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Drought disaster mitigation efforts based on water catchment potential in Samosir Island

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ABSTRACT

Samosir Island is in North Sumatra Province's upstream portion of the Asahan Toba watershed. The island frequently suffers from drought, making obtaining groundwater and rain challenging. The information of spatial distribution of water catchment potential areas is important for drought mitigation. The spatial distribution of these catchment areas is examined in this study, and drought mitigation techniques are assessed. Slope, land use, rainfall, and soil type are important factors. Geographic Information System (GIS) approaches, which included overlay and grading procedures, were used for the analysis. The results show that there are four classes of possible water catchment areas on Samosir Island: Moderately critical: 48,000.327 hectares (74.369%), Critical: 7,732.647 hectares (11.980%), starting to be critical: 8,808.001 hectares (13.647%), and natural normal: 2.77 hectares (0.004%). Samosir Island should have vegetation maintained, trees and understory plants planted programs, terrace boundaries maintenanced, rainwater harvesting installations constructed, and biopores created to lessen drought.
Keyword: Drought Mitigation, Infiltration, Samosir Island, Water Catchment Area

1. Introduction

Ground surface water enters a water-saturated zone in water catchment areas, forming a groundwater flow distributed to lower places [1]. Water catchment areas contribute to overcoming flood and drought disasters. The information obtained can be used to conserve groundwater resources. The Pringsewu District government has created a water management program and requires information on water catchment areas to determine groundwater conservation zones. This information is obtained through mapping areas that have the potential to become water catchment areas by utilizing a geographic information system [2]. This method can be implemented in Samosir Island, one of the watersheds with a high potential for drought disaster. It is part of the upstream area of the Asahan Toba watershed, making getting water from rainwater and groundwater difficult. Samosir Island has 8 sub-basins: Silabung, Simala, Binanga Bolon, Sijamajama, Sitiung-Tiung, Guluan, Simaratuang, and Aron. Siregar [3] reported that Samosir Island has rainfall in the July-August range that is below normal (low), and three main factors influence the drought. The factors are the climate type, which is classified as an E2 agro-climatic zone according to Oldeman, where the wet period is less than three months and the dry period is two to three months, whereas according to Schmidt and Ferguson, it is a C climate; wavy to very steep topography which causes higher surface runoff than infiltration; and institutional intervention in hilly areas in the form of deforestation for the production of pulp raw materials. Abadi *et al.* [4] also found that for three consecutive years, from 2009-2011, the daily drought index on Samosir Island ranged from 0-2000. Therefore, there is a need for mitigation against drought on Samosir Island, which spatial information. Spatial information can be obtained by analyzing the potential of water catchment areas with remote sensing technology and geographic information systems (GIS) because they support statistical and spatial data and information [5]. This research aims to analyze the potential and spatial distribution of water catchment areas and to analyze drought disaster mitigation efforts on Samosir Island.

2. Method

2.1. Time and place

This research was conducted from May to November 2023 on Samosir Island, Samosir District, North Sumatra Province (Fig.1) which consists of 6 sub-districts, namely Simanindo, Pangururan, Ronggur Ni Huta, Palipi, Nainggolan, and Onan Runggu.

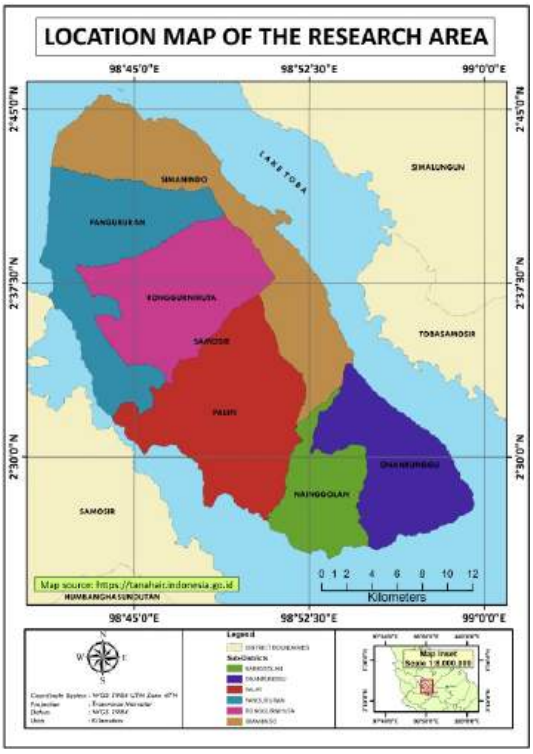

Figure 1. Location map of the research area

2.2. Tools and materials

The tools used in this research are Google Earth Engine (GEE) platform, and ArcGis 10.8. The material used include Indonesia Landform Maps, Sentinel 2 images, soil type map, Digital Elevation Model data, rainfall data, and field data observation. The types and sources of data used in this research are presented in Table 1.

