www.bircu-journal.com/index.php/birci
Budapest International Research and Critics Institute-Journal (BIRCI-Journal)
Humanities and Social Sciences
ISSN 2615-3076 Online)
ISSN 2615-1715 (Print)
Budapest Institute

Sustainability Analysis of Wae Batu Elephant River Flow Management Ambon City

Jusmy D. Putuhena
Faculty of Agriculture, Universitas Pattimura, Indonesia
jusmy_putuhena@yahoo.com

Abstract

The role of the Wae Batu Gajah watershed which has a function to regulate water management and as a water source is currently starting to experience a very significant change with the rate of change of forest land cover into settlements which ultimately destroys the sustainability of the ecological function. This damage can be proven by the phenomenon of flooding and that occurs in the rainy season and drought in the dry season. The analysis of the sustainability of the Wae Batu Gajah watershed has the following objectives: 1). Analyzing the index and sustainability status of the Wae Batu Gajah watershed from the ecological, economic and social dimensions. 2). Testing the validity and testing the accuracy of the sustainability index of the Wae Batu Gajah watershed management. The results of the study show that the multidimensional sustainability index for the three ecological, economic and social dimensions is 50.97% in the moderately sustainable category. The validation test shows the difference in the value of the Monte Carlo and MDS analysis at the 95% confidence level the average for the three dimensions is 0.72%; the value of determination (R2) between 93.86% - 95.18% means that the sustainability index estimation model is good and adequate; stress value 0.2, which means that the MDS analysis model obtained has a high accuracy (goodness of fit) to assess the sustainability index of the Wae Batu Gajah watershed.

Keywords
watershed; sustainability index.

I. Introduction

Watersheds (DAS) are often used by the forestry sector because forests are considered a conservation function, which among others functions as a catchment area, while the term DAS is generally better known because it is used by the general public. In a watershed, there are various types of land cover that have their respective functions (Intopiana et al. 2020).

The function of this watershed ecosystem will decrease as a result of human activities as well as due to changes that occur naturally. In general, the identification of watershed problems can be divided into four (4) namely hydrology, land, socio-economic and institutional. Watershed problems are reviewed on the land aspect due to the high level of erosion and sedimentation causing the expansion of critical land and decreasing land productivity. In the socio-economic aspect, watershed problems are caused by the conversion of large areas of land to increase the income of the people in the watershed. In the institutional aspect, watershed problems can be seen in the lack of coordination, integration, synergy (KISS) between stakeholders in watershed management, causing conflicts in their management (Directorate of Forestry and Water Resources Conservation, 2004); Putuhena and Sapei (2016).

DOI: *https://doi.org/10.33258/birci.v5i4.7052*

Rogers et al. (2007) cited Munashinge (1993), Smith and Jalal (2000) that there are three main pillars in sustainable development, namely the ecological dimension, the social dimension and the economic dimension. The ecological dimension means that the optimization of ecological benefits does not have to ignore economic and social aspects. The social dimension does not have to ignore the economic and ecological aspects. While the economic dimension means not ignoring the ecological and social dimensions. Thus, the three pillars must be moved simultaneously in the planning and implementation of development. The economic condition of the population is a condition that describes human life that has economic score (Shah et al, 2020). Economic growth is still an important goal in a country's economy, especially for developing countries like Indonesia (Magdalena and Suhatman, 2020).

Changes in the watershed area in the Leitimor Semenajung, Ambon City have increased significantly since entering the 2000s, including the Wae Batu Gajah watershed area. Putuhena et al (2014); This land use change is influenced by the population growth rate which tends to increase by 1.25% in 2009 (284,809 inhabitants), social conflicts that occurred in early 2000 were the main factor in accelerating the change in the function of the watershed area into settlements (BPS Kota Ambon, 2010).

The role of the Wae Batu Gajah watershed which has a function to regulate water management and and as a water source is currently starting to experience a very significant change with the rate of change in forest land cover into settlements which in turn destroys the sustainability of the ecological function (Latuihamallo 2016; Putuhena, 2019). This damage can be proven by the phenomenon of flooding and what occurs in the rainy season and drought in the dry season (Putuhena, 2013).

The sustainability of a watershed (DAS) is an indicator that can be measured to what extent the watershed can support the availability of water for the people who occupy the watershed (Putuhena et all. 2014). Wae Batu Gajah watershed needs to be known to what extent the value of the sustainability index is and what steps need to be followed up so that it can support activities in the watershed.

