EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2024, 25(7), 260–273
https://doi.org/10.12912/27197050/188715
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Received: 2024.05.08
Accepted: 2024.05.20
Published: 2024.06.01

Analysis of the Impact of Land Use Change on Water Management Balance East Sinjai Regency, Indonesia

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ABSTRACT

This study aims to analyze the impact of land use change in East Sinjai Sub-district on the Kalamisu River Watershed and evelop water management strategies to balance availability with population needs. Utilizing GIS methods with ArcGIS 10.8 and Landsat satellite imagery, land use change in East Sinjai District was examined. Additionally, water infiltration capacity analysis considered factors such as rock type, rainfall, soil type, slope, and land use. Reference materials include the Technical Guidebook for Groundwater Management (DESDM Geological Agency, 2007) and the Regulation of the Minister of Forestry of the Republic of Indonesia No. P.32/MENHUTII/2009 on Procedures for the Preparation of RTkRHL-DAS. The study's outcomes will feed into a SWOT analysis to craft a management strategy for the area over the next decade. This research aims to contribute positively to the Sinjai Regency government and enhance scientific discourse on water governance and spatial management. Qualitative analysis was employed to elucidate the area's physical condition and analyze quantitative data and information pertinent to resource management processes and water management strategies. Primary data from satellite image interpretation and interviews supplemented by secondary data were utilized for problem identification and data analysis. The analysis indicates a substantial increase in land use in East Sinjai Sub-district from 2012 to 2017, notably in residential areas, with a rise of 136.6 hectares due to a population surge of 58,986 people. Water infiltration in the Kalamisu River watershed is critically low. Water availability in East Sinjai District has notably decreased by -4,658,505 cubic meters per year from 2012 to 2022. To enhance groundwater absorption capacity and availability, promoting the use of high water-absorbent plantation land is essential. Additionally, developing mangrove areas is crucial for improving water infiltration, particularly in quality and quantity, especially during dry seasons.

Keywords: land use, water discharge, population, water balance, East Sinjai Sub-district.

INTRODUCTION

Utilizing natural resources without regard to environmental aspects of development aimed at improving human welfare with an emphasis on economic growth can put pressure on the environment. The population is increasing from year to year, but this also has the potential to cause environmental degradation. Increased changes in land use patterns and increased industrial activity with the aim of meeting the economic needs of the community as high environmental pressure.

As an important force shaping landscapes globally, the place of natural and semi-natural areas has become an important consideration for policymakers. Among the drivers mentioned above, factors related to socio-economics, and politics have the most significant implications for land cover change, which in turn impacts habitat and bio-frame loss and land degradation on a global scale (Girao et al., 2023; Qi et al., 2022; Delphin et al., 2022).

Land use change on a massive scale (for example due to the opening of large-scale plantation areas, such as oil palm plantations, opening of residential and industrial areas) can cause rainwater that should seep into the soil (in the form of infiltration and percolation), will turn into surface flow runoff which generally flows into rivers and lakes. This can affect the water balance and the surrounding environment (Arsyad, 2006). Relatively extensive land use changes in watershed areas can cause disruption of the hydrological cycle. This can disrupt the balance of water resources in a watershed.

East Sinjai Sub-district is a sub-district in Sinjai Regency that is experiencing relatively rapid population growth. Based on the results of the 2023 population census of Sinjai Regency, the population growth of East Sinjai District can be seen from the increase in population in 2010–2022 which experienced an increase in population of 1,588 people and BPS 2023 data for East Sinjai District shows that the population in 2022 was 35,629 people. According to Regional Regulation Number 28 of 2012 concerning the Regional Spatial Plan (RTRW) of Sinjai Regency for 2012–2032, water sources in East Sinjai District include the Kalamisu Watershed (DAS) with an area of 32.8489 km^2 located in East Sinjai but still need to be managed to fulfill clean water needs in East Sinjai District. There are conditions where during the dry season many residents experience a crisis of clean water. Therefore, it is necessary for an adequate management strategy to be carried out to maximize the level of clean water demand in East Sinjai District.

Water resources in the East Sinjai Sub-district are currently dominated by the community using deep groundwater sources, springs, and some deep wells. Water sources in East Sinjai Sub-district are currently dominantly still managed by each family head and part of the government's management with community sanitation-based clean water supply activities (Pamsimas). Kalamisu River water discharge fluctuation data for the last 5 years based on Kalamisu River irrigation data shows that there is a decreasing level of Kalamisu water discharge in 2019 of 1,285,483.49 liters/second and in 2023 with a discharge of 479,346.30 liters/second.

For this reason, it is necessary to manage land use change so that the water catchment area in East Sinjai District is maintained. Thus the water balance in the Kalamisu River basin in East Sinjai District to meet the water needs of the community can function optimally. Based on this, it is necessary to research the impact of land use change on the balance of water management in the Kalamisu River basin, East Sinjai District. Therefore, this research will enrich scientific discussions about spatial management related to water management.

STUDY AREA

Sinjai Timur Sub-district is astronomically located in Sinjai Regency, one of the nine sub-districts in Sinjai Regency with an area of 71.88 km^2 out of 819.96 km^2. East Sinjai District is one of the sub-districts in Sinjai Regency which is experiencing rapid growth located georaphically between 120º14´17,64“ East Longitude 5º9´24,309” South Latitude. Based on the physical aspects of the area East Sinjai District Topographic conditions generally have a flat to undulating surface and a small portion is hilly. The dominating condition of the East slope is plain 2,458.81 ha to sloping 2,196.74 ha. The type of soil in an area or region will be related to the condition of the area which is formed from a rock that has undergone weathering. The climate of an area or region is strongly influenced by the amount of rainfall and air temperature. Tropical rainfall climate conditions with two seasons, namely the dry season and the rainy season. The characteristics of land use in East Sinjai Subdistrict currently consist of several forms of land use, of the total land use in East Sinjai Subdistrict rice fields and plantations/gardens are the largest land use with rice fields having an area of 2,867.73 ha or 37.55% and plantations/gardens having 2,604.31 ha or 34.10%. Based on the results of the 2023 population census of Sinjai Regency, the population growth of East Sinjai District can be seen from the increase in population in 2010–2022 experiencing an increase in the population of 1,588 people and Statistics Center or BPS (abbreviation of in Indonesia) 2023 data for East Sinjai District shows that the population in 2022 is 35,629 people. Kalamisu River water discharge fluctuation data for the last 5 years shows that there is a decreasing level of Kalamisu water discharge in 2019 of 1,285,483.49 m^3 /s and in 2023 decreased with a discharge of 479,346.30 m^3/s.

