Journal of Sustainability Science and Management
Volume 13 Number 2, December 2018:129-142
ISSN: 1823-8556

SUSTAINABILITY ASSESSMENT ON WATERSHED MANAGEMENT IN THE AESESA FLORES WATERSHED, EAST NUSA TENGGARA PROVINCE OF INDONESIA

NICOLAUS NOYWULI[1*], ASEP SAPEI[2], NORA H. PANDJAITAN[2] AND ERIYATNO[3]

[1]*Study Program of Environmental and Natural Resources Management, Bogor Agricultural University, Indonesia*
[2]*Department of Civil and Environmental Engineering, Bogor Agricultural University, Indonesia*
[3]*Research Centre for Agriculture and Villages Development, Bogor Agricultural University, Indonesia*

**Corresponding author: nicolausnoywuli@gmail.com*

Abstract: This study was conducted to assess the sustainability of watershed management in the Aesesa Flores (AF) watershed, which located in the East Nusa Tenggara Province of Indonesia. There were five dimensions of sustainability used in this study, namely: economy, ecology, social, technology and access, and governance. The sustainability assessment was done by using the Rapid Appraisal approach that has been tailor made for the AF watershed (RAP-DASAF). The sustainability assessment was done at three different regions, which are: upstream, middle and downstream region. Data collection was done by primary interview with 127 respondents, along with field observations. Each respondent was given questionnaire to assess the corresponding attributes in each dimension. The results from the MDS analysis showed that both the upstream and downstream regions were categorized as "Less Sustainable" with the overall (five dimension) sustainability index of 48.52% and 49.13%, respectively. The middle region was categorized as "Moderate Sustainable". The MDS analysis also generated 23 attributes that considered to be the sensitive attributes to the sustainability of the AF watershed management. The results from this study are recommended as policy analysis to the regional government in the AF watershed, in order to increase the sustainability of the AF watershed.

Keywords: Watershed management, community collaboration, soil and water conservation, sustainability index.

Introduction

Watershed is defined as regions or an area with natural borders of ridges and mountain that captures rainfall and other precipitation and funnels it through streams and rivers to a lake, and/or larger outlet channel (Asdak, 2010). Blomquist and Schlager (2005) explain that watershed management is a series of policy and activities to manage natural resources in the watershed area without causing a resource depletion and environmental degradation. These policy and activities are including region and land use planning, in all regions in the watershed (Blomquist & Schlager, 2005). The watershed management is integral in the efforts to create a sustainable development.

The concept of sustainable development is related to the efforts on balancing the economic growth, social equality and environmental protection that fulfill the needs of present, to ensure that future generations could meets their needs based on the legacy we provide in the present (WCED, 1987; Mebratu, 1998). In the perspective of watershed management, the concept of sustainable development is integral to the efforts to maintain (and/or conserve) natural resources as well as using those resources for regional development and social prosperity. The sustainable watershed management involves multiple stakeholders in various regions, namely the upstream, middle and downstream region (Asdak, 2010). In order to achieve a sustainable watershed management, those stakeholders must work together in an integrated management plan.

The AF watershed is one of the priority watersheds in the East Nusa Tenggara Province of Indonesia, which consists of an area of 129,005 ha. The AF watershed is stretch from the upstream region in the town of Bajawa (Ngada District) to the downstream region in the town of

Mbay (Nagekeo District). The AF watershed is important in these regions, since the rainy season only occurs for three months in these regions, the AF watershed become the main source of water in both Ngada and Nagekeo District (Mann *et al.*, 2006). The main challenges to achieve a sustainable watershed management in the AF watershed includes: (1) high proportion of critical land in these regions (75% lands in these regions are degraded); (2) low land cover (only 17.6%); (3) low rainfall especially in the downstream area; (4) low volumetric flow in these regions (8,100 L.second-1 in dry season, and 587,000 L.second-1 in rainy season); and
(5) low community's welfare, which indicated by 45.1% of poor people from total of 18,918 family in the regions (BPDAS Benain Noelmina, 2013; Noywuli *et al.*, 2017). These challenges showed the needs to assess the sustainability of AF watershed management through various dimensions, in order to achieve a sustainable watershed management (Rasul & Thapa, 2004).

This study was aimed to assess the sustainability of AF watershed management. In this study, the sustainability assessment conducted using Rapid Appraisal for fisheries (RAPFish) analysis that has been tailor-made for watershed management sustainability analysis. The RAPFish is a multi-disciplinary rapid appraisal to evaluate comparative sustainability of fisheries using various attributes that contributing to the sustainability assessment (Fauzi & Anna, 2002). The sustainability of given attributes is drawn using the Multi-Dimensional Scaling (MDS) analysis. Originally, the RAPFish was used to assess the sustainability of fisheries development in Indonesia (Fauzi & Anna, 2002; Nurhayati & Purnomo, 2014). The RAPFish approach can be tailor-made to assess different sustainability assessment, such as agricultural sustainability assessment (Rahayu *et al.*, 2013) and estuaries watershed management assessment (Yusuf *et al.*, 2013). The MDS analysis in the RAPFish approach allowed user to compare sustainability condition based on different sustainability dimensions. There are five sustainable dimensions used in this study, namely the economic, social, ecology, technology and access, and institution and governance. The MDS analysis also generate various factors that are sensitive to the sustainability assessment, thus could become key factor in the sustainable watershed management. The results from this study are important as policy analysis in the AF watershed management.