Table 1. Sources of the research data

No.	Data	Sources
1.	RBI map	Geospatial Information Agency (BIG)
2.	Soil type map	Balai Besar Sumberdaya Lahan Pertanian
3.	Sentinel 2 images of 2022	Google Earth Engine
4.	DEM data	Geospatial Information Agency (BIG)
5.	Rainfall data	CHIRPS (Climate Hazards Group Infrared Precipitation with Station)
6.	Field data observation	GPS and digital camera documentation

2.3. Analysis of determinants of water catchment areas

The potential water catchment area uses the scoring method, which is the sum or combination of several parameters [6]. The parameters used are soil type, rainfall, land use, and slope [7]. Analyzing the determinants of water catchment areas is by using Spatial Multi Criteria Evaluation (SMCE), where the weight of a parameter will indicate the level of influence of the parameter to the potential of water catchment areas [8]. The weighting of each parameter is presented in Table 2.

Table 2. Weighting of potential water catchment areas parameters.

No.	Parameters	Weight
1	Soil type	40
2	Rainfall	30
3	Land use	20
4	Slope	10

2.3.1. Soil type

The score of each soil infiltration type is presented in Table 3.

Table 3. Scoring value of soil infiltration type parameters.

No.	Soil type	Remarks	Score
1	Regosol	Very Fast	9
2	Alluvial and andosol	Fast	7
3	Latosol	Medium	5
4	Litosol, mediterranean	Slow	3
5	Grumusol	Very Slow	1

2.3.2. Rainfall

The score of each rainfall class is presented in Table 4.

Table 4. Scoring value of rainfall parameters.

No.	Rainfall (mm/year)	Remarks	Score
1	> 5500	Very High	9
2	4500 – 5500	High	7
3	3500 – 4500	Medium	5
4	2500 – 3500	Low	3
5	< 2500	Very Low	1

2.3.3. Land use

The score of each land use class is presented in Table 5.

Table 5. Scoring value of land use parameters.

No.	Land use	Remarks	Score
1	Forest	Very High	9
2	Farm, mixed farm	High	7
3	Shrubs, fields	Medium	5
4	Grassland	Low	3
5	Settlements, rice fields, open land, water body	Very Low	1

2.3.4. Slope

The score of each slope class is presented in Table 6.

Table 6. Scoring value of slope parameters.

No.	Slope (%)	Description	Remarks	Score
1	< 8	Flat	Very High	9
2	8 – 15	Ramps	High	7
3	15 – 25	Medium	Medium	5
4	25 – 40	Steep	Low	3
5	> 40	Very steep	Very Low	1

2.4. Analysis of potential water catchment areas

The potential of water catchment areas is obtained through the overlay technique and adding up the total score for each parameter using Equation 1 [9]. Based on the 2009 Procedures for Preparing Technical Plans for the Land and Forest Rehabilitation of the Watershed (RTkRHLDAS), there are six classes for the condition of water catchment areas, namely good, natural normal, starting to be critical, moderately critical, critical and very critical [9].

$$Total\ Value = STw.STs + Rw.Rs + LUw.LUs + Sw.Ss \qquad (1)$$

Description :

STw	=	Soil type weight value
STw	=	Soil type class score
Rw	=	Rainfall weight value
Rs	=	Rainfall class score
LUw	=	Land use weight value
LUs	=	Land use class score
Sw	=	Slope weight value
Ss	=	Slope class score

The interval value of water catchment ability is determined based in the Sturgess Interval formula (Equation 2), which is the difference between the highest and the lowest data then divided by the number of classes desired.

$$Ki = \frac{(Xt - Xr)}{k} \qquad (2)$$

Description: Ki : Interval class
Xr : Highest data
Xt : Lowest data
k : Number of desired classes

The map of potential water catchment areas was then carried out with a validation test to evaluate the level of accuracy of the final map through a comparison between analytical data and field data by using a confusion matrix table. The United States Geological Survey (USGS) has determined that the map's accuracy level is at least 85% [10].

3. Result and Discussion

3.1. Soil type

The distribution of soil types on Samosir Island is presented in Table 7. Soil types in Samosir Island are dominated by latosol types with a distribution of 60,820.792 hectares or 94.232% of the area, while the least soil type found is alluvial of 11.536 hectares only 0.018% of the area. The hydromorph alluvial soil type is spread over 1,196.459 hectares while the andosol soil type is spread over 2,514.959 hectares. Based on Table 6, alluvial and andosol soil types compared to latosol soils have greater infiltration. Syukur [11] points out that after testing the infiltration rate of four types of soil for 4-5 hours until where the rate is constant the results show the alluvial soil is in the first place and the latosol soil type is in third place. The average infiltration rate of alluvial soils was found to be 7-9 times greater than latosols. The map of soil types on Samosir Island is presented in Figure 2.