II. Research Method

2.1 Research sites

This field research was conducted in the Wae Batu Gajah watershed, Ambon City with an area of 549.55 ha of the Wae Batu Gajah watershed, with the consideration that the Wae Batu Gajah watershed is one of the locations for raw water sources and is currently experiencing very high forest conversion into settlements.

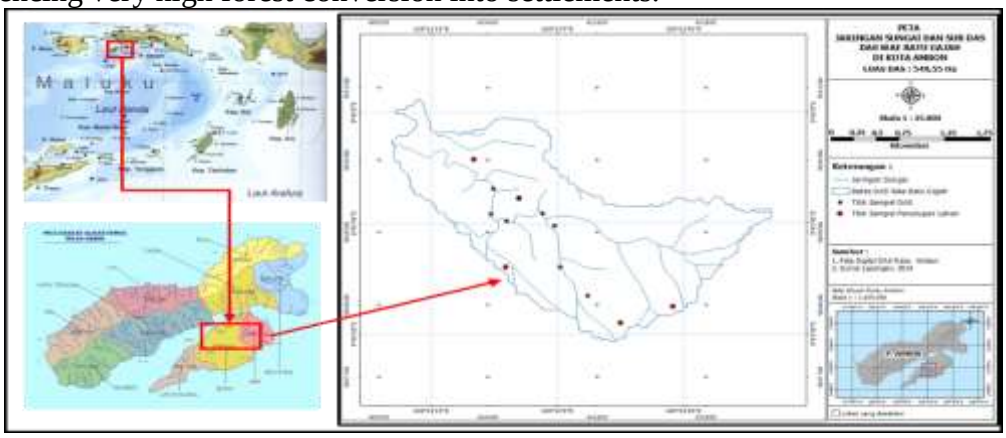


Figure 1. *Research Location Map*

2.2 Data Types and Sources

The data collected is primary data in the form of attributes related to the three dimensions of watershed management sustainability. The data was obtained by conducting interviews with various respondents and selected experts, as well as the results of measurements and field observations. while secondary data comes from related agencies, and several library sources.

2.3 Method of collecting data

The types of data collected in this study are primary data and secondary data. Primary data collected in the field through interviews, measurements. Secondary data from various related agencies from Bappedalitbang Ambon City, BPDAS-HL Wae Apu Batu Merah.

2.4 Data analysis

Land cover analysis in the Wae Batu Gajah watershed in 2009 and 2020 was carried out through a spatial approach using the ArcGIS application to map land cover conditions in those years. The calculated data are then analyzed for trends in land cover changes.

The analysis of the sustainability of the Wae Batu Gajah watershed management was carried out using the Multi Dimensional Scaling (MDS) approach. This analysis is carried out through several stages, including:

- Determination of sustainable attributes of catchment area management which includes five dimensions, namely: ecology, economy, socio-culture, infrastructure/technology and institutions.
- The assessment of each attribute on an ordinal scale is based on the sustainability criteria of each dimension.
- Each attribute in each dimension is given a score based on the scientific judgment of the scorer. The score ranges from 0–3 or depending on the state of each attribute, which is interpreted from bad to good.

The score results for each attribute are analyzed by multi-dimensional scaling to determine one or more points that reflect the position of the sustainability of sustainable management development against two reference points, namely good points and bad points. The estimated score for each dimension is expressed on a scale of worst (bad) 0% to best (good) 100%. The score value which is the sustainability index value for each dimension can be seen in Table 1. below:

Table 1. Category of sustainability status of Wae Batu Gajah watershed management

Index Value	Sustainability category
0.00 - 25.00	Bad
25.01 - 50.00	Not enough
50.01 - 75.00	Enough
75.01 - 100.00	Well

Through the MDS method, the position of the sustainability point can be visualized in the form of a kite diagram as shown in Figure 1 below:

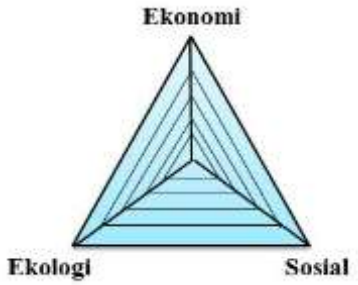


Figure 2. *Illustration of multidimensional sustainability index*

III. Result and Discussion

3.1 Characteristics of the Wae Batu Gajah watershed

The development of Ambon City in recent years requires a very large area of land, so that changes in land use have occurred quite recently. The Wae Batu Gajah watershed as part of the urban area in the center of Ambon City has also experienced changes in land use leading to open areas/vacant land becoming built-up areas. The results of data processing using spatial analysis show that there are changes in land use that occur in the Wae Batu Gajah watershed which can be seen in Figure 4. The area of land use per year and the difference is presented in Table 2.

