculation. After that, the final limit of the simulation period is determined in 2025. The last is to determine the units used such as energy units, debit units, and area.

3.1.2 Schematic

The second stage after setting the basic parameters is to create a schematic view of the watershed system or stream to be modelled. To help draw the river and display the position of certain sites such as hydropower, wastewater treatment, groundwater storage, etc., users can enter GIS-based maps as the basic screen in WEAP. In this study, which became the basic screen is a map of

West Sumatra that contained the river and the location of the MHP to be assessed. The next step is to redraw the river and put the MHP according to the layer that has been displayed. Figure 3 Shows the view schematic view in this research.

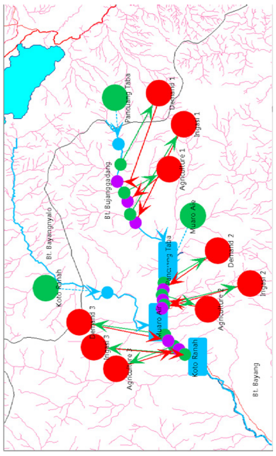

Fig. 3. Schematic view.

3.1.3 Catchments

Catchments are part of a branch that serves to model the watershed to be studied. As the basis of the simulation, first one of the calculation method, based on the data owned. Watershed modelling in this research using Soil Moisture Method.

After determining the calculation method, hereinafter is entering data in current account condition that is base year condition (base year). The base year used is 2013, so the initial input written in the expression section is based on the data of that year.

In this study, the available data is only sufficient to meet the Land use and Climate categories. The data included in the Land use category is the watershed area for each MHP. As for the Climate category, climatological data required are rainfall data, temperature, humidity, wind speed, and solar radiation.

Evapotranspiration in WEAP was calculated using the Penmann-Monteith equation, whereas the discharge was calculated by equation.

3.1.4 Supply Analysis

Supply Analysis is a branch that determines the characteristics of calculating the value of water availability. In this study water availability is calculated to generate electricity at three MHPs. To model the MHP system, technical data i.e. effective head and turbine efficiency data are included to calculate the production of electricity generated factually.

3.1 Input-Output Research

The data used in this study are summarized in Table 1 below:

Table 1. Data input and output on LEAP & WEAP.

Calculation	Input	Assumption	*Software*	Output
Energy Demand	- Energy Intensity - Electricity Consumption - Total Population - Electricity Customers - PDRB		LEAP	Energy Consumtion
Debit	- Temperature - Humidity - Wind Velocity - Sun Radiation	- The annual solar radiation is constant against the earth	WEAP	Evapotranspiration
	- Evapotranspiration - Rainfall - Watershed Area	- Soil moisture coefficient (RRF = 3) - Numbers of groundwater catch (SMC = 200mm) - No land use change	WEAP	Debit
Plant Irrigation	- Harvest crop production - area of harvest - number of cropping cycles per year - rainfall - crop water requirements	- planting cycles per year based on crop cycle theory prevailing in Indonesian society - crop water requirements calculated from Kc	WEAP	Irrigation water volume
Basic Water Requirement	Population	- ideal water requirement 50liter / day / person	WEAP	Volume of staple water
MHP Electricity Production	- Debit - *Head* MHP	- The efficiency of MPH system is considered constant - MHP works 8760 hours / year	LEAP & WEAP	Power

There are two stations that record rainfall and climatology data on the Bayang basin. Both stations are located on different sub-watersheds, but can represent climatological conditions that affect the flow of the river (shaft) of Shadow. The location of the station is shown in Table 2.

Table 2. Rainfall monitoring and climatology stations.

Station	Coordinat	Sub-DAS
Danau Diatas	01^{0}04’40,3” LS / 100^{0}46’35,7” BT	Bt. Bujanggadang & Bt. Bayanggadang
Tarusan	01^{0}15’12” LS / 100^{0}29’13” BT	Bt. Bayangnyalo

Rainfall and climatology data used in the calculation is in the form of monthly data for the last 20 years (1992 - 2012). The rainfall chart on both stations is shown in Figure 4.