MATERIALS AND METHODS

The study approach in this research was conducted using quantitative analysis and qualitative analysis to identify the need and availability of water resources. To identify the potential for additional water resources in the study area.

Research approaches and techniques data used in this study are primary data and secondary data. The collection of information was carried out by studying literature as a theoretical reference and documents from related agencies, while primary data was obtained by conducting interviews with stakeholders related to strategy formulation. The survey techniques used are, literature studies, Agency surveys and interviews conducted to explore information through secondary data that can support the process of problem identification and data analysis to formulate strategies for managing water infiltration in the Kalamisu watershed with the level of population needs in East Sinjai District. Direct observation, (cross check) to get definite information about the data changes that occur at the research location.

Data on the physical characteristics of the area include Regional maps: administrative maps, topography, slope, geology, and land use from relevant agencies. Administrative map data, topography, slope, and geology are used to determine the physical condition of East Sinjai District. Climate data of East Sinjai Subdistrict 2012 to 2022 from the National Disaster Management Agency and the Environmental Management Office of Sinjai Regency Land use map data from 2012 to 2022 is used to determine land use changes by using rainfall values, and the value of the water runoff coefficient to obtain the potential amount of surface water runoff and the potential amount of water that seeps into the ground. Kalamisu River flow discharge data for the last 5 years 2019 to 2023 from the UPT Jeneberang Blangko No. 0.8 0–2 Office is used to determine changes in water flow in the East Sinjai District area.

Objective 1 is to identify the influence of land use change in East Sinjai Sub-district on water availability, as well as factors that influence land use change. Land use data used to assess the composition of land use is the condition in the past and the current existing conditions of the research location in the span of 3 periods, namely in 2012, 2017, and 2022. The data processing method used in the analysis of land use change is the Geographic Information System (GIS) method with Arcgis 10.8 application tools with Landsat high-resolution satellite imagery by overlaying the conditions of the research location.

Objective 2 is to formulate a strategy for managing the Kalamisu water catchment area so that there is a balance with the level of demand in the next 10 years in East Sinjai District. The approach used is a mathematical calculation with a certain formula to predict the population for the next 10 years to anticipate the needs and supplies in terms of water use for the benefit of water governance in the Kalamisu River basin.

The types of data used are secondary data from relevant agencies and primary data obtained from interviews. The types and sources of data used in the analysis are, data on the physical characteristics of the area and landscape of East Sinjai District, land use map data in 2012, 2017, and 2022.

Analysis of land use change

The analysis begins with the interpretation of Landsat satellite imagery in the span of 3 different periods, namely in 2012, 2017, and 2022, and then the methodological process of extracting thematic information from satellite imagery to produce land use maps (Figure 1). To find out how much land use changes in the research location during the specified period. This process was conducted using GIS application as an analytical tool to determine the extent of land use change in East Sinjai Subdistrict.

Analysis of water infiltration capacity

This method shows the condition of the water carrying capacity of an area, by considering the ability of water infiltration conditions and water availability. With this method, it can be known in general whether water resources in an area are in surplus or deficit. Water availability is determined using the runoff coefficient method based on land use information and yearly rainfall data. The calculation is carried out in the following stages:

- calculation of water availability (supply),
- calculation using the runoff coefficient method modified from the rational method,
- guidelines for determining environmental support capacity in Regional Spatial Planning (2009).