Materials and Methods

Location

This study was conducted in the Aesesa Flores (AF) Watershed in the East Nusa Tenggara Province of Indonesia which located at 120º56'48" – 121º22'42" longitude and 8º29'01" – 8º49'41" latitude. Data collection was done from March to April 2018. The AF watershed region is located between two government districts. The upstream and a small part of the middle region are located in the Ngada district, while the middle and downstream region are located in the Nagekeo district (Figure 1). The upstream area in the southern region of Aesesa Flores watershed has a fairly low branching rate. The density of river branching is increasingly downstream in the northern part of the watershed within Nagekeo district. There are two micro-watersheds in the upstream region, five micro-watersheds in the middle region and three micro-watersheds in the downstream region. Of those ten micro-watersheds, the Ae Mau micro-watershed is the most critical micro-watershed compared to the other (Mann, 2006). The Ae Mau micro-watershed is the largest area that vulnerable to erosion, landslide and fire, and also has a high level of poverty (Mann *et al.*, 2006).

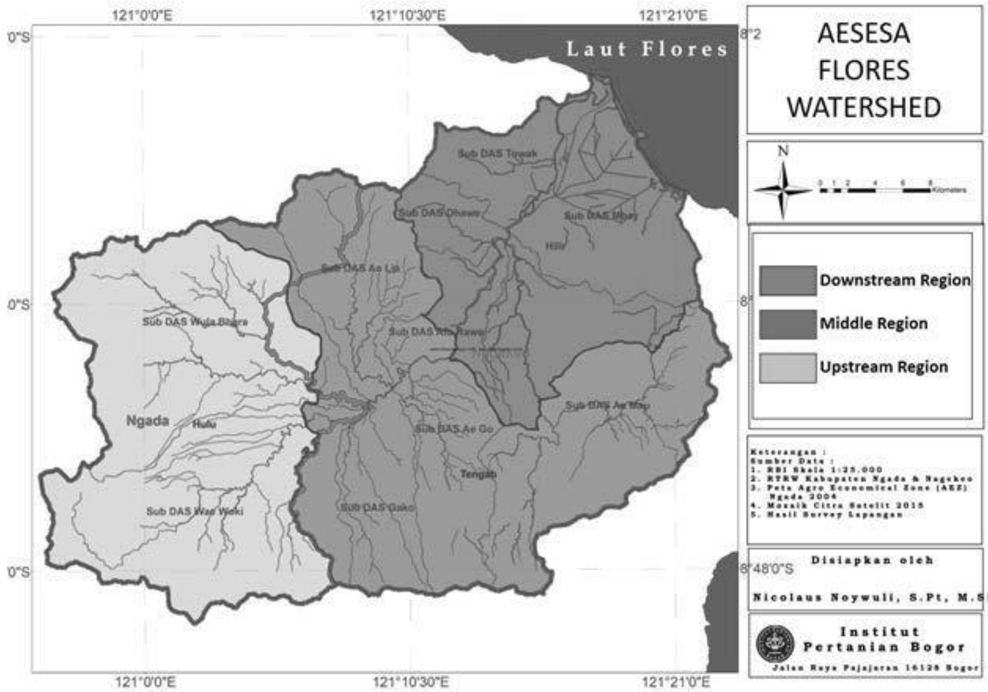


Figure 1: Aesesa watershed

Data Collection

This study used primary data from field observation, in-depth interview with experts, and field survey using questionnaire to the relevant stakeholders in the AF watershed management. The field observation was done to identify the condition of AF watershed. An in-depth interview with experts was done with Focus Group Discussion (FGD) to determine the relevant attributes in the sustainability analysis of AF watershed. The field survey was conducted using the questionnaire to 127 respondents, including local government bodies (head village chiefs) and multiple stakeholders in the AF watershed, including community groups, farmers groups and Non-Government Organization (NGO). The secondary data collection includes literature review, and other reports from the relevant government institution that involve in the AF watershed management (e.g., regional agricultural agency, regional environmental protection agency and district government).