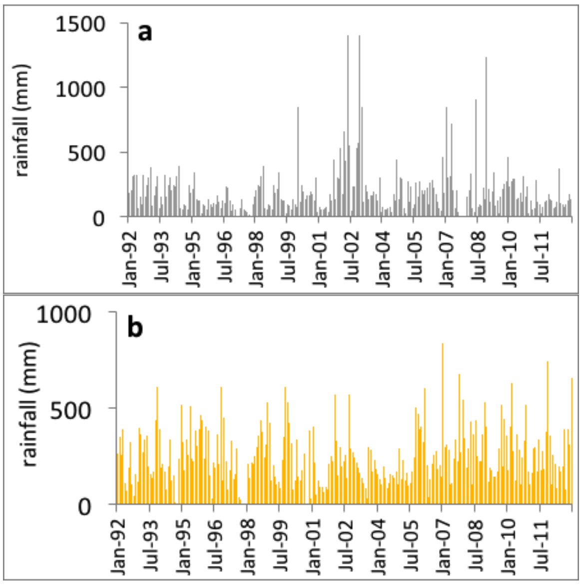

Fig. 4. Rainfall chart on both stations.

The rainfall graph shows the variability of rainfall events per month on both stations. In the Diatas lake station data, there are three times extreme rainfall events exceeding 1000 mm in one month. While at the data station Tarusan, the highest rainfall only reached about 800 mm. Average rainfall per year on both stations is 2328 mm for the Lake Diatas station, and 2998 for the Tarusan station. Other input data are temperature, relative humidity, wind speed and solar radiation.

3.2.1 Business as Usual (BAU) Scenario

BAU scenario is a continuation of the trend that occurred in previous years, both in terms of electricity demand and water availability. In terms of electricity demand, since 2008 there was an average growth of 11.12%. The projected output of electricity demands up to 2025 with a constant growth rate is shown in Figure 5.

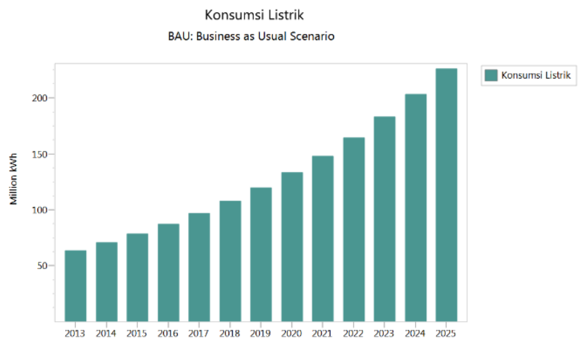

Fig. 5. Output of electricity demand.

In the BAU scenario, there is a very sharp increase in electricity demand side. By 2025, electricity demand is projected to be at 226.4 GWh, whereas in 2013 electricity demand was at 63.3 GWh. This means that within the next 12 years, electricity demand is predicted to grow to 257.67% or almost 2.5 times.

In terms of water availability, the trend approach is used to predict watershed conditions and sub the next 12 years. This trend approach is used in the BAU scenario with the assumption that there is no significant land use change and the MHP remains functioning normally during the projection year.

The electricity production of each MHP is shown in Figure 6, While the overall MHP electricity production until 2015 is shown in Figure 5.28. On the graph shows that MHP Pancuang Taba is relatively more susceptible to fluctuation of debit compared to Muaro Air and Koto Ranah MHP. The fluctuation of the discharge that occurs is influenced by the variation of rainfall in that period.

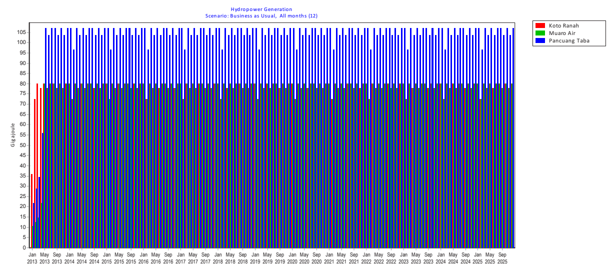

Fig. 6. The electricity production of each MHP.

In the projection of electricity MHP BAU scenario there are several times a significant decrease in electricity production, among others in the period January - May 2014, March - June 2017, and August - December 2020. MHP Pancuang Taba power production decreased drastically and MHP Muaro Water is reduced by 50%. This is due to the occurrence of dry season in the period of no-rainy upstream periods recorded in 1994, 1997, 1999, 2001, 2004 and 2007. The simulation results show the flowing discharge at the Bt. Sub-watershed. Bayanggadang and Bt. Bujanggadang is below the 0.2 m3 / s.

Fluctuating electricity production is also predicted to occur in the year 2024 - 2025. This can happen if the rainfall conditions that occur is a repetition of rainfall in 2011 & 2012 where monthly rainfall changed in the extreme.