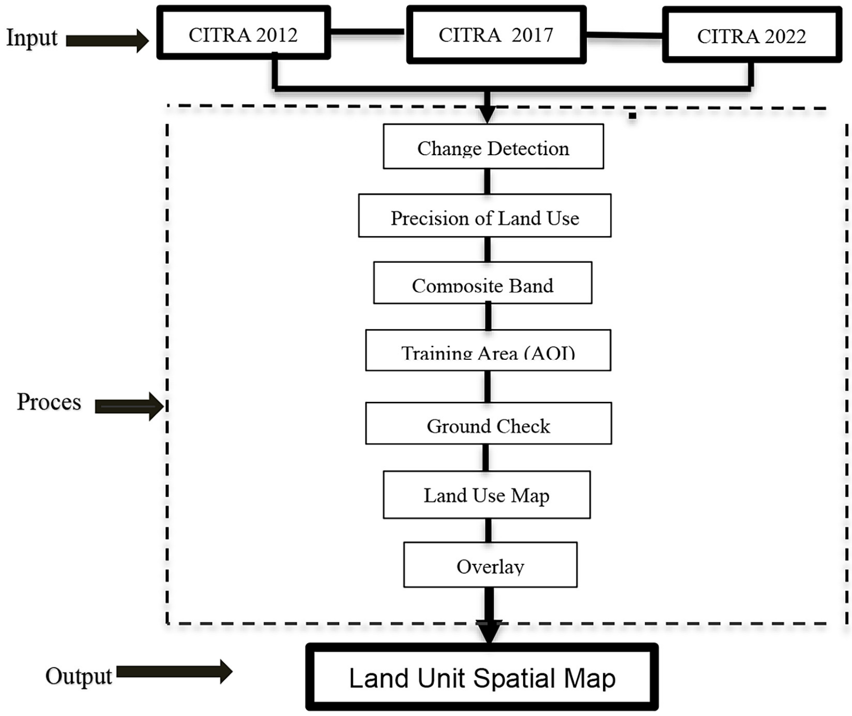

Figure 1. GIS work method

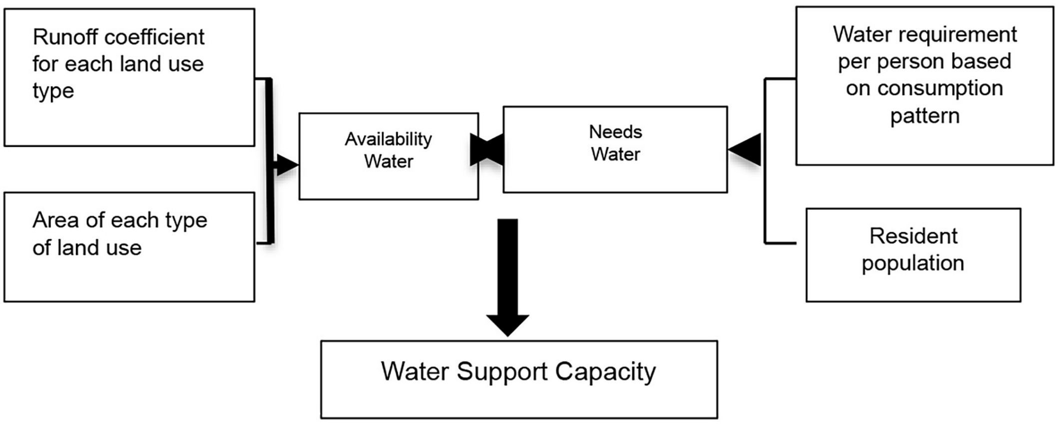

Figure 2. Source water support research design: procedures for the preparation of technical plans for forest and land rehabilitation in watersheds (RTkRLH-DAS, 2009)

Water balance analysis

To calculate the water balance, it is needed to calculate population projections for the next 10 years. To find out the projected amount of population growth in the next 10 years in East Sinjai District, population projections are carried out in each year with the purpose of estimating the amount of water needed in the future. Population projections of population numbers are carried out mathematically, namely arithmetic, geometric and exponential methods (Central of Statistics, 2010).

Next calculation of water availability (supply) calculation using the runoff coefficient method modified from the rational method is shown in formula below:

$$C = \sum(ci \times Ai)/\sum Ai \quad (1)$$

$$R = \sum Ri/m \quad (2)$$

$$SA = 10 \times C \times R \times A \quad (3)$$

where: SA – water availability (m^3/year), C – weighted runoff coefficient, Ci – runoff coefficient of land use, Ai – area of land use i (ha) from BPS or regional data, in

Figures, or from the data of the National Land Agency (BPN), R – algebraic average of the region's annual rainfall (mm/year) from BPS or BMG data or local related agencies, Ri – annual rainfall at station I, m – number of rainfall observation stations, A – area (ha), 10 – conversion factor from mm·ha to m^3.

$$Qd = \gamma \times Sd \quad (4)$$

where: Qd – domestic water demand discharge (liters/day), Sd – standard domestic water demand (liter/day), γ – total population (soul).

Calculation of water demand with the rational method:

$$\text{DDA} = \text{SA}/\text{DA} \quad (4)$$

where: DDLB < 1 – water carrying capacity is exceeded or poor, DDLB 1–3 – conditional or medium carrying capacity, DDLB > 3 – safe or good water-bearing capacity, DDA – water carrying capacity, SA – water availability, DA –water demand.

The status of water carrying capacity is obtained from the comparison between water availability (SA) and water demand (DA). If SA > DA, the water carrying capacity is declared surplus. If SA < DA, the water carrying capacity is declared deficit or exceeded.

Next, the calculation of the amount of clean water demand is based on the Practical Guidelines for Planning the Development of Rural Clean Water Supply Systems, DPU Directorate General of Human Settlements in 2008. Domestic water demand for rural areas uses the daily water usage rate, which is for raw water needs of 30 litres/person/day.

Qualitative descriptive analysis

This qualitative descriptive analysis is a narrative analysis that is used to analyze and describe various conditions and situations of various data collected from survey results and also observations regarding the problems studied in the field. This qualitative descriptive analysis is used to reveal and strengthen the results of other analyses used to answer the two problem formulations in this study by the facts, phenomena, and circumstances that occur and based on the results of the analysis that has been carried out previously, using this qualitative descriptive analysis it is hoped that the results of the research to be carried out will be able to produce an accurate and more informative conclusion by the circumstances of the researcher's research area.

SWOT analysis

To determine the management strategy of the Kalamisu River basin water management strategy so that there is a balance with the level of population needs in East Sinjai District, the SWOT analysis method is used. SWOT analysis in this study was used to answer the second problem formulation, namely How is the Kalamisu River basin water management strategy so that there is a balance with the level of population needs in East Sinjai District.

Alternative strategies are the result of a SWOT analysis matrix that produces SO, WO, ST, and WT strategies. Alternative strategies produced at least 4 strategies as a result of SWOT matrix analysis. According to Rangkuti (1998: 31–32) the resulting strategies are as follows: SO strategy: made based on the mindset of utilizing all strengths to seize and take advantage of the maximum opportunities. ST strategy: created by using the strengths possessed to overcome threats. WO strategy: implemented based on the utilization of existing opportunities by minimizing existing weaknesses. WT strategy: based on minimizing existing weaknesses and avoiding threats.

RESULTS

East Sinjai Subdistrict has 11 villages with an area of 71.88 km^2. Kampala village is the largest of the 12 villages with an area of 6.09 km^2. Samataring village is the capital of the East Sinjai Subdistrict with an area of 4.50 km^2. The topographic condition of East Sinjai Subdistrict generally has a flat to undulating surface and a small part of the most dominating hills with a height of 20–60 meters above sea level with an area of 4,005.35 ha with a percentage of 48.03 which is plain to sloping. The dominating slope condition of East Sinjai Subdistrict is plain 2,458.81 ha to sloping 2,196.74 ha. The dominating soil type in East Sinjai District is young alluvial soil where this soil type is hydromorphic and has gray, brown, and black colors. According to data from the Central Bureau of Statistics of Sinjai Regency, the rain intensity in East Sinjai District is included in 2 categories, half of the area is in the 2500–3000 mm/year category. The characteristics of land use in

East Sinjai Subdistrict currently consist of several forms of land use, of the total land use in East Sinjai Subdistrict rice fields and plantations/gardens are the largest land use with rice fields having an area of 2,867.73 ha or 37.55% and plantations/gardens having 2,604.31 ha or 34.10%. although rice fields and plantations currently dominate the use in East Sinjai Subdistrict, settlements have a fairly developed development after rice fields and plantations with settlements having an area of 586.39 ha or 7.68%.