Data Analysis using Rapid Appraisal Approach

The Rapid Appraisal approach for sustainability assessment in this study was conducted according to Pitcher (1999) and Fauzi and Anna (2002). The Rapid Appraisal approach was performed using the RAPFish by Microsoft Excel 2007 software (Microsoft Inc.) (Kavanagh & Pitcher, 2004) that tailor made for AF watershed sustainability assessment hence named RAP-DASAF. The RAP-DASAF mainly consist of three main analysis, which are: (1) ordination analysis to assess the sustainability index; (2) leverage analysis to determine which attributes in the sustainability analysis that become the main factor (sensitive attributes) that determine the sustainability index value; and (3) Monte Carlo simulation to test the degree of uncertainty for the corresponding attributes tested in the ordination analysis.

There are five dimensions of sustainability used in this study (economy, social, ecology, technology and access, and institution and governance). In each dimension, there were attributes (factors related to the watershed management) that selected because its significance to the sustainability issues (Fauzi & Anna, 2002). The selected attributes for each dimension were shown in Table 1. Scoring for each attribute was done by field survey and questionnaire. Score for each attribute will influence the ordination process in the sustainability assessment (Fauzi & Anna, 2002). The scoring processes were done in all three regions (upstream, middle and downstream region). The ordination process in the MDS analysis will determine the relative position of each dimension between good and bad, in which are related to the sustainability index. The sustainability index value in this study is presented in Table 2.

The next step in RAP-DASAF approach for sustainability assessment is the sensitivity analysis, or also known as leverage analysis (Pitcher & Preikshot, 2001). This sensitivity analysis was based on the sum squares of the difference between scoring with attributes and scoring without attribues, thus provides a standard error that expresses the leverage of each attributes (Pitcher & Preikshot, 2001). The results from this sensitivity analysis were presented in a bar chart, where the higher standard error value indicates that the corresponding attributes were sensitive and more likely to influence the sustainability assessment (Fauzi & Anna, 2002).

Following the leverage analysis in the RAP-DASAF is the Monte Carlo simulation. The Monte Carlo simulation was done to analyze the uncertainty level, which is reflecting the differences in opinion in the scoring the attributes in the 95% degree of confidence (Kavanagh & Pitcher, 2004; Pitcher, 1999; Pitcher & Preikshoht, 2001). Kavanagh and Pitcher (2004) suggested that a good model was achieved when the S-Stress value less than 0.25, with R_2 close to 1. Furthermore, in this study, the Monte Carlo Simulation was done using the scatter plot method as proposed by Fauzi and Anna (2002). In the scatter plot, the random error from the Monte Carlo simulation is showed by the scatter pattern in the ordination of relevant attributes (Fauzi & Anna, 2002).

Table 1: Sustainability attributes of AF watershed management.

No.	Sustainability Attributes				
	Ecology	Economy	Social	Technology & Access	Institution & Governance
1	Watershed Carrying Capacity	Contribution of water usage to Gross Domestic Product	Community's motivation and participation in the land and forest conservation	Acceptance level on new technological and innovation	Regulation and law enforcement
2	Rainfall intensity	Percentage of poor people	Community involvement in the watershed management activities	Watershed infrastructure	Capacity of watershed institution and governance
3	Critical land in Watershed	Level of average income	Local wisdom on the watershed management	Agricultural techniques (seedling, planting and maintenance)	Action on sustainable watershed planning
4	Flooding Occurrences	Investment climate	Community income level	Technologies used on watershed management	Ownership regime on natural resources in the watershed

No.	Sustainability Attributes				
	Ecology	Economy	Social	Technology & Access	Institution & Governance
5	Agricultural Productivity	Demand on natural resources, market access and agricultural input-output	Community welfare level	Technologies used on land conservation	Local wisdom and custom law
6	Land Conservation	Level of agricultural land ownership	Community education level	Technologies used on soil and water conservation	Agricultural organization
7	Forest Area	Tourism index	Education services	Technologies used on post-harvest	Coordination between Regional Government and Stakeholders
8	Land Conversion Rate	Income from non-agricultural activities	Health services	Agricultural techniques on bamboo	Land rehabilitation decision making
9	Annual water debit	Agricultural workforce	Religion services	Road access to public infrastructures	Financial institution and agricultural market institution
10	Water catchment area conservation	Service sector workforce	Unemployment rate	Education and health public infrastructures	Agricultural and forestry extension officer
11	Increasing Bamboo Area	Farmer's adaptation to the changing in market demand	Social contribution from bamboo	Technologies to make organic fertilizers	Agricultural and forestry extension activities
12	Regional planning (Housing and Coastal)	PDAM (Regional Water Authority) services			Information on Regional Development
13		Regional economic development			Organization in charge of bamboo management
14		Economical contribution from bamboo			
15		Irrigation services			

Table 2: Sustainability index in the RAP-DASAF software.