Annual electricity production is shown in Figure 7. Decrease in the discharge that occurred in several periods also influence the decrease of electricity production. In this scenario of BAU, the decrease of MHP electricity production is predicted to occur in 2014, 2017, and 2020. The highest electricity production occurs in 2015 which reaches 3,152 GWh, while the lowest electricity production occurs in 2014 of 2,751 GWh. Electricity production in 2025 (the end of the projection) is predicted to be 3.152 GWh.

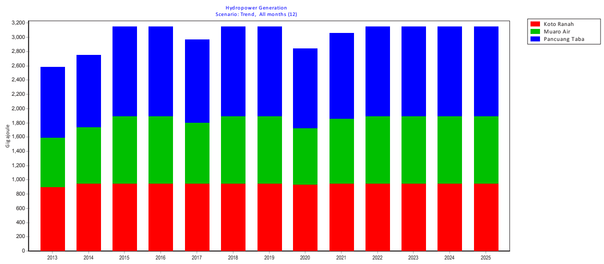

Fig. 7. Annual electricity production.

The projection of electricity generation by MHP is then compared with the projection of electricity demand of Pesisir Selatan regency. So that the electrical production data from WEAP. It can be exported in the form of excel to facilitate the calculation. Electrical production is then divided by electricity demand in Figure 8. From LEAP which can also be exported into excel form and then the result can be seen in graphic form. This comparison will result in the percentage of electricity demand fulfilled as shown in the graph in Figure 8.

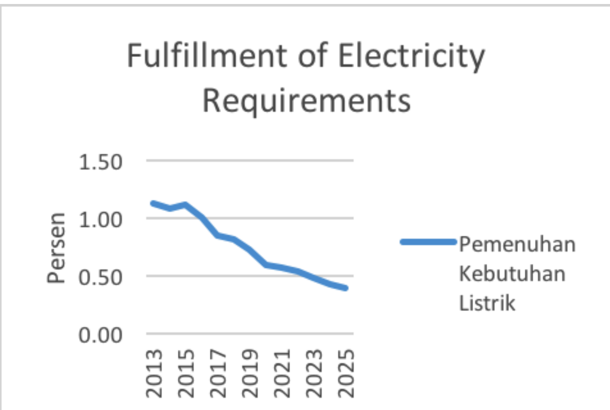

Fig. 8. Fulfilment of electricity requirements.

The percentage of electricity demand fulfilled by MHP shows a downward trend until 2025. This is due to the demand of electricity itself which continues to increase to 226.4 GWh or by 257.67% in the final year of projections. In 2013, MHP is able to generate electricity by 0.72 GWh or 1.13% of total electricity demand for the year. However, by 2025, MHP will only generate 0.875 GWh of electricity or 0.39% of total electricity demand for the year. Calculation of the percentage of electricity consumption can be seen in Table 3.

Table 3. Electricity consumption percentage.

Electricity Consumption	63.3	70.4	78.3	87.1	96.8	107.7	119.7	133.1	148.0	164.6	183.1	203.6	226.4
Electricity Production	0.72	0.76	0.88	0.88	0.83	0.88	0.88	0.79	0.85	0.88	0.88	0.88	0.88
Fulfillment (%)	1.13	1.09	1.12	1.01	0.85	0.81	0.73	0.59	0.58	0.53	0.48	0.43	0.39

In WEAP Schematic, basic water requirement is assumed as Demand 1, Demand 2, and Demand 3. Demand 1 is the staple water requirement of Pancung Taba population, Demand 2 is the main requirement of drinking water of Muaro Aie, whereas Demand 3 is the basic need of drinking water Residents of Koto Ranah area.

To enter the value of the basic water needs, data on the number of residents of Pancung Taba, Muaro Aie and Koto Ranah are multiplied by the amount of water required in one day, 60 liters then multiplied by 365 days, the water needs of the three regions in the period One year. In Figure 9, can be seen input data entered in Demand 1, Demand 2, and Demand 3.

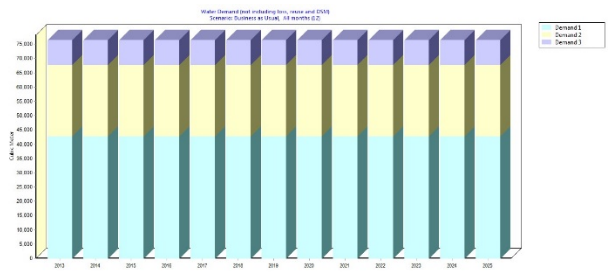

Fig. 9. Data entered in Demand 1, Demand 2, and Demand 3.