Based on BPS East Sinjai Subdistrict in 2023, the total population is 35,629 people spread over 13 areas of 1 subdistrict and 12 villages with Samataring Urban Village as the sub-district with the largest population of 4,671 people with a population density of 1038 Jiwa/km^2, and for the sub-district with the lowest population, it is in Salohe Village and Bongki Lengkese Village, which is 987 people with a population density of 186 Jiwa/km^2 (Table 1).

The development of the population of East Sinjai Subdistrict in 2010–2022 shown in Table 2 shows a varying level of increase and decrease starting from 2010–2011 which experienced a fairly large growth of 21.802% but after that in 2012–2019 there was no significant increase or decrease and in 20220 the development of new population growth was seen with a development rate of 2,566 people with a growth of 7,566%. (Figure 3).

Table 1. Population per village in East Sinjai Sub-district, 2022

No	Village	Area (km^2)	Population (people)	Density (people/km^2)
1	Biroro	5.97	2,639	442
2	Lasiai	7.14	2,282	320
3	Sanjai	8.20	4,032	492
4	Pasimarannu	3.40	2,160	635
5	Pattalassang	7.50	2,522	336
6	Panaikang	4.72	2,057	436
7	Samataring	4.50	4,671	1038
8	Kaloling	5.09	2,275	447
9	Saukang	6.00	2,834	472
10	Kampala	6.09	2,834	465
11	Tongke-tongke	4.75	4,503	948
12	Salohe	3.22	1,837	570
13	Bongki Lengkese	5.30	987	186
Total population		71.88	35,629	496

Note: East Sinjai District in Figures (2023).

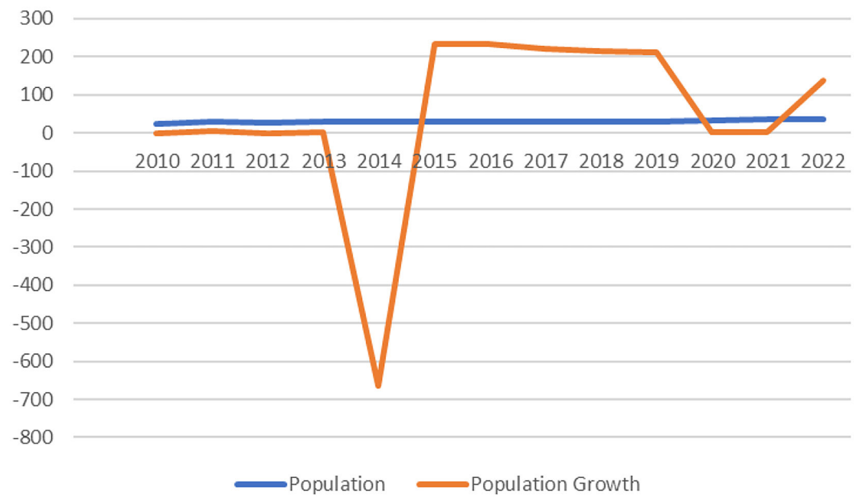

Figure 3. Population development of East Sinjai Sub-district in 2010–2022 (District of East Sinjai in Figures, 2023)

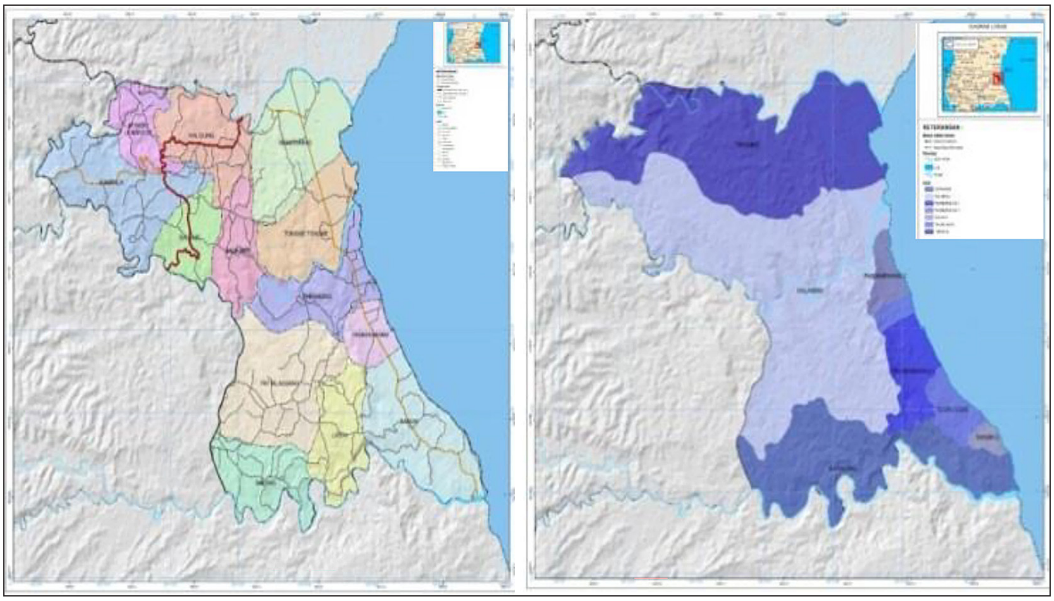

Figure 4. (a) Administrative map of East Sinjai Sub-district (b) Kalamisu Watershed map

Analysis of land use change in East Sinjai Sub-district for 10 years (2012, 2017, 2022) (Table 2). In 2012–2017 land use in East Sinjai Subdistrict which experienced a significant increase was settlements of 136.6 ha which can be explained that in 2012–2017 the population growth increased by 58,986 people then tamba also increased by 2.99 ha. The type of plantation land use experienced a considerable reduction of -74.57 ha which is quite significant in terms of the amount of land use in East Sinjai District. There is an increase in community settlements in East Sinjai District which certainly needs adequate water resources for the daily needs of the people in East Sinjai District.