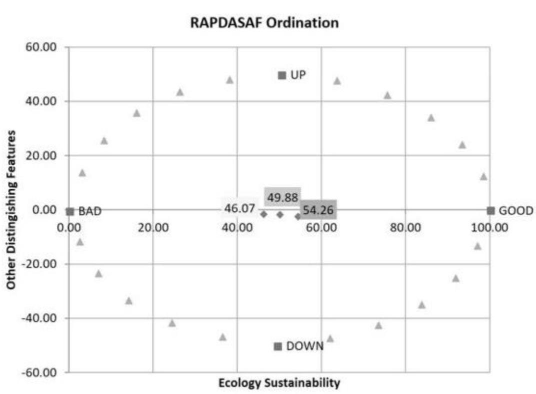
Index	Categorize
0.00 – 24.99	Worse (Unsustainable)
25.00 – 49.99	Bad (Less Sustainable)
50.00 – 74.99	Moderate (Moderate Sustainable)
75.00 - 100	Good (Sustainable)

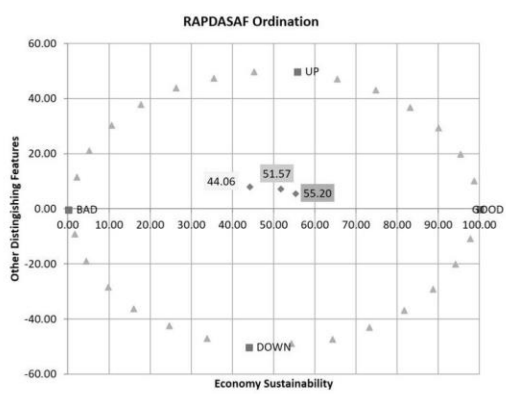
Results and Discussion

In this study, the sustainability assessment on the AF watershed management was done on three different regions and consists of five dimensions as explained in the methods section. The results from ordination analysis for each sustainable dimension will be explained in the latter section, whereas the sustainable index value ranging from 0 to 100 and correlated to the sustainability status (Table 2). The result from ordination analysis for each dimension will be explained below.

Sustainability Assessment

The result from ordination analysis on the ecology dimension showed that both the upstream and the downstream regions are categorized as less sustainable, while the middle region is categorized as moderate sustainable (Figure 2A). The analysis on the social sustainability dimension showed similar results, where both the upstream and the downstream regions are categorized as less sustainable, while the middle region is categorized as less sustainable (Figure 2C). On the sustainability status of economic dimension, the ordination analysis showed that both the middle and the downstream regions are categorized as moderate sustainable, while the upstream region is categorized as less sustainable (Figure 2B). Similar to that, institution and governance dimension showed that both the middle and the downstream regions are categorized as moderate sustainable, while the upstream region is categorized as less sustainable (Figure 2E). Interestingly, all the regions in the AF watershed are categorized as less sustainable in the technology and accessibility dimension (Figure 2D). The Monte Carlo simulation (Figure 3) showed that the dispersion in the scatter plot of all dimension is not significant (less than 0.25), thus the ordination analysis was in a good fit to the model, and the results of the ordination analysis is reliable to be used as sustainability assessment (Kavanagh & Pitcher 2004).