Irrigation water demand can be used as a demand that will be calculated for planting water requirement for each plant in m3 / Ha. Data to be included in the form of land area and water volume requirement within one year. Because the required data is the land area of Nagari Pancung Taba, Muaro Aie, and Koto Ranah, so to find the planting area of each nagari obtained from the percentage of the area multiplied by the total planting area of North Bayang District. In this WEAP simulation.

The water requirements of the plants to be simulated are for the needs of rice and *palawija*.

To find the rice cultivation area and the crops of each Nagari is obtained by multiplying the percentage of Nagari area compared to the area of North Bayang then multiplied by the total area of rice harvest and the crops. As for the water requirement on rice according to the Ministry of Agriculture is at least 99.7 m3 / Ha which is then multiplied 3 times the planting time within a year. As for the crops of *palawija* according to the Ministry of Agriculture, requires 2300-2400 m3 / Ha for water planting purposes, which will be taken the middle value between the two is 2350 m3 / Ha. Next will be multiplied also with 3 times the planting time in a year. For rice and *palawija*, it is an almost equal standard in Indonesia if it has average planting time 3 times a year.

In Figure 10 can be seen all the demand required in WEAP simulation, namely the demand of water staple named Demand 1, Demand 2, and Demand 3. Then the demand for rice irrigation is called Agriculture 1, Agriculture 2, and Agriculture 3. Then the demand of the crops Called Irrigation 1, Irrigation 2, and Irrigation 3.

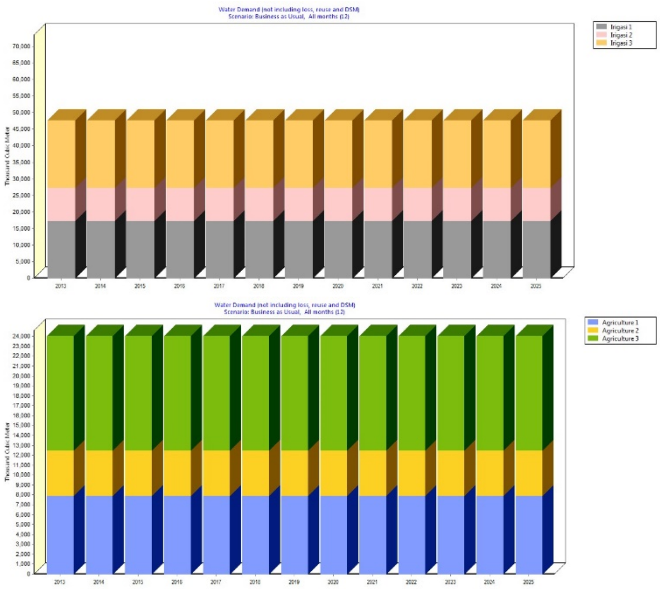

Fig. 10. Demand required in WEAP simulattion.

4 Conclusion

Based on the research that has been done, it can be concluded as follows:

1. Demand for South Pesisir Regency up to 2025 is predicted to reach 226.4 GWh with growth of 11.2% per year in BAU scenario; And 113.7 GWh with a 5% annual growth in efficiency scenario.
2. MHP electricity production in final year of projection (2025) with BAU scenario is 0.88 GWh; While with a climate change scenario of 0.63 GWh.
3. The electricity demand fulfilled in 2025 by MHP is predicted to be only 0.39% in the BAU scenario; 0.28% in climate change scenarios; And 0.55% in the electricity savings scenario.
4. Of the three MHP, MHP Pancuang Taba is the most vulnerable to climate change, while MHP Koto Ranah is relatively more stable.
5. The highest staple water requirement is at Demand 1 ie Pancuang Taba which is 3643.4 thousand m3. The growth of staple water needs until 2025 tends to be constant.
6. Most rice irrigation needs are in Agriculture 2 of 976 thousand m3. The growth of irrigation needs of Bayang watershed until 2025 tends to be constant.
7. The most irrigation needs of rice is in Irrigation 3 of 1726.5 thousand m3. The growth of irrigation needs of Bayas watershed until 2025 tends to be constant.

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