Analysis of land use change of Sugai Kalamisu watershed over 10 years for 3 time ranges: 2012, 2017, and 2022 (Figure 5). Land use change of Kalamisu Watershed for a period of 10 years where it can be seen that the analysis of land use for 2012–2017 the most dominating land use is settlements with an increase in land use of 115.82 ha (Table 3). which experienced a decrease in plantations with a decrease of -38.07 ha. Furthermore, in the Kalamisu watershed land use in 2017–2022, the most experienced increase is settlements with an increase in the amount of land use area of 41.55 ha and a decrease of -3.94 ha. Image classification conduceted with supervised classification techniques

Table 2. Land use change of East Sinjai Sub-district 10 – year period

No	Type of land use	Area (ha)		Change in total area (ha)	Description	Area (ha)		Change in total area (ha)	Description
		2012	2017			2017	2022		
1	Mangrove forest	88.13	88.13	0	Stay	88.19	88	-0.19	Reduced
2	Jungle	540.25	532.37	-7.88	Reduced	532.38	532.37	-0.01	Reduced
3	Housing	449.79	586.39	136.6	Increased	586.39	586.39	0	Stay
4	Rice paddies	2887.39	2867.76	-19.63	Reduced	2867.74	2867.73	-0.01	Reduced
5	Plantation garden	2678.74	2604.17	-74.57	Reduced	2604.32	2604.31	-0.01	Reduced
6	Shrubs	211.54	213.37	1.83	Increased	213.37	213.37	0	Stay
7	Farm/field	241.85	238.15	-3.7	Reduced	238.15	238.14	-0.01	Reduced
8	River	120.39	120.36	-0.03	Reduced	120.39	120.39	0	Stay
9	Pond	382.07	385.06	2.99	Reduced	385.06	385.06	0	Stay
10	Empty land	2.38	2.38	0	Stay	2.38	2.38	0	Stay
Total		7602.53	7638.14	35.61		7638.37	7638.14	-3.41	

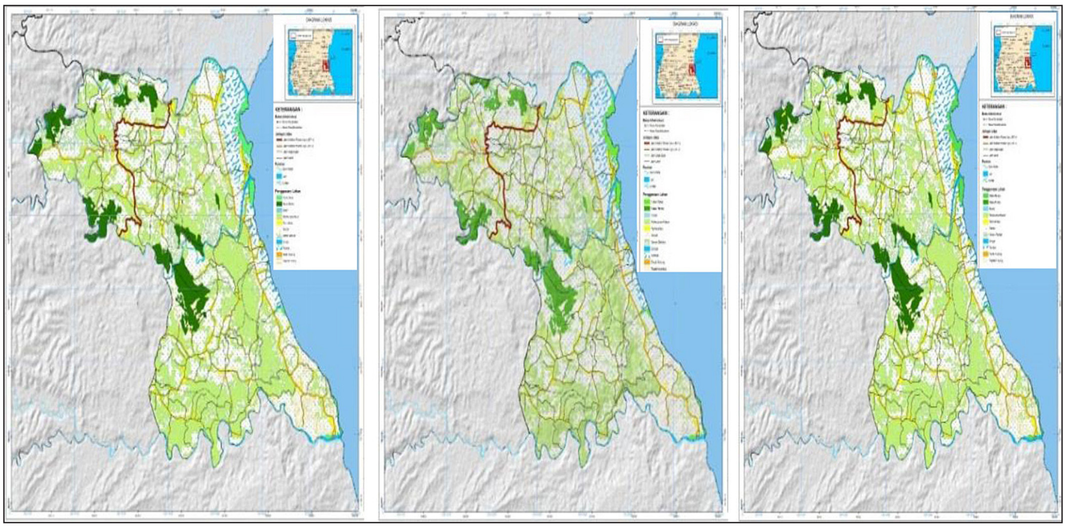

Figure 5. Existing map of East Sinjai Sub-district (a) year 2012 (b) year 2017 (c) year 2022

Table 3. Land use of the Kalamisu River watershed for a 10-year period (Analysis Result, 2023)

No.	Type of land use	Area (ha)		Change in total area (ha)	Description	Area (ha)		Change in total area (ha)	Description
		2012	2017			2017	2023		
1	Mangrove forest	19.47	19.47	0	Stay	19.47	19.46	-0.01	Reduced
2	Jungle	365.64	364.89	-0.75	Reduced	364.89	365.42	0.53	Increased
3	Housing	77	192.82	115.82	Increased	192.82	234.37	41.55	Increased
4	Rice paddies	1213.41	1213.69	0.28	Increased	1213.69	1212.48	-1.21	Reduced
5	Plantation garden	1216.94	1178.87	-38.07	Reduced	1178.87	1174.93	-3.94	Reduced
6	Shrubs	122.36	122.48	0.12	Increased	122.48	122.47	-0.01	Reduced
7	Farm/field	51.54	58.07	6.53	Increased	58.07	58.06	-0.01	Reduced
8	River	40.32	40.33	0.01	Increased	40.33	40.32	-0.01	Reduced
9	Pond	57.05	57.48	0.43	Increased	57.48	57.04	-0.44	Reduced
Total		3163.73	3248.1	84.37		3248.1	3284.59	36.45	

in ER Mapper software. Before the classification process is carried out, first the sample or training area based on the appearance of objects in the image and validation of the results of field surveys. Making training areas is based on the desired number of land cover classes, namely settlements, rice fields, forests, grass, plantations, mixed gardens, waters, and fields.

The following is the training area and field validation for each land cover class. Field validation measurements using handheld GPS using the WGS 84 datum system UTM coordinate zone 51s (Figure 6).