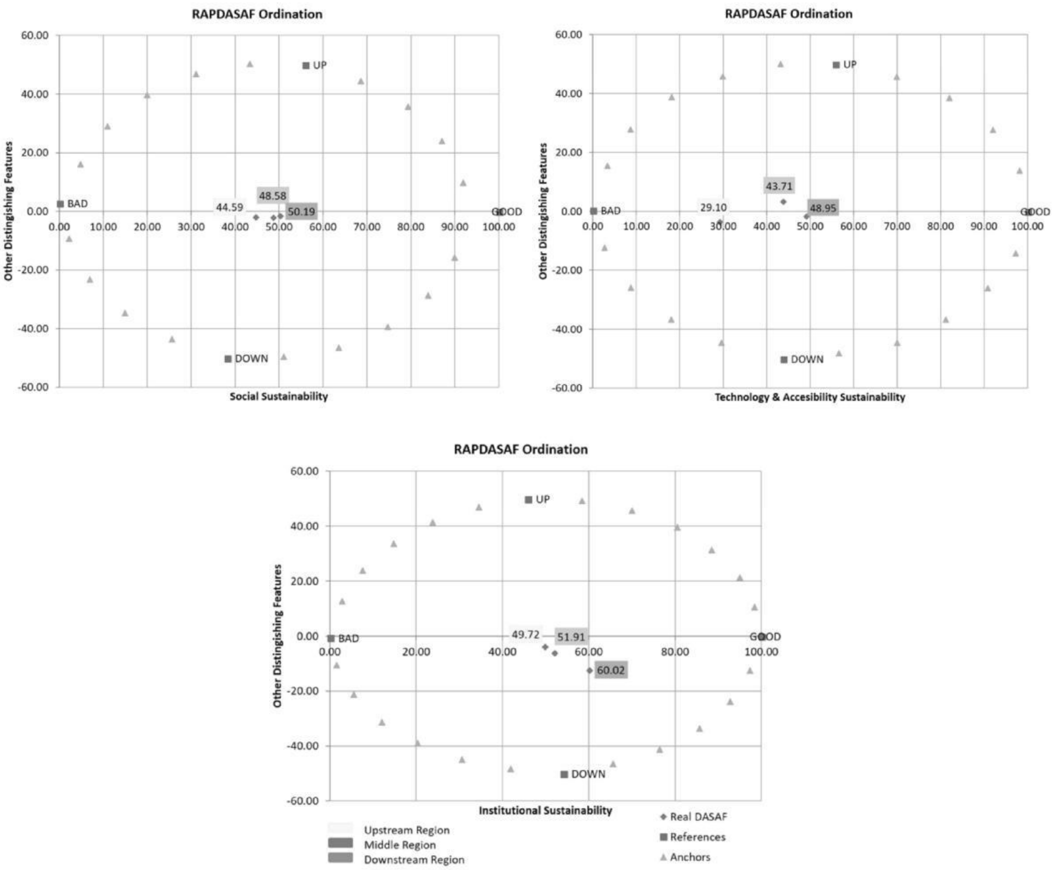
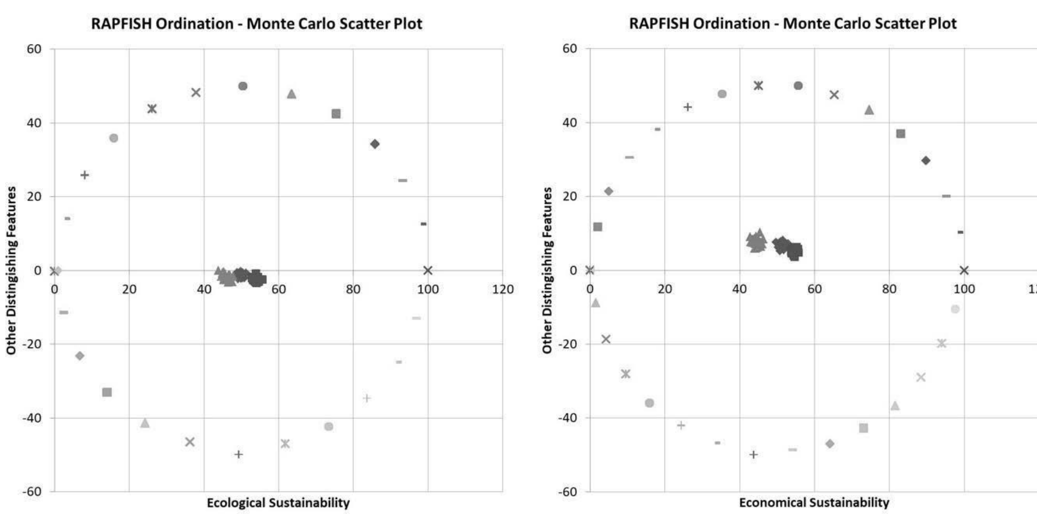


Figure 2: ordination analysis on the sustainability status of AF watershed in A) Ecology; B) Economy; C) Social; D) Technology and Accessibility and E) Institutional and Governance Dimension.