Table 7. Distribution of soil types on Samosir Island

No.	Soil type	Infiltration	Score	Area (ha)	Area (%)
1	Alluvial Fluvaquents,Tropaquents,Tropohemists	Fast	7	11.536	0.018
2	Hydromorphic alluvial Tropaquepts,Trofopluvents,Pluvaquents	Fast	7	1,196.459	1.854
3	Andosols Hydrandepts,Eutropepts,Troporthents	Fast	7	2,514.959	3.897
4	Latosol Dystropepts,Distrandepts,tropudults Dystropepts,Eutrandepts,Dystrandepts Dystropepts,Tropudults,Troportens Dystropepts,Tropudults,Tropudalts Eutropepts, Dystropepts Eutropepts, Dystropepts, Humitropepts	Medium	5	60,820.792 2,107.082 617.449 993.824 106.256 40,176.850 16,819.330	94.232
	Total			64,543.746	100.000

Source: Processed data on soil types of Center for Agricultural Land Resources, Ministry of Agriculture 2005

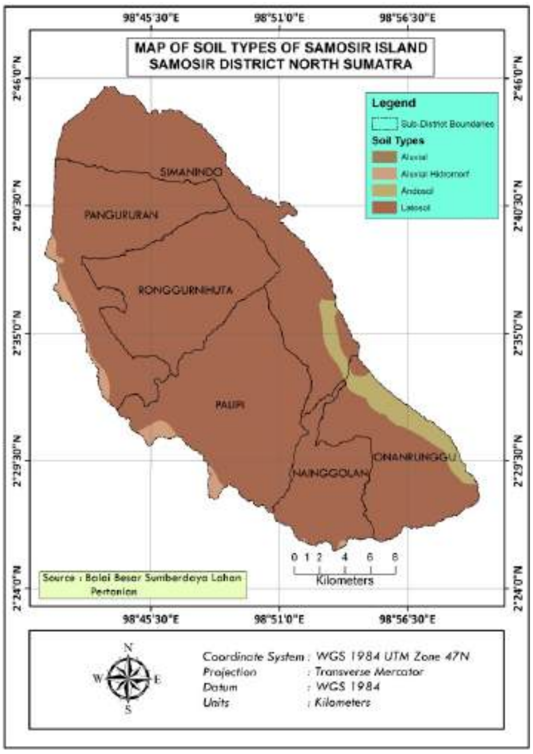

Figure 2. Map of soil type distribution in Samosir Island

3.2. Rainfall

The distribution of rainfall over 10 years on Samosir Island is presented in Table 8. The rainfall classification on Samosir Island is divided into two classes: rainfall < 2500 mm/year and 2500-3500 mm/year. Rainfall more dominant on Samosir Island within 10 years is < 2500 with a distribution area of 61,207.039 hectares. If rainfall intensity is low, then the amount of water that will enter the soil is also tiny, resulting in a small potential water catchment area in the watershed. The low rainfall on Samosir Island is greatly influenced by the climatic conditions and topography of the area [12]. Rainfall intensity and infiltration capacity determine the infiltration rate. The infiltration rate is equal to the rainfall intensity if the rainfall is less than the infiltration capacity. Surface runoff occurs when the amount of rainfall exceeds the infiltration capacity. As a result, changes in rainfall intensity cause changes in infiltration rate [13]. The rainfall distribution map of Samosir Island is presented in Figure 3.

Table 8. Distribution on rainfall in Samosir Island

No.	Description (mm/year)	Remarks	Score	Area (ha)	Area (%)
1	< 2,500	Very Low	1	61,207.039	94.830
2	2,500 – 3,500	Low	3	3,336.706	5.170
Total				64,543.746	100

Source: Climate Hazards Group Infrared Precipitation with Station (CHIRPS)

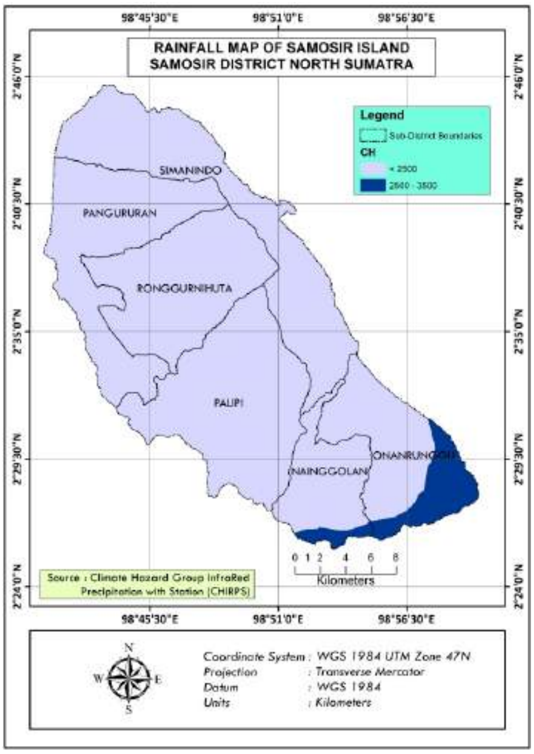

Figure 3. Map of rainfall distribution in Samosir Island

3.3. Land use

Land use is defined as various forms of intervention or activities carried out by humans on land to fulfill their needs. It is a human activity on land that is not visible through satellite imagery taken far from the Earth [14]. Table 9 presents the distribution of land use on Samosir Island in 2022.