The Wae Batu Gajah watershed is a series of main rivers with tributary branches. The watershed of the Wae Batu Gajah River from upstream to the middle is in the Petuanan of Soya Village, to Batu Gajah Village and downstream is in the Honipopu Village, Ahusen to Waihaong Beach.

Table 2. Changes in Land Use in the Wae Batu Gajah Watershed in 2009-2020

Tuplah Type	**The year 2009**		**2020**		**Difference (ha)**	
	Ha	**%**	**Ha**	**%**	**(-)**	**(+)**
Secondary Dryland Forest	299.94	54.49	275.29	50.01	-24.67	0
Settlement	56.39	10.25	94.13	17.12	0	37.84
Dryland farming	20.26	3.68	96.12	17.46	0	75.86
Mixed Dryland Farming	63.29	11.50	61.19	11.12	-2.1	0
Shrubs	92.51	16.81	23.59	4.29	-68.92	0
Open field	18.01	3.27	0	0	-18.01	0
Total	550.41	100	550.19	100	-113.70	113.70

Note: % change 2009/2020 = (2020 area-2009 area)/watershed area x 100%.

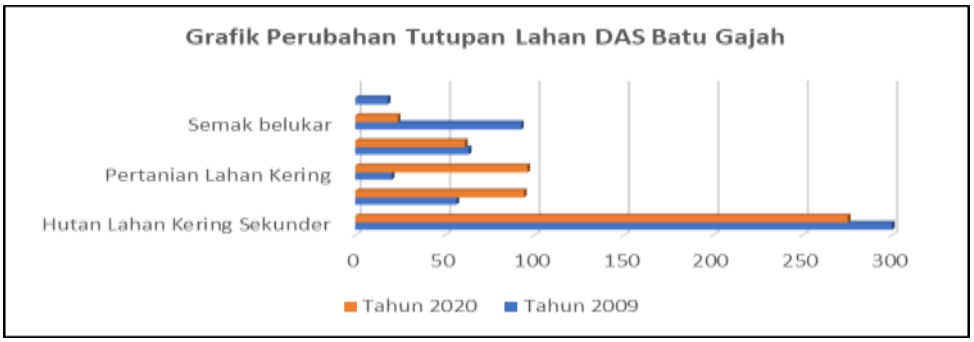
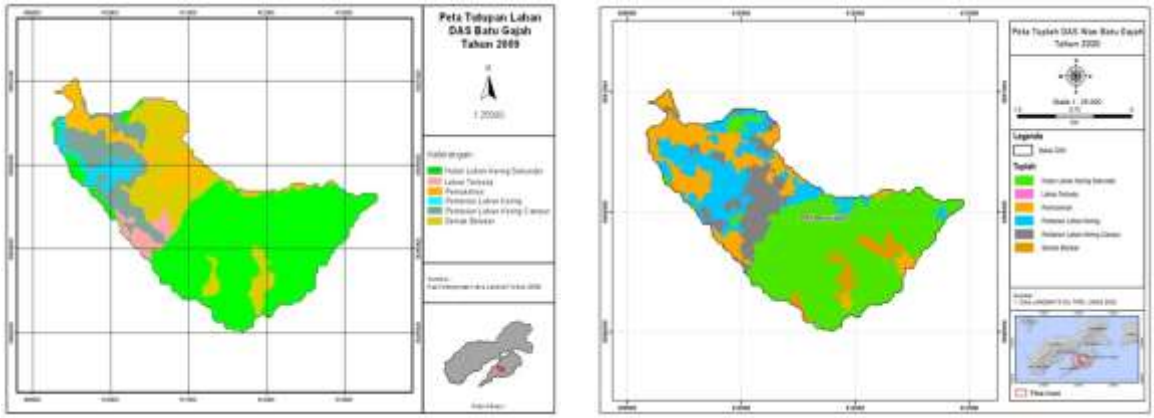


Figure 3. *Changes in land cover in the Batu Gajah watershed in 2009-2020.*

Changes that occurred were 113.70 Ha, with changes in land cover which increased in area of land use: settlements by 37.84 ha and dry land agriculture by 75.86 ha; while the decrease in land use occurred in secondary dryland forest by 24.76 ha, shrubs by 68.92 ha and the absence of vacant land by 18.01 ha.