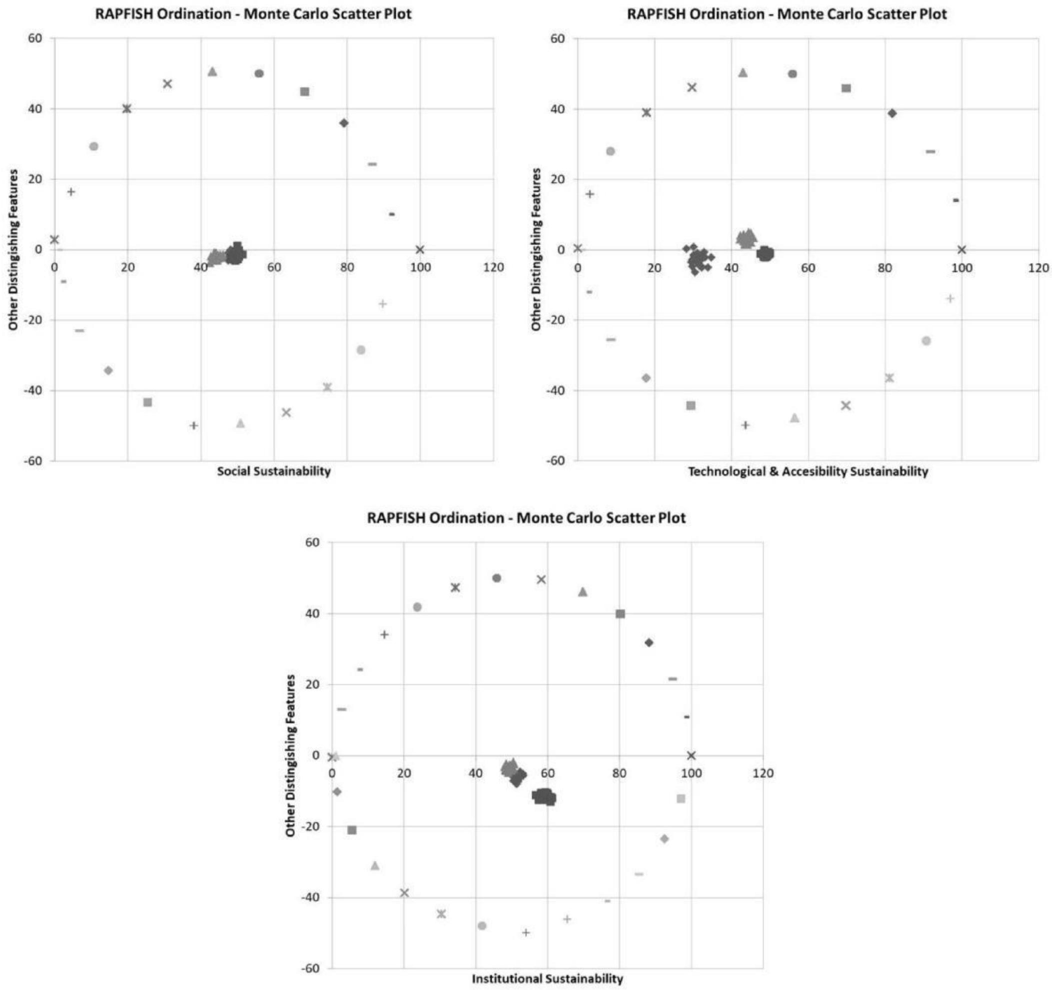


Figure 3: Monte Carlo analysis on the sustainability dimension of watershed management.

Leverage Factor Analysis

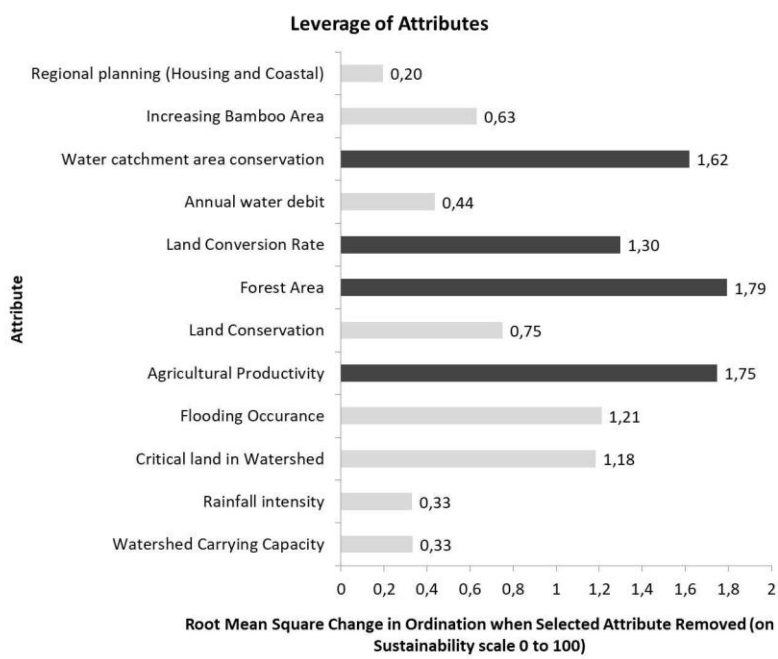
The results from the sensitivity analysis, also known as the leverage analysis, showed that from 11 attributes tested in the ordination analysis, there were four main attributes that sensitive to ecology dimension of sustainability (Figure 4A). Those four attributes are: (1) water catchment area conservation; (2) land conversion rate; (3) forest area and (4) agricultural productivity. Based on the leverage analysis, these four attributes are the main factors that determining the ecological sustainability in the AF watershed. Previous research by Maan *et al.* (2006) reported that the economic pressure results in the degradation of environment in the AF watershed. The typical slash and burn agricultural practices resulted in large-scale deforestation activities in the AF watershed (Maan *et al.*, 2006).

The results from the leverage analysis showed that there were five main attributes that sensitive to economic dimension of sustainability (Figure 4B). Those five attributes are: (1) regional water authority services; (2) service sector workforce; (3) agricultural workforce; (4) tourism index and (5) level of agricultural ownership. These five attributes are the main factors that influenced the economic sustainability in the AF watershed. Water seems to be the main concern in the AF watershed management. Previous analysis showed that the AF watershed is the main water source for economic activities both in Ngada and Nagakeo District. These activities include water provisioning for consumption, and rice production (Maan *et al.*, 2006).