Table 9. Distribution of land use on Samosir Island in 2022.

No.	Land use	Remarks	Score	Area (ha)	Area (%)
1	Forest	Very High	9	10,862.381	16.829
2	Farm	High	7	12,097.016	18.742
3	Mixed farm	High	7	11,803.832	18.288
4	Fields	Medium	5	8,983.943	13.919
5	Shrubs	Medium	5	7,794.946	12.077
6	Grassland	High	3	4,604.832	7.134
7	Water body	Very Low	1	725.931	1.125
8	Open land	Very Low	1	345.686	0.536
9	Settlements	Very Low	1	783.318	1.214
10	Rice fields	Very Low	1	6,541.862	10.136
Total				64,543.746	100

Source: Sentinel 2 image interpretation in 2022

Based on Table 9, Samosir Island is dominated by farmland use, with an area of 12,097.016 hectares (18.742%) generally planted with coffee, cacao, and cloves. The land use type of mixed farm is 11,803.832 hectares (18.288%), and the forest is 10,862.381 hectares (16.829%) located in the upper part and is a protected forest. Fields on Samosir Island also cover an area of 8,983.943 hectares (13.919%). The land use of shrubs is 7,794.946 hectares (12.077%). The least land use is open land with an area of 345.686 hectares (0.536%), such as former rock excavation, erosion, and harbor, and there is also a layer of sulfur left over from the eruption on Mount Toba. Settlements are 783.318 hectares (1.214%) and are scattered following the road network. Land use on Samosir Island (Table 9) with a significant infiltration rate is forest, while very low infiltration rate is in water bodies, open land, settlements, and rice fields, with the smallest area being open land. The infiltration rate are ordered from the most considerable infiltration to the very low according to the area: farm, mixed farm, forest, fields, shrubs, rice fields, grassland, settlements, water bodies, and open land. The difference in infiltration rates indicates the influence of land use on infiltration and the water cycle. Changes in the hydrological cycle are influenced by land use, and both are related. Land with a form of uses forest, mixed farm, and farm are relatively better in terms of infiltration because the vegetation has a root form with a more significant influence on the physical, chemical, and biological properties of the soil, such as porosity, bulk density, texture, humidity, compared to land uses such as rice fields which tends to be saturated with water and its roots so that it does not allow considerable infiltration into the soil [15]. The amount of vegetation significantly influences infiltration; if 90% of the area is covered with forest or something similar, the infiltration rate will be high. On the other hand, if there is only a little adequate vegetation cover, the infiltration rate will be low [16]. The map of land use distribution in Samosir Island presented in Figure 4.

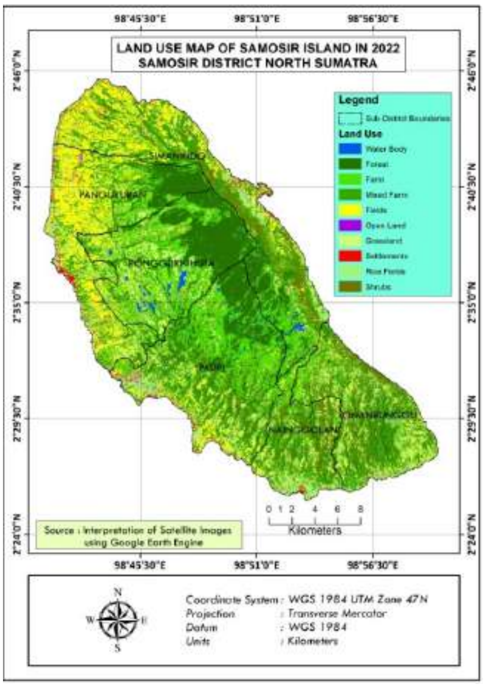

Figure 4. Map of land use distribution in Samosir Island in 2022

3.4. Slope

The slope affects the potential of water catchment areas. The higher the slope, the lower the infiltration power, so the potential for water catchment areas is also smaller, which increases the probability of drought disasters. The distribution of slope in Samosir Island is presented in Table 10. Samosir Island is dominated by slopes <8% with an area of 40,610.611 hectares. However, the area with the lowest area distribution is in the >40% class, with a very steep classification of 113.475 hectares. The slope indicates that the lower an area is, the more water that falls will seep into the ground. It can be ensured that there will be high surface runoff at a slope >40%. Most of Samosir Island's topography is in an area with flat to medium slopes. A small part of it is an area with steep to very steep topography, with an area reaching 2% of the total area. Research by Qur'ani *et al.* [16] mentioned that the slope of a land can affect the availability of water in the soil. The steeper the slope, the lower the infiltration rate. Wiyanti *et al.* [17] stated that undulating areas and steep slopes result in a decrease in the amount of water that can seep in because most of the rainwater will become surface runoff, while areas with flat and ramp slopes will have a good impact on the infiltration process because the water that falls is retained first on the ground surface. The map of slope distribution in Samosir Island is presented in Figure 5.