Analysis of water infiltration capability determination of water catchment areas needs to use several parameters, namely: rock type, rainfall, soil type, slope, and land use. The reference used in determining the level of water infiltration is the Technical Guidebook for Groundwater Management published by the Ministry of Energy and Mineral Resources of the Geological Agency in 2007 and the Regulation of the Minister of Forestry of the Republic of Indonesia Number: P.32/MENHUTII/2009 concerning Procedures for Preparing Technical Plans for Forest and Land Rehabilitation in Watersheds (RTkRHL-DAS). Each parameter has a different level of influence on the condition of water infiltration which is distinguished using the weight value of each parameter used in the study.

Assessment of water infiltration based on rock type scores using geological structure data sourced from secondary data, including in the category of sandstone rock types (> 10^{-2} – 10^{1}) with an area of 2,989.38 ha or 91.004% with a score of 3 and infiltration in the medium category. Assessment of water infiltration ability based on rainfall score using rainfall data sourced from secondary data. East Sinjai District is 2500–3000 mm/year based on the results of the analysis in East Sinjai District included in score 4, which is included in the high infiltration category. Assessment of soil infiltration ability based on soil type score using soil type data sourced from secondary data. East Sinjai sub-district is included in the rather coarse category with young alluvial soil types and andosol with a rather large infiltration process (Figure 7).

Assessment of water infiltration ability based on slope score using slope data sourced from secondary data. East Sinjai Subdistrict is categorized

Citra	Field Photo	Location
		Village: Patalassang Sub-district : East Sinjai Coordinates : 5°12'16 "S 120°15'14 "E

Figure 6. Training area and field validation: housing (Analysis Result, 2023)

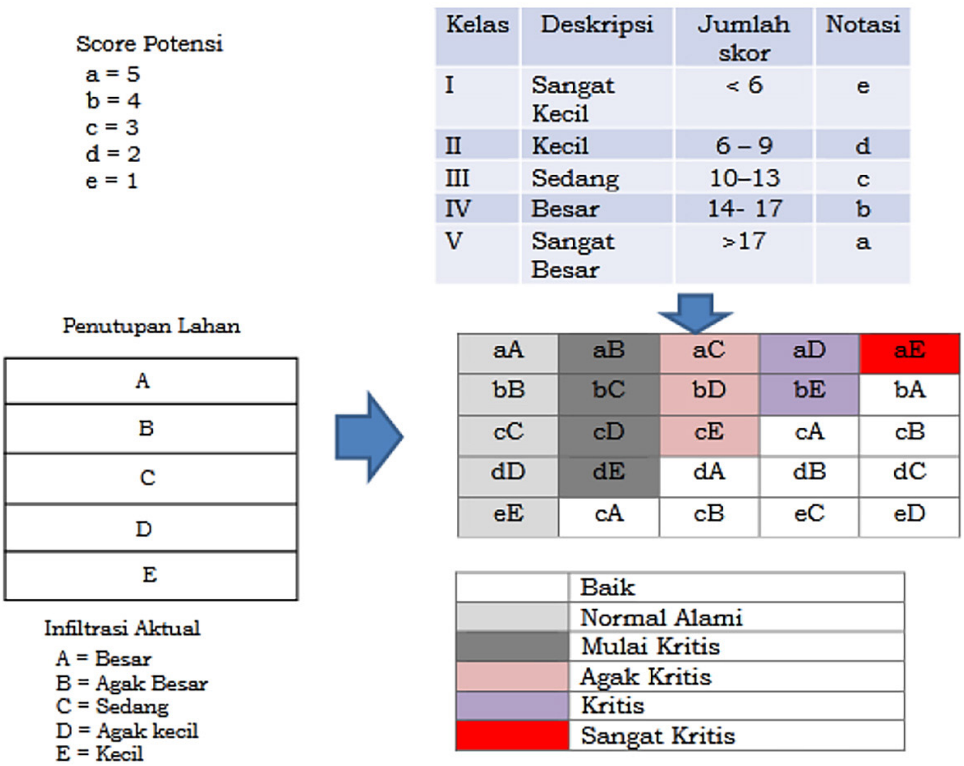

Figure 7. Infiltration area analysis modelling diagram

Table 4. Classification of physical aspects of the Kalamisu watershed (Analysis Result, 2023)

No	Classification type	Description	Infitration	Skor
1	Rock type	Permeibality > 10^{-2} – 10^{1} m/day (sandstone)	Medium	3
2	Rainfall	2500–3000	High	4
3	Soil type	Alluvial	Somewhat coarse	4
4	Slope	< 8 (flat)	Large	5

Table 5. Relationship between land use and infiltration ability

No	Land use type	Infiltration	Notation	Land area of Kalamisu Watershed in 2022 (ha)
1	Forest	Large	A	384.88
2	Farming	Somewhat large	B	1174.93
3	Shrubs, grassland	Medium	C	122.47
4	Horticultural	Somewhat small	D	58.06
5	Housing, rice fields	Small	E	1446.85

Note: Procedure for preparation of technical plan for forest and land rehabilitation in watershed areas (RTkRLH-DAS, 2009).

as plain 2,458.81 ha to sloping 2,196.74 ha with a score of 5 and large infiltration.

Based on the results of the analysis in Table 4 it is found that the total overall score is 16. This value shows a large infiltration category which is in class 4 with the notation b (Figure 6).

Based on the relationship between land use and infiltration ability (Table 5), it appears that the largest land use is settlements, rice fields with an area of 1,445.85 ha with the notation E. The combination of the results of physical analysis (b) with the results of land cover analysis (E) results in a bE score (Figure 6, purple colour), which based on the description of the East Sinjai District area is in the critical category.

Next, to find out the condition of water availability in East Sinjai District based on calculations using the runoff coefficient method from the rational method contained in the regulation of the Minister of Environment Number 17 of 2009 concerning Guidelines for Determining Environmental Support Capacity in Regional Spatial Planning in Table 5 which aims to calculate the carrying capacity of water in an area.