Wae Batu Gajah watershed is the main watershed where many tributaries flow with river flow patterns including dendritic patterns. The shape and size of the watershed area is elongated and relatively narrow which can describe the level of drainage density in the watershed area.

Wea Batu Gajah watershed in Ambon City has slopes divided into 4 (four) slope classes, namely 8-15%, 15-30%, 30-45%, and > 45%. The results of the formation of the Hydrology Response Unit formed, the slope conditions are classified as flat to steep because they represent slopes of 8-15% to >45%.



(a) The year 2009 (b) 2020

Figure 4. *Land Cover Map of Wae Batu Gajah Watershed*

The slopes of the Wae Batu Gajah watershed are dominated by moderately steep slopes (15-30%) with an area of 121.16 ha, gentle slopes (8-15%) with an area of 45.32 ha, steep (30-45%) with an area of 362.06 ha and the last undulating slopes up to very steep (>45%) with an area of 21 ha. It can be said that the Wae Batu Gajah watershed is located in an area with steep (mountainous) slopes.

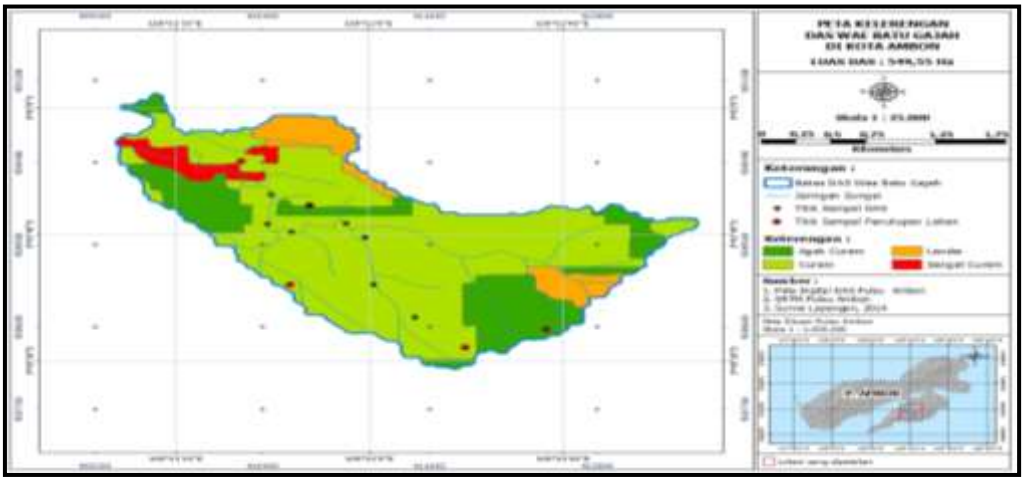


Figure 5. *Slope Class Map of Wae Batu Gajah Watershed.*

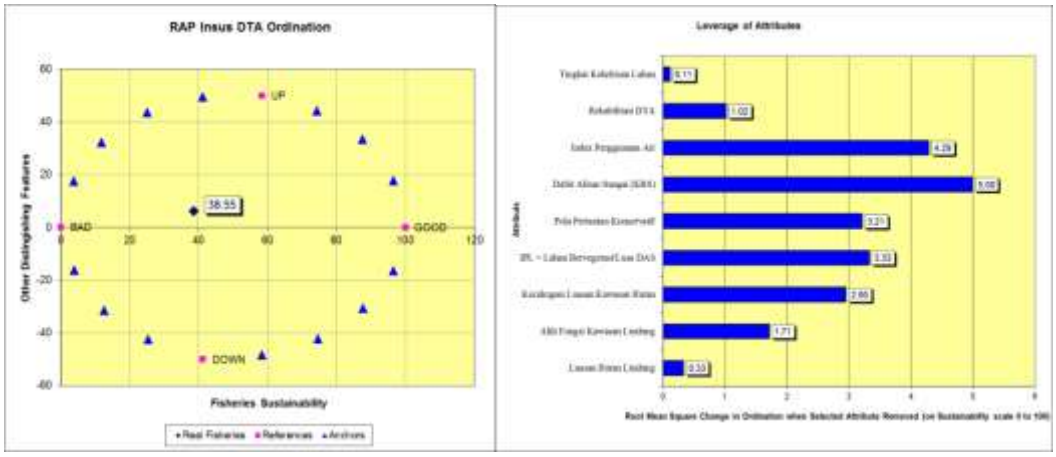
Table 3. Slope conditions in the watershed in Ambon City