Table 10. Distribution of slope in Samosir Island

No.	Slope	Description	Remarks	Score	Area (ha)	Area (%)
1	< 8 %	Flat	Very High	9	40,610.611	62.920
2	8 - 15 %	Ramps	High	7	15,622.169	24.204
3	15 - 25 %	Medium	Medium	5	6,628.424	10.270
4	25 - 40 %	Steep	Low	3	1,569.066	2.431
5	> 40 %	Very steep	Very Low	1	113.475	0.176
	Total				64,543.746	100.000

Source: DEM (Digital Elevation Model) Image processing results

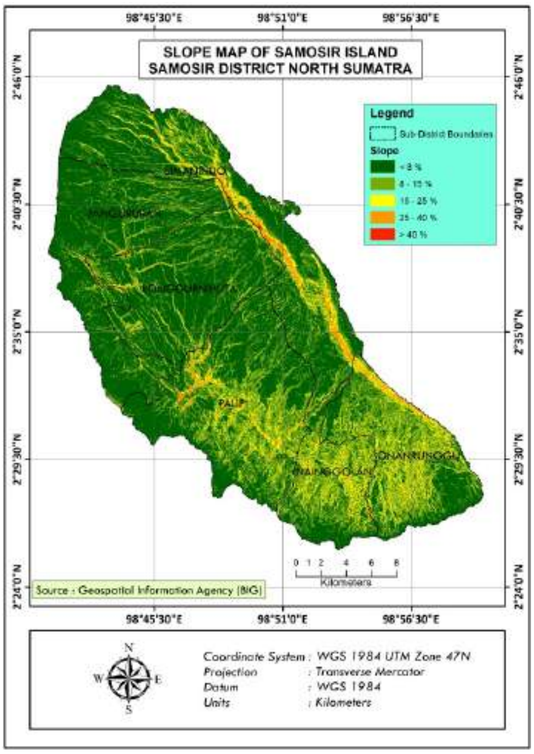

Figure 5. Map of slope distribution in Samosir Island

3.5. The potential of water catchment area

The continued decline of land that functions as a water catchment will result in various environmental problems, including high volumes of surface runoff water, which if it exceeds the capacity of the catchment area to drain can cause localized flooding. However, in times of dry season, it can cause drought. Water shortages can be caused by a decrease in the land's capacity to absorb water. If the water catchment area is disrupted, watersheds that function as groundwater buffers will not be able to do their job properly [18]. Based on the results of overlaying the parameter maps of soil type, rainfall, land use, and slope, a map of potential water catchment areas on Samosir Island was obtained from four classes and presented in Tables 11 and 12.

Table 11. The potential of water catchment areas distribution on Samosir Island

No.	The potential of water catchment area	Score Interval Class	Area (ha)	Area (%)
1	Natural Normal	633 – 767	2.770	0.004
2	Starting to be critical	500 – 633	8,808.001	13.647
3	Moderately Critical	367 – 500	48,000.327	74.369
4	Critical	233 – 367	7,732.647	11.980
	Total		64,543.746	100

Source: Parameter analysis results

Table 12. Distribution of water catchment potential per sub-district on Samosir Island

Sub-District	The potential of water catchment area (Ha)				Total
	Natural Normal	Starting to be critical	Moderately Critical	Critical	
Nainggolan	0.00	235.296	4,494.644	900.663	5,630.603
Onan Runggu	2.770	1,884.163	6,298.490	864.968	9,050.392
Palipi	0.00	1,825.404	10,482.935	1,577.244	13,885.584
Pangururan	0.00	1,239.104	9,023.542	1,312.781	11,575.427
Ronggur Ni Huta	0.00	2,432.766	7,449.844	1,013.675	10,896.285
Simanindo	0.00	1,191.268	10,250.872	2,063.315	13,505.455
Total	2.770	8,808.001	48,000.327	7,732.647	64,543.746

Source: Analysis results

Table 13. Water catchment validation confusion matrix

	Water catchment class	Field data				Total
		Natural Normal	Starting to be critical	Moderately Critical	Critical	
Analysis result	Natural Normal	5	0	0	0	5
	Starting to be critical	0	12	1	0	13
	Moderately Critical	0	0	59	1	60
	Critical	0	0	1	44	45
	Total	5	12	61	45	123
	Overal Validation	97.56				