Table 6 shows the availability of water in East Sinjai District in 2012 with a total of 4,890.1536 m^3/year, in 2017 with a total of 56,856,620 m^3/year and in 2022 with a total of 64,099,656 m^3/year. So it can be concluded that the total water availability in East Sinjai District

Table 6. Water supply of East Sinjai Sub-district (Analysis Result, 2023)

No	Type of land use	Water supply (m^3/year)	Water supply (m^3/year)	Change in total water availability	Description	Water supply (m^3/year)	Water supply (m^3/year)	Change in total water availability	Description
		2012	2017			2017	2022		
1	Mangrove forest	326,563	326,563	-	Stay	326,563	326,082	481	Increased
2	Jungle	3,336,475	3,287,810	-48,665	Reduced	3,287,810	3,287,811	1	Increased
3	Housing	6,481,563	1,207,142	-5,274,421	Reduced	1,207,142	8,449,997	7,242,855	Increased
4	Rice paddies	17,831,943	17,710,712	-121,231	Reduced	17,710,712	17,710,527	-185	Reduced
5	Plantation garden	16,543,362	16,082,833	-460,529	Reduced	16,082,833	16,083,698	865	Increased
6	Shrubs	1,524,166	15,373,252	13,849,086	Increased	15,373,252	15,373,252	0	Stay
7	Farm/field	497,872	490,255	-7,617	Reduced	490,255	490,235	-20	Reduced
8	Pond	2,359,587	2,378,053	18,466	Increased	2,378,053	2,378,054	1	Increased
Total		48,901,531	56,856,620	7,955,089		56,856,620	64,099,656	7,243,998	

has decreased from 2012, 2017 and 2022, that is -41,658,495 m^3/year. Water balance analysis – to produce a water balance analysis, it is necessary to calculate population projections for the next 10 years to determine the extent of water demand in East Sinjai District. Furthermore, a population projection analysis is carried out for the next 20 years so that the amount of water resources needed by the community in East Sinjai District can be known. Based on the results of mathematical calculations carried out using arithmetic, geometric, and exponential methods, The calculation of the net water demand for the projected population of East Sinjai District and the water needs of East Sinjai District, in 2023 the projected population is 35,629 with a water demand of 1068.87 liters/day and a population projection of 2023–2032. Calculation of clean water needs with the results of these calculations it can be concluded that water demand from year to year continues to increase with a total demand from 2023–2032 of 2,1959.97 liters/orang/day or 0.26081 liters/second (Table 7).

Based on the calculation of water availability obtained from the results of the calculation of water availability using data runoff coefficient, rainfall data, and land use data. The availability of water availability in East Sinjai District in 2012–2022 has decreased, namely -41,658,495 m^3/year. Based on the calculation of water demand associated with population projections for 10 years. Associated with population projections for 10 years, namely in 2023–2032, with the results of these calculations, it can be concluded that the need for water from year to year continues to increase with a total demand from 2023–2032 of 2,195 m^3 per year. In 2023–2032 amounting to 2,1959.97 liters/person/day or 0.26081 liters/second. The result of water availability divided by water demand is -0.1768, so it can be it can be concluded that the availability of water in East Sinjai District is deficit or exceeded, which means water availability > water demand.

Based on the results analysis of land use change affects the change in water balance water balance where there is an increase in settlements by 136.6 ha and a decrease in the type of plantation land use. type of plantation land use also affects the level of water availability, which is water availability which has decreased, namely 4658505 m^3/year because of the high level of community needs due to the increase in settlements and reduced water absorption into the soil due to reduced plantations as a container for water absorption into the soil plantations as a container for water absorption into the soil.

Based on the water supply of East Sinjai Subdistrict in 2012, it resulted in a total of 4.890,1536 m^3/year with the type of land use that has a large enough water supply, namely rice fields 1.783,1943 m^3/year and plantations 1.654,3362 m^3/year, in 2017 it resulted in a total of 56,856,620 m^3/year. With the type of land use that has a large enough water supply namely rice fields 1.77,10712 m^3/year and plantations 1.608,2833 m^3/year in 2022 it produces a total of 64,099,656 m^3/year with the type of land use that has a large enough water supply namely rice fields 1.77,10527 m^3/year and plantations 1.608,3698 m^3/year. So it can be concluded that the total water supply in East Sinjai Subdistrict experienced a reduction in water from 2012 to 2022 namely -41,658,495 m^3/year.

Table 7. Calculation of water demand (Analysis Result, 2023)

Projection year	Total projected population	Total water demand (litres/person/day)	Total water demand (litres/second)
2023	35.629	1068.87	0.01237
2024	35.795	1073.85	0.01243
2025	40.096	1202.88	0.01392
2026	43.694	1310.82	0.01517
2027	47.615	1428.45	0.01653
2028	60.564	1816.92	0.02103
2029	77.036	2311.08	0.02103
2030	97.986	2939.58	0.03402
2031	124.634	3739.02	0.04328
2032	204.579	6137.37	0.07103
Total		21959.97	0.26081

Table 8. Identification of SWOT analysis factors (Analysis Result, 2023)