Slope Class (%)	Area (Ha)	Percentage (%)	Information
8 – 15	45.32	8.25	Sloping
15 – 30	121.15	22.04	Slightly Steep
30 – 45	362.07	65.88	Steep
>45	21.03	3.83	Very Steep
TOTAL	**549.57**	**100**	

3.2 Ecological Dimension Sustainability Status

The results of the analysis of the Wae Batu Gajah Rap-DAS found that the index value of the sustainability level on the ecological dimension of 38.55% means less sustainable. The sustainable index value of less than 50% indicates the worsening ecological condition of the Wae Batu Gajah watershed area. The ecological capacity of the area to support activities in the area is decreasing. If this ecological carrying capacity is left unchecked, it will affect the sustainability of other dimensions so that the management of the Wae Batu Gajah watershed is increasingly unsustainable. The results of the analysis of the sustainability of the ecological dimensions are presented in the cological figure, obtained 5 attributes that are sensitive to the level of sustainability of the ecological dimension, namely (1) River Flow Discharge; (2) Water Use/IPA Index; (3) IPL Vegetation Index = Vegetated Land/Watershed Area; (4) Conservative Agricultural Patterns; and (5) Sufficiency of Forest Area. Changes to these 5 leverage factors will easily affect the increase or decrease in the value of the ecological dimension sustainability index. The results of the Sustainability analysis are presented in Figure 6 (A).

Leverage analysis on ecological attributes obtained 5 attributes that are sensitive to the level of sustainability from the ecological dimension, namely (1) River Flow Discharge; (2) Water Use/IPA Index; (3) IPL Vegetation Index = Vegetated Land/Watershed Area; (4) Conservative Agricultural Patterns; and (5) Sufficiency of Forest Area. Changes to these 5 leverage factors will easily affect the increase or decrease in the value of the ecological dimension sustainability index. The results of the leverage analysis are presented in Figure 6 (B).



(A)
The value of the sustainability index of the ecological dimension of the Wae Batu Gajah watershed

(B)
The results of the analysis of attribute leverage on ecological dimension

Figure 6. *Sustainability index value and leverage analysis results*

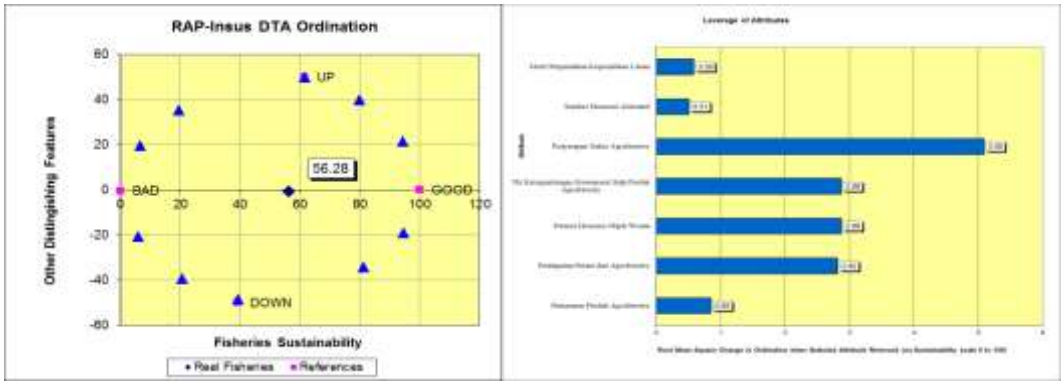
To increase the sustainability index of the ecological dimension, it is necessary to have policy interventions, including: a) It is necessary to increase the area of vegetated cover and reduce the rate of conversion of vegetated land into settlements so as to reduce river flow discharge; b) Good use of water for domestic water needs, good management of water production by the PDAM, increasing water production by utilizing the potential of new water sources; c). Maintaining a conservative agricultural system in the form of mixed and long-lived types of plants, using organic fertilizers, without pesticides by the people who live upstream of the catchment area; d). This vegetation-covered land needs to be maintained and its area must be increased.