Source: Analysis results

The study revealed that of the six sub-districts, the natural normal condition water catchment potential is only found in the sub-district of Onan Runggu, with an area of 2.770 hectares. However, other classes of potential water catchment areas are scattered in each sub-district. The largest area with Starting to be critical water catchment potential is the Ronggur Ni Huta sub-district at 2,432.766 hectares, and the smallest area is Simanindo at 1,191.268 hectares. The most dominant moderately critical water potential is in the Palipi sub-district, with an area of 10,482.935 hectares, while the area with the lowest area is in the Nainggolan sub-district, with an area of 4,484.644 hectares. The largest area of the critical class of water catchment potential is the Simanindo sub-district at 2,063.315 hectares. The least is found in the Onan Runggu sub-district, which has only 864.968 hectares. The analysis revealed that more than 80% of Samosir Island has the criteria of water catchment potential, which is moderately critical and critical. The overall validation value (Table 13) of the water catchment area map on Samosir Island is 97.56%, greater than 85%. The distribution of potential water catchment areas on Samosir Island is presented in Figure 6.

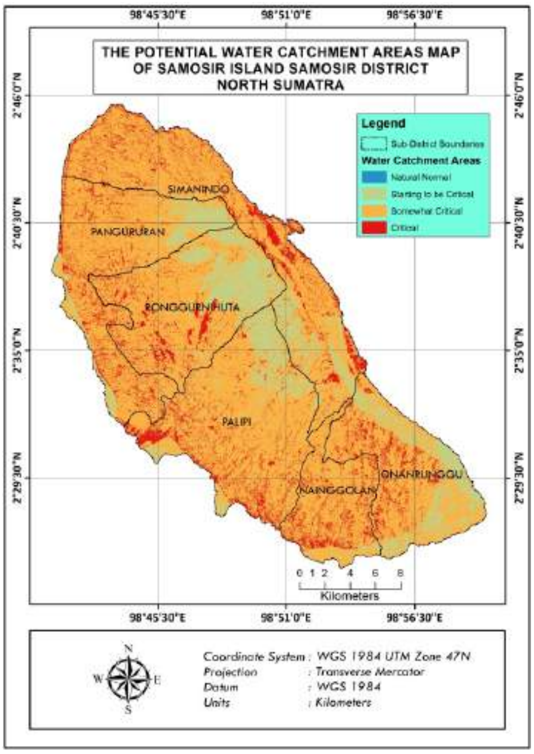

Figure 6. Map of the potential of water catchment areas distribution on Samosir Island

3.6. Drought Disaster Mitigation Efforts based on Water Catchment Potential

Disaster mitigation, according to UU No. 24/2007 on Disaster Management, is a form of effort made in the face of disaster risk, both through physical development and awareness and improvement of the ability to face disaster threats [19]. Conservation of water catchment areas that can be done on Samosir Island is presented in Table 14.

Table 14. Drought Disaster Mitigation Efforts based on Potential Water Catchment Areas

Water catchment area potential	Land use	Description
Natural Normal	Forest	Vegetation forest need preserved and retained
Starting to be critical	Forest	Vegetation forest need preserved and retained
	Farm	Vegetation need preserved and retained
	Mixed farm	Vegetation need preserved and maintained
	Fields	Planting trees with agrisilviculture system (perhutani)
	Grassland	Trees planting
	Shrubs	Planting trees in addition to maintaining shrubs
Moderately Critical	Forest	Vegetation forest need preserved and retained
	Farm	Vegetation need preserved and retained
	Mixed farm	Vegetation need preserved and maintained
	Fields	Planting trees with agrisilviculture system (perhutani)
	Open land	Trees and understoreys planting
	Grassland	Trees planting
	Settlements	Building Rainwater Harvesting Installation, creating biopores to reduce surface runoff, and planting trees around settlements to improve soil texture
	Rice field	Repairing of the terrace boundaries
	Shrubs	Planting trees in addition to maintaining shrubs
Critical	Fields	Planting trees with agrisilviculture system (perhutani)
	Open land	Trees and understoreys planting
	Grassland	Trees planting
	Settlements	Building Rainwater Harvesting Installation, creating biopores to reduce surface runoff, and planting trees around settlements to improve soil texture
	Rice fields	Repairing of the terrace boundaries
	Shrubs	Planting trees in addition to maintaining shrubs

Source: Analysis results based on fields conditions

Planting trees with an agro-silviculture system and understoreys helps the process of infiltration because the root system supports improving soil texture. A small part of the land has been implemented, but the majority has not. Implementing an agro-silviculture system on fields/moors positively impacts soil's biological, physical, and chemical properties, which have implications for infiltration and percolation [20]. Conservation of water infiltration through the creation of bio-pores in residential areas contributes to increasing infiltration so that water will not pool or flow over the surface of the land so that groundwater reserves will be more significant. This is one of the innovations not developed on Samosir Island. Bio-pores absorption holes have the working principle of storing and absorbing rainwater and seeping it into the soil as infiltration water [21]. Biopores integrated into agroforestry systems have demonstrated significant benefits in dry regions (Samosir Island), improving soil moisture retention and crop water use efficiency, which is crucial for adapting to climate variability. Furthermore, biopores optimize water and soil conservation, suggesting a biomimetic approach to environmental challenges. Overall, bio-pores represent a sustainable and cost-effective technology for enhancing water management practices across diverse landscapes.