Internal	Strenghts (S)	Weakness (W)
External	1. The amount of water discharge in the rainy month in East Sinjai District has been fulfilled. The result of water availability divided by water demand is -0.1768, it can be concluded that water availability in East Sinjai District is deficit or exceeded, which means water availability > water demand. 2. Community enthusiasm in participating in socialization, and training, on water treatment 3. Willingness to use personal funds for well water treatment and Pamsimas water distribution 4. The community knows that declining well water quality will have an impact on health 4.	1. Land Use Change in East Sinjai Sub-district for a 10 – year period in 2012, 2017 and 2022 which experienced an increase, namely the type of residential land use of 136.6 ha. agricultural land use experienced a reduction of – 74.54 ha, rice fields – 19.63 ha, jungle – 7.88 ha. 2. Infiltration conditions in East Sinjai District this value shows the infiltration category bE category with a pontensi score of 1 actual infiltration is small and critical conditions. 3. Total water availability in East Sinjai Sub-district has increased from 2012, 2017 and 2022, namely 44,382,942.52 m^3/year.
	Strategy SO (strenghts – opportunity)	Strategy WO (weakness-opportunities)
Opportunity (O) 1. Availability of easy and cheap alternative technology options 2. A community that is open to having better clean water management.	• Conduct intensive socialization of both the government and NGOs and BUMDs to the community regarding infiltration ponds and the primary need for clean water for family primary needs. • Maximizing the maintenance of pamsimas waterways • Developing a blueprint for both the government and related stakeholders to the community of East Sinjai Sub-district regarding good clean water management. • The combination of community enthusiasm and the support of government parties who are willing to be important to conduct adequate studies for the construction of artificial water infiltration, in the form of infiltration wells, inundation of the ledok area, making reservoirs.	• Encourage an increase in the type of plantation land use that has a large water catchment so that there is new water catchment during the dry season both for plants and environmental sustainability such as Mangrove Development in order to increase water catchment both in quality and quantity. • Providing support to the community both in the form of capital financing assistance facilities and also facilities and infrastructure, especially piping and well infiltration locations that are qualified for the community's clean water needs. • Increase river capacity by normalizing the Kalamisu watershed area and making jetty construction at the mouth of the river vegetatively by reforesting the land. • Maximizing water infiltration into the soil by developing various kinds of soil conservation technologies that are more pro-active both vegetative and non-vegetative (physical and mechanical) methods, namely Infiltration Wells and other forms of physical methods such as terraces to reduce or harvest runoff which aims to increase the ability of the soil to absorb water (Soil infiltration capacity) and is expected to increase groundwater availability in the upper watershed area.
	Strategi ST (strengths – threats)	Strategi WT (weakness-threats)
Threats (T) 1. Unsustainability of Pamsimas water management 2. In 2023 the projected population was 35,629 people with a water demand of 1068.87 liters/person/day and the projected population for 2032 was 6,137.37 liters/person/day. The total demand from 2023–2032 is 2,1959.97 liters/person/day or 0.26081 liters/second.	• Maximizing community enthusiasm regarding socialization and water management in the form of wells and pamsimas to deal with the water needs of the population. • Maximizing the potential for water infiltration in the rainy season to provide adequate water storage for residents in East Sinjai District. • Taking into account the total demand from 2023–2032 of 2,1959.97 liters/person / day or 0.26081 liters/second to the government both from the irrigation of the Kalamisu river basin such as an increase in infrastructure both capacity and water distribution.	• Encourage the sustainability of Pamsimas management from both the government and the authorities so that water availability in East Sinjai Sub-district can be fulfilled. • Improve guidance and direction to the community regarding the Pamsimas Program regulations or Technical Guidelines (Juknis) in the Pamsimas Program. • Encourage the government to be able to provide adequate infrastructure for future water needs.

The formulation of the Kalamisu River basin water management strategy so that there is a balance with the level of the population needs for the next 10 years in East Sinjai District is conducted using the SWOT analysis method as an analytical tool to carry out data processing and strategy formulation which in its implementation will be more emphasized on understanding the aspects of strengths, weaknesses, opportunities, and threats as obtained from secondary data, field observations and the results of the analysis that has been conducted (Table 8).
There are IFAS and EFAS results:
- IFAS results strengths – weaknesses = 2.9 – 3.32 = -0.42
- EFAS results opportunities – threats = 3.63 – 2.5 = 1.13

The position is on the x axis = -0.42 and the y axis = 1.13. Therefore, the position of the SWOT analysis results is in quadrant IV, so the strategy used and prioritized is the WO strategy, which minimizes weaknesses to take advantage of existing opportunities or take advantage of existing opportunities by minimizing weaknesses.
The results of WO are as follows:
1. Encourage an increase in the type of plantation land use that has a large water catchment so that there is new water catchment during the dry season both for plants and environmental sustainability such as Mangrove Development in order to increase water catchment both in quality and quantity.
2. Provide support to the community both in the form of capital financing assistance facilities and also facilities and infrastructure, especially piping and well infiltration sites that are qualified for the community's clean water needs.
3. Increase river capacity by normalizing the Kalamisu watershed area and making jetty construction at the mouth of the river vegetatively by reforesting the land.
4. Maximizing water infiltration into the soil by developing a variety of more pro-active soil conservation technologies both vegetative and non-vegetative methods (physical and mechanical) namely infiltration wells and other forms of physical methods such as terraces to reduce or harvest runoff which aims to increase the ability of the soil to absorb water (soil infiltration capacity) and is expected to increase groundwater availability in the upper watershed area.

CONCLUSIONS

Factor that affects land use change in 2012–2023 is settlements that experienced a significant increase, which is a housing area of 136.6 ha, which can be explained that in 2012–2017 the number of population growth has increased, namely 58,986 people. The type of plantation land use experienced a considerable reduction of -74.57 ha which is quite significant in terms of the amount of land use in East Sinjai District, then plantations/gardens with a reduction in area of -74.43 ha which is scattered around the community settlements of East Sinjai Sub-district In the analysis of land use in the Kalamisu watershed in 2012–2017 the most dominating land use is settlements with an increase in land use of 115.82 ha. land use around the Kalamisu watershed is a settlement with an increase in area from 2012 to 2017 of 157.37 a which is scattered around the community settlements of the Kalamisu watershed of East Sinjai Sub-district. Furthermore, there was a significant decrease in land use in the type of plantation land use, this requires special attention so that crop productivity is quite good and effective in one unit of land area, it requires sufficient water supply through irrigation.

Water resources management needs to be carried out by involving all parties. Therefore, the government as the regulator must be able to provide a legal umbrella that guarantees integrated water resources management so that it can provide space for communities, NGOs, BUMDs, and also the private sector to manage natural resources. It is necessary to strengthen water management institutions, in this case, PDAMs, both in terms of human resources and infrastructure to improve their performance optimally. Development of wider network infrastructure by PDAMs to provide clean water more evenly. This is necessary to increase the supply of clean water from only 1,800 liters per second to a larger one, to optimally meet the needs of the community. The construction of artesian wells and the implementation of rain harvesting systems by the local government, by creating water reservoirs in people's homes at several points prone to drought. Development and enforcement of better policies and regulations, such as integration of water management, conservation, and sanitation into trade policies. Procurement of pamsimas (community-based water supply and sanitation) in villages with potential water crisis. Transfer of science and technology from other cities or regions that have been successful or able to help mitigate water management problems in East Sinjai Sub-district.

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