3.3 Economic Dimension Sustainability Status

The results of the analysis of the Ambon City Watershed Rap-Insus obtained that the sustainability index value from the economic dimension was 56.28%, meaning that it was quite sustainable. This means that economically, the Wae Batu Gajah watershed still provides support for sustainable management. The results of the analysis of the sustainability of the economic dimension are presented in Figure 6 (A).

Based on the results of the leverage analysis presented in Figure 3 (B), there are 4 (two) attributes whose changes are sensitive to the value of the economic sustainability index, namely (1) Agroforestry Labor Absorption; and (2) the level of consumer dependence on agroforestry products; (3) Potential Tourism Objects; and (4) Farmers' Income from Agroforestry. The results of the analysis of the economic dimension of leverage are presented in Figure 7 (A).

In order to maintain and improve the sustainability index of the economic dimension, it is necessary to have policy interventions, including: a). Absorption of Naker Agroforestry, in this case is an economic activity that is not based on an agroforestry system that has high economic value compared to seasonal crops, so that it can absorb labor to manage agroforestry production; b). There is a need for post-harvest handling of agroforestry products originating from the upstream watershed of Ambon City, considering that the community's dependence on these products is very high; c). Utilization and management of areas that have good tourism potential so that they can attract many visitors, thus the potential of this tourist attraction can be an alternative source of income for the community around the location of the tourist attraction; d).



(A) The value of the sustainability index of the economic dimension of the Wae Batu Gajah

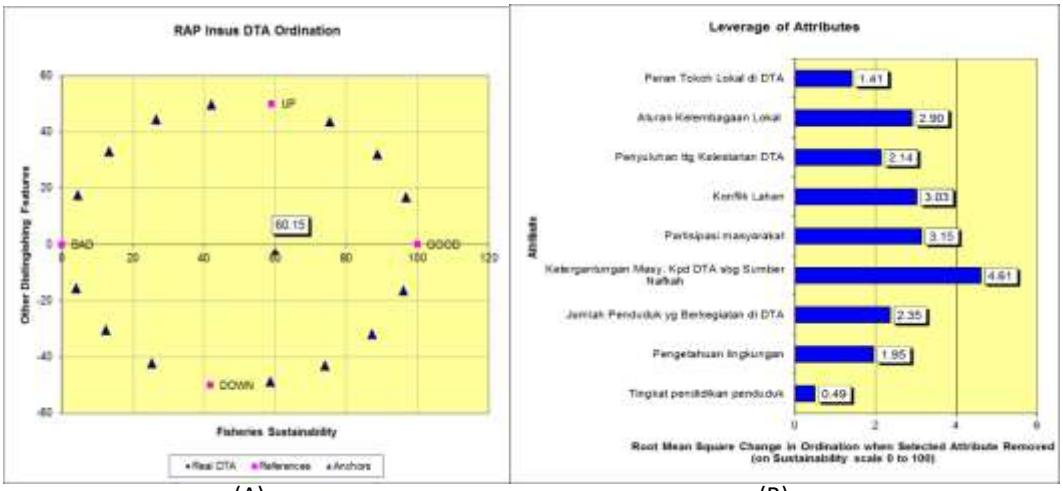
(B) The results of the analysis of attribute leverage on economic dimension

Figure 7. *Sustainability index value and economic dimension leverage analysis*

3.4 Social Dimension Sustainability Status

The results of the sustainability analysis produce an index value on the social dimension of 60.15% which means it is quite sustainable. The results of the analysis of the sustainability of the social dimension are presented in Figure 8 (A). Based on the results of leverage analysis obtained 4 (five) attributes that are sensitive to the index of social and cultural sustainability, namely (1) community dependence on watersheds as a source of livelihood; (2) The level of community participation; (3) Land Conflicts; (4) Local institutional rules. The results of the analysis of leverage on the social dimension are presented in Figure 8 (B).