The terracing pattern in Samosir Island has been implemented, but the paddy fields boundary land is poorly managed. Water from the paddy field tends to flow rather than infiltrate. Therefore, the paddy field boundary plots must be improved to increase water infiltration into the soil. A terracing system on a paddy field will increase its water-holding capacity so that if precipitation occurs, the water will seep and enter the soil as a groundwater reserve. Rainwater harvesting installation is another innovation that several communities on Samosir Island have implemented. The principle of this innovation is collecting as much rainwater as possible when precipitation occurs so that it can meet community needs [22]. The rainwater harvesting system is in the form of piping installation, which collects rainwater from rain gutters and directs it to wells, infiltration wells, or water storage tanks the rainwater harvesting system is in the form of piping installation, which collects rainwater from rain gutters and directs it to wells, infiltration wells, or water storage tanks [23].

4. Conclusion

The potential for water catchment areas on Samosir Island was categorized into four classes, dominated respectively by moderately critical, starting to be critical, critical, and natural normal. The Moderately critical area covers an area of 48,000.327 hectares (74.369%), starting to be critical of 8,808.001 hectares (13.647%) and critical of 7,732.647 hectares (11.980%). The three critical levels are spread across six sub-districts: Simanindo, Pangururan, Ronggur Ni Huta, Nainggolan, and Onan Runggu. The natural normal class for water catchment is only 2.770 hectares (0.004%) in Onan Runggu. Drought mitigation on Samosir Island could be achieved by maintaining vegetation, planting trees and understoreys, repairing terrace boundaries, building rainwater harvesting installations, and creating bio-pores.

References

[1] A. Aprilana and H. Oktavian, "Analisis Spasial Sebaran Kondisi Resapan Air di Kabupaten Bandung (Studi Kasus: Kecamatan Soreang dan Kecamatan Kutawaringin)," *FTSP* pp.: 512-517, 2021.

[2] D. N. Simanjutak, E. Rahmadi, and C. Dewi, "Analisis Potensi Daerah Resapan Air di Kabupaten Pringsewu-Propinsi Lampung," *Rekayasa: Jurnal Ilmiah Fakultas Teknik Universitas Lampung,* vol. 26, no. 1, pp. 1-4, 2022.

[3] B. L. Siregar, "Pengurangan Risiko Bencana Kekeringan di Lereng Perbukitan Pulau Samosir," *Tangguh: Jurnal Penanggulangan Bencana dan Pengembangan Masyarakat,* vol. 1, no. 1, pp. 42-49, 2009.

[4] P. Abadi, R. Rahmawaty, and Y. Afifuddin, "Informasi Kebakaran Hutan dan Lahan Berdasarkan Indeks Kekeringan dan Titik Panas di Kabupaten Samosir," *Peronema Forestry Science Journal,* vol. 2, no. 2, pp. 6-12, 2013.

[5] A. Zaitunah, A. Y. Mandalahi, and L. Syaufina, "Mapping Land Cover and Vegetation Detection in Urban Areas," *Journal of Sylva Indonesiana,* vol. 5, no. 01, pp. 68-80, 2022.

[6] R. P. N. Pardede, I. N. Dibia, and W. Wiyanti, "Aplikasi Sistem Informasi Geografis untuk Analisis Potensi Daerah Resapan Air di Kecamatan Buleleng," *Jurnal Agroekoteknologi Tropika* vol. 10, no. 1, pp. 26-37, 2021.

[7] N. L. Pandiangan, I. W. Diara, and T. B. Kusmiyarti, "Analisis Kondisi Daerah Resapan Air Kecamatan Sukasada Kabupaten Buleleng Menggunakan Sistem Informasi Geografis," *Jurnal Agroekoteknologi Tropika* vol. 10, no. 3, pp. 324-336, 2021.

[8] N. P. U. Handayani, N. M. Trigunasih, P. P. K. Wiguna, and I. W. Sedana, "Analisis Faktor Prioritas Daerah Resapan Air di Kota Denpasar Provinsi Bali," *Jurnal Agroekoteknologi Tropika* vol. 11, no. 2, pp. 229-235, 2022.

[9] R. R. Husaini, M. Yazid, and M. Al Amin, "Identifikasi Kondisi Daerah Resapan Air Berbasis SIG (Studi Kasus di Kabupaten Bengkalis)," *Jurnal Teknologi dan Rekayasa Sipil,* vol. 1, no. 2, pp. 15-23, 2022.