In regard to the social dimension of sustainability, the results from the sensitivity analysis showed there were three main attributes that sensitive to social dimension of sustainability (Figure 4C). Those three attributes are: (1) religion services; (2) community welfare level and (3) community's motivation and participation in the forest and land conservation efforts. One of the proposed strategies to achieved sustainable watershed management in the AF watershed is the collaborative community-based management (Maan *et al.*, 2006). The broad objectives of the proposed strategy are focusing in improving physical watershed condition and to improve the community awareness and participation in the watershed management (Mann *et al.*, 2006).

The results from the sensitivity analysis on the technology and accessibility dimension showed that there were five sensitive attributes (Figure 5A). Those five attributes are: (1) agricultural techniques on bamboo plantation; (2) technologies used on post-harvest activities; (3) technologies used in the soil and water conservation activities; (4) technologies used on land conservation and (5) technologies used on watershed management. Communities in the upstream regions of AF watershed have a lower level of education (Noywuli *et al.*, 2017). The lower level of education in the upstream region could contributing to the less sustainable status.

The results from the sensitivity analysis showed there were six main attributes that sensitive to institution dimension of sustainability (Figure 5B). Those six attributes are: (1) agricultural and forestry extension officer; (2) financial and agricultural market institution; (3) land rehabilitation decision making; (4) coordination between regional government and stakeholders; (5) local wisdom and custom law and (6) ownership regime on the natural resources in the watershed. Mann et al. (2006) emphasized the needs for community collaboration to achieve a sustainable watershed management in the AF watershed. Local wisdom and custom law are important in the AF community watershed management (Maan *et al.*, 2006).



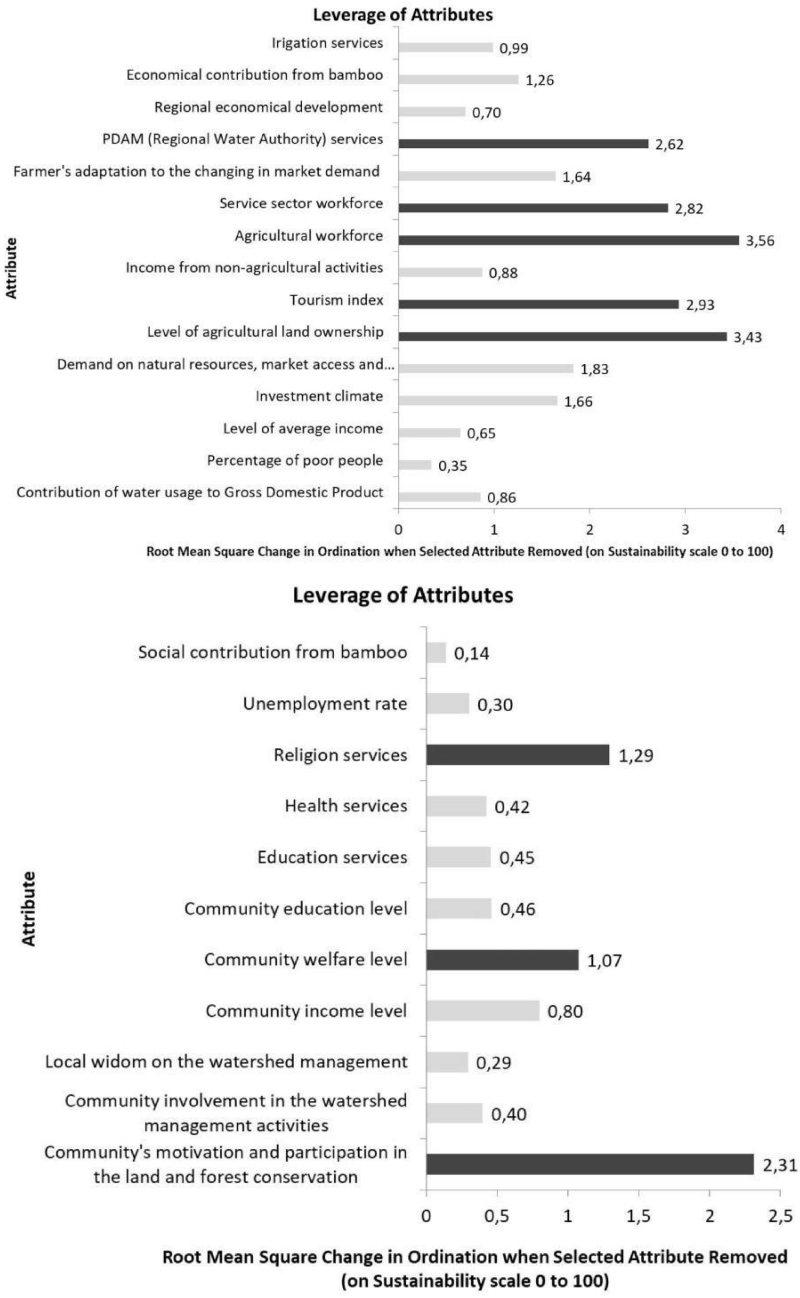


Figure 4: The sensitive attributes that affect the sustainability of AF watershed management on A) Ecological Dimension; B) Economic Dimension; C) Social Dimension.