In order to maintain and increase the value of the sustainability index of the social dimension, it is necessary to have policy interventions, including: a). Increase dissemination to the community in the upstream watershed about the importance of the watershed so that the community's dependence on the watershed as a source of livelihood will be efficient if the land area is in accordance with the number of farmers because it is related to the carrying capacity of the land; b). Involving the community together in various catchment management activities, c). The role of the government as a policy maker may be as a bridge in terms of resolving land ownership statuses that are in conflict, so that the conflicting parties can end; d). Maintaining local institutional rules (sasi) that apply to Ambon City in general and the Wae Batu Gajah watershed area in particular is still going well and there are unwritten rules and there are customary institutions that manage the prohibition or postponement of harvesting on certain types of plants. This institutional rule is still running today so it needs to be maintained in the context of conserving natural resources in general and watersheds in particular.



(A) The value of the sustainability index of the social dimension of the Wae Batu

(B) The results of the analysis of attribute leverage on

Figure 8. *Sustainability index value and social dimension leverage analysis*

3.5 Status of Multidimensional Sustainability of Wae Batu Gajah Watershed Management

The results of the multidimensional Rap-Insus analysis on the sustainability of the Wae Batu Gajah watershed management resulted in a sustainability index value of 50.97, a value classified as quite sustainable. This value is obtained based on the assessment of 25 attributes that include ecological, economic and social dimensions. The results of the Rap-Insus analysis of the Wae Batu Gajah watershed are presented in Figure 9 below.

Figure 9. *Multidimensional sustainability index of Wae Batu Gajah watershed sustainability*

3.6 MDS Validity Test and Accuracy Test

The validation test pointed to the results of the Monte Carlo analysis and the MDS analysis at the 95% confidence level. It was found that the value of the sustainability index of Wae Batu Gajah watershed management shows that the difference in the values of the two analyzes is very small (see Table 3). This means that the resulting MDS analysis model is adequate to estimate the sustainability index value of the Wae Batu Gajah watershed. The small difference in the results of these two analyzes indicates that: 1) errors in the analysis process can be minimized or avoided. The errors in scoring in the attributes are relatively small; 2). Variations in scoring that are multidimensional due to the existence of different opinions are relatively small; 3). the data analysis process which is performed repeatedly is relatively stable; 4). errors in inputting data and missing data can be avoided.

Table 3. Differences in the value of the MDS sustainability index and the Monte Carlo analysis

Dimension	Sustainability Index Value (%)			
	MDS	Monte Carlo (MC)	Difference (MDS-MC)	Difference (MDS-MC)%
Ecology	38.55	38,48	0.07	0.18
Economy	56.28	57.16	0.88	1.56
Social	60.15	60,30	0.15	0.25
Average	51.66	51.98	0.37	0.72

The results of the Rap-Insus analysis of the Wae Batu Gajah watershed obtained a coefficient of determination (R2) between 93.86% - 95.18% or greater than 80% or close to 100%, meaning that the sustainability index estimation model is good and adequate (Kavanagh, 2001). The stress value is between 0.14 – 0.16 or the difference in the stress value is 0.2. This determination value is close to the value of 95-100% and the stress value of 0.2 is less than 0.25 or 25% so that the MDS analysis model obtained has a high accuracy (goodness of fit) to assess the sustainability index of the Wae Batu Gajah watershed (Fisheries, 2004). 1999). The stress value, the coefficient of determination from the analysis of the Rap-Insus Wae Batu Gajah watershed is presented in Table 3 below.

Table 4. Stress value and determination value (R2) from the Wae Batu Gajah Rap-watershed

No.	Parameter	Ecological Dimension	Economic Dimension	Social Dimension
1	Stress Value	0.14	0.16	0.14
2	R2 value	95.18	93.86	95.12

IV. Conclusion

1. The sustainability index of the ecological dimension of 38.55% is categorized as less sustainable, the sustainability index of the economic dimension of 56.28% is categorized as moderately sustainable; social sustainability index of 60.15% in the moderately sustainable category; the multidimensional sustainability index for the three ecological, economic and social dimensions is 50.97% in the moderately sustainable category.
2. The results of the validation test show that the difference in the value of the Monte Carlo and MDS analysis at the 95% confidence level, the average for the three dimensions is 0.72%; with a value of determination (R2) between 93.86% - 95.18% or greater than 80% or close to 100% means that the sustainability index estimation model is good and adequate; with a stress value of 0.2 less than 0.25 or 25% so that the MDS analysis model obtained has a high accuracy (goodness of fit) to assess the sustainability index of the Wae Batu Gajah watershed.

References

[BPS]. Badan Pusat Statistik Kota Ambon, (2009). Kota Ambon dalam Angka Tahun 2010.