[10] M. J. Wiggers, I. W. Nuarsa, and I. D. N. N. Putra, "Monitoring Perubahan Penggunaan Lahan Pesisir di Kecamatan Batu Layar, Kabupaten Lombok Barat pada Tahun 2002 dan 2019," *JMRT,* vol. 3, no. 2, pp. 68-74, 2020.

[11] S. Syukur, "Laju Infiltrasi dan Peranannya Terhadap Pengelolaan Daerah Aliran Sungai Allu-Bangkala," *Agroland: Jurnal Ilmu-ilmu Pertanian,* vol. 16, no. 3, pp. 231-236, 2009.

[12] B. Utomo, J. R. Marpaung, Y. G. G. Togatorop, and A. Dalimunthe, "Rainfall Observation and Utilization of Rooter System Technology to Increase Water Infiltration Rate in Urban Area," *Journal of Sylva Indonesiana,* vol. 4, no. 01, pp. 36-44, 2021.

[13] C. Yunagardasari, A. K. Paloloang, and A. Monde, "Model Infiltrasi pada Berbagai Penggunaan Lahan di Desa Tulo Kecamatan Dolo Kabupaten Sigi," *Agrotekbis: E-Jurnal Ilmu Pertanian,* vol. 5, no. 3, pp. 315-323, 2017.

[14] S. Asfiati and Z. Zurkiyah, "Pola Penggunaan Lahan Terhadap Sistem Pergerakan Lalu Lintas di Kecamatan Medan Perjuangan, Kota Medan," in *Seminar Nasional Teknik (SEMNASTEK) UISU*, 2021, vol. 4, no. 1, pp. 206-216.

[15] M. B. Syauqi and S. Dibyosaputro, "Studi Pengaruh Perubahan Penggunaan Lahan Terhadap Perubahan Infiltrasi dan Limpasan Permukaan di Sebagian Wilayah Desa Maguwoharjo, Depok, Sleman, Daerah Istimewa Yogyakarta," *Jurnal Bumi Indonesia,* vol. 6, no. 4, pp. 1-13, 2017.

[16] N. P. G. Qur'ani, D. Harisuseno, and J. S. Fidari, "Studi Pengaruh Kemiringan Lereng Terhadap Laju Infiltrasi," *Jurnal Teknologi dan Rekayasa Sumber Daya Air,* vol. 2, no. 1, pp. 242-254, 2022.

[17] W. Wiyanti, K. D. Susila, R. Suyarto, and M. Saifulloh, "Analisis Spasial Potensi Resapan Air untuk Mendukung Pengelolaan Daerah Aliran Sungai (DAS) Unda Provinsi Bali," *Jurnal Penelitian*

Pengelolaan Daerah Aliran Sungai (Journal of Watershed Management Research), vol. 6, no. 2, pp. 111-124, 2022.

[18] N. Nasrah, M. Yasar, and D. Devianti, "Pemetaan Potensi Daerah Resapan Air Tanah (Recharge) di Sub DAS Krueng Jreu," *Jurnal Ilmiah Mahasiswa Pertanian,* vol. 7, no. 4, pp. 791-798, 2022.

[19] N. Wahdaniyah, K. Kartini, I. P. Rahayu, A. I. Asman, and D. N. Annisa, "Mitigasi Bencana Kekeringan di Kawasan Daerah Aliran Sungai Maros Kabupaten Maros Provinsi Sulawesi Selatan," in *Seminar Nasional Geomatika*, 2017, vol. 2, pp. 361-370.

[20] E. Junaidi, "Peranan Penerapan Agroforestry Terhadap Hasil Air Daerah Aliran Sungai (DAS) Cisadane," *Jurnal Penelitian Agroforestry,* vol. 1, no. 1, pp. 41-53, 2013.

[21] A. Hidayat *et al.*, "Pembuatan Biopori sebagai Upaya Peningkatan Laju Infiltrasi dan Cadangan Air Tanah serta Pengendalian Banjir," *Jurnal Pasopati: Pengabdian Masyarakat dan Inovasi Pengembangan Teknologi,* vol. 3, no. 3, pp. 129-133, 2021.

[22] I. Ardi, R. Razali, and H. Hanum, "Identifikasi Status Hara dan Produksi Padi pada Lahan Sawah Terasering dan Non Terasering di Kecamatan Onan Runggu Kabupaten Samosir," *Jurnal Agroekoteknologi Universitas Sumatera Utara,* vol. 5, no. 2, pp. 338-347, 2017.

[23] B. Riyanta, S. Sunardi, T. Thoharudin, and F. A. K. Yudha, "Perancangan Instalasi Pemanen Air Hujan," *Mitra Abdimas: Jurnal Pengabdian kepada Masyarakat,* vol. 2, no. 2, pp. 40-44, 2022.