Asdak C. (2007). Hidrologi dan Pengelolaan Daerah Aliran Sungai, Cetakan keempat, Yogyakarta, Gadjah Mada University Press.

Bertram G. (1986). Sustainable Development in Pasific Micro-economies. World Dev. 14 (7), 809-822

Djuansah M.R., Sastramihardja T.P., Hadi I. (2004). Sumber Daya Air Pulau Ambon: Tinjauan Hidrogeologi dan Hidrokimia Jazirah Hitu Pulau Ambon. Sumber Daya Air di Pulau Kecil. Penerbit LIPI Press. Jakarta.

Fauzi A., Anna Z. (2005). Pemodelan Sumberdaya Perikanan dan Kelautan. Untuk Analisis Kebijakan. Jakarta, Gramedia.

Hartisari (2007). Sistem Dinamik. Konsep Sistem dan Pemodelan Untuk Industri dan Lingkungan. Seameo Biotrop, Bogor.

Humfschmidt M.M. (1987). A Conseptual Framework for The Analysis of Integrated River Basin Development/Watershed Management Program. Environment of policy institute, East West Small Center, Honolulu-Hawai.

Intopiana L. V. Putuhena J. D. Aryanto B. (2020). Pemetaan Daerah Rawan Erosi di DAS Wae Batu Merah Kota Ambon. Makila. Jurnal Penelitian Kehutanan. Volume 14 Nomor 1.

Kementerian Kehutanan, (2004). Surat Keputusan Menteri Kehutanan Nomor: 25/KPTS-II/2001 tentang Pedoman Penyelenggaraan Pengelolaan Daerah Aliran Sungai. Departemen Kehutanan, Direktorat Jenderal Rehabilitasi Lahan dan Penghutanan Sosial, Direktorat Rehabilitasi Lahan dan Konservasi Tanah. Republik Indonesia. Jakarta.

Kodoatie R.J., Sjarief R. (2008), Pengelolaan Sumber Daya Air Terpadu Edisi kedua, Yogyakarta, Penerbit Andi.

Latuihamllo J. Putuhena J. D. (2016). Analisis Nilai Guna Hutan Sebagai Penyedia Air Bersih dan Implementasi PES (Payment for Ecosystem Service) Bagi Pemilik Dusun di Hutan Lindung Gunung Sirimau Kota Ambon. Jurnal Hutan Pulau-Pulau Kecil. Volume 1 Nomor 1.

Lokollo J.A., (2002). Analisis Pengaruh Perubahan Fungsi Ruang Hidrologi Terhadap Keseimbangan Air: Studi Kasus Kawasan Kotamadya Ambon, Propinsi Maluku. Tesis Program Pascasarjana Institut Pertanian Bogor. Tidak dipublikasikan.

Magdalena, S., Suhatman, R. (2020). The Effect of Government Expenditures, Domestic Invesment, Foreign Invesment to the Economic Growth of Primary Sector in Central Kalimantan. Budapest International Research and Critics Institute-Journal (BIRCI-Journal). Volume 3, No 3, Page: 1692-1703.

Putuhena J, Sapei A. (2016). Institutional System of Watershed Management in Leitimor Peninsula, Ambon Island (Watershed Management Institution in Ambon Island Peninsula Leitimor). Modern Applied Science; Vol. 10, No. 1; 2016. Published by Canadian Center of Science and Education

Putuhena J. (2013). Model Dinamik Pengelolaan Daerah Aliran Sungai (Watershed) Dalam Upaya Penyediaan Air Yang Berkelanjutan Di Semenanjung Leitimor Pulau Ambon

Putuhena J. (2019). Pengelolaan Daerah Aliran Sungai (DAS). Dimensi Pengelolaan Berkelanjutan DI Kota Ambon. Penerbit Pascasarajana Manajemen Hutan Unpatti.

Putuhena, J. D., Sapei, A., Purwanto, M. T. J., & Prasetyo, L. B. (2014). Sustainable Water Supply Model in Ambon Island. Journal of Environment and Ecology, 5(2).

Rogers P.P, Jalal K.F, Boyd J.A. (2007). An Introduction to Sustainable Development. Earthscan, UK and USA.

Shah, M. M., et al. (2020). The Development Impact of PT. Medco E & P Malaka on Economic Aspects in East Aceh Regency. Budapest International Research and Critics Institute-Journal (BIRCI-Journal). Volume 3, No 1, Page: 276-286