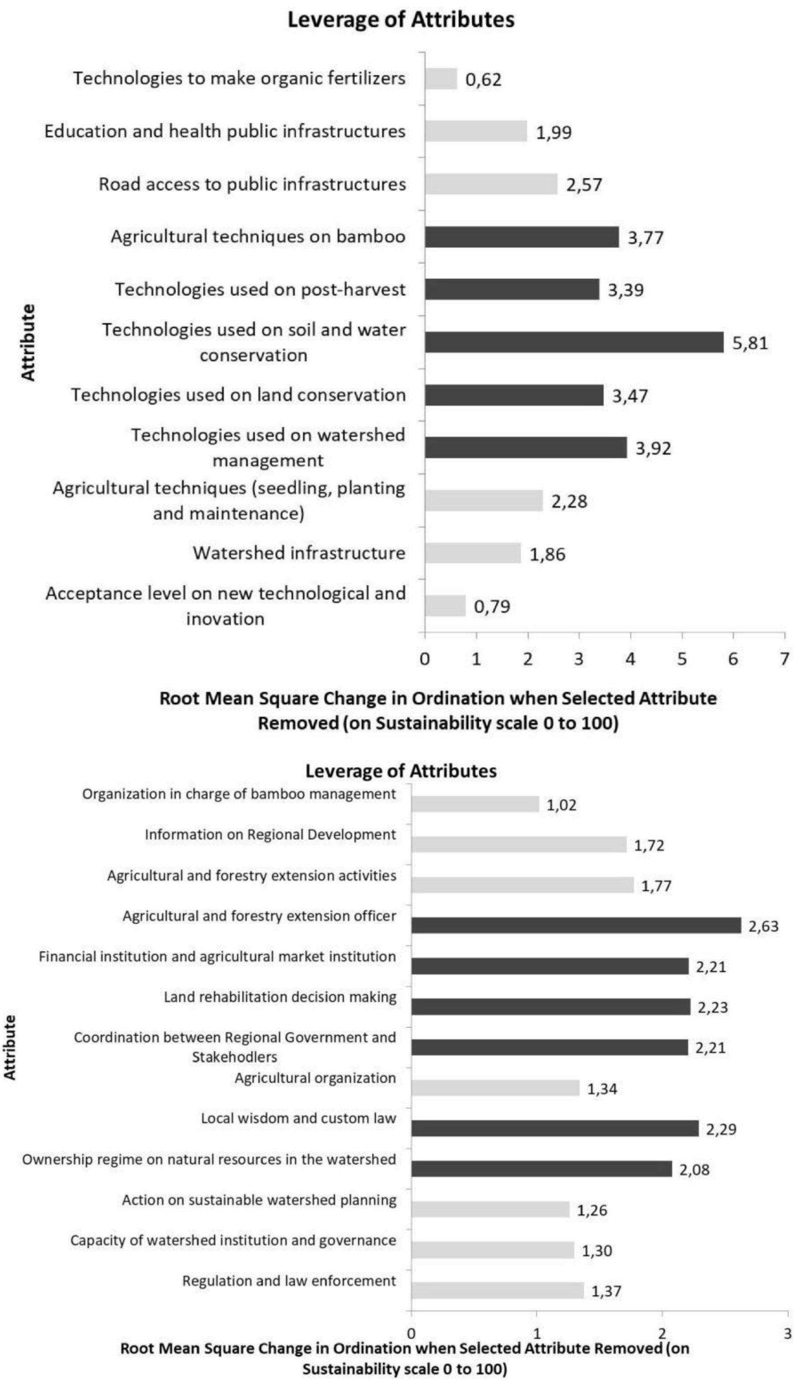


Figure 5: The sensitive attributes that affect the sustainability of AF watershed management on A) Technology and Access Dimension; B) Institution and Governance Dimension

Sustainable Assessment: Multidimensional Sustainability

Based on the ordinal analysis and the generated sustainability index, each region was calculated the overall multidimensional sustainability (Figure 6). In this study, all dimensions were assumed to have the proportional weight of 20%. Based on the multidimensional sustainability assessment (Figure 6 & Table 3), the middle region is categorized as moderate sustainable (53.72%). Both the upstream and downstream regions, however, are in the less sustainable category (49.13% and 42.71%, respectively). The upstream region was observed to have a better ecological sustainability (49.88%) compare to the downstream region (46.07%). However, when looking at the technology and access sustainable dimension, the downstream region was better (43.71%) than the upstream region (29.10%). Surprisingly, the upstream region showed better economic sustainability (51.57%) compared to the downstream region (44.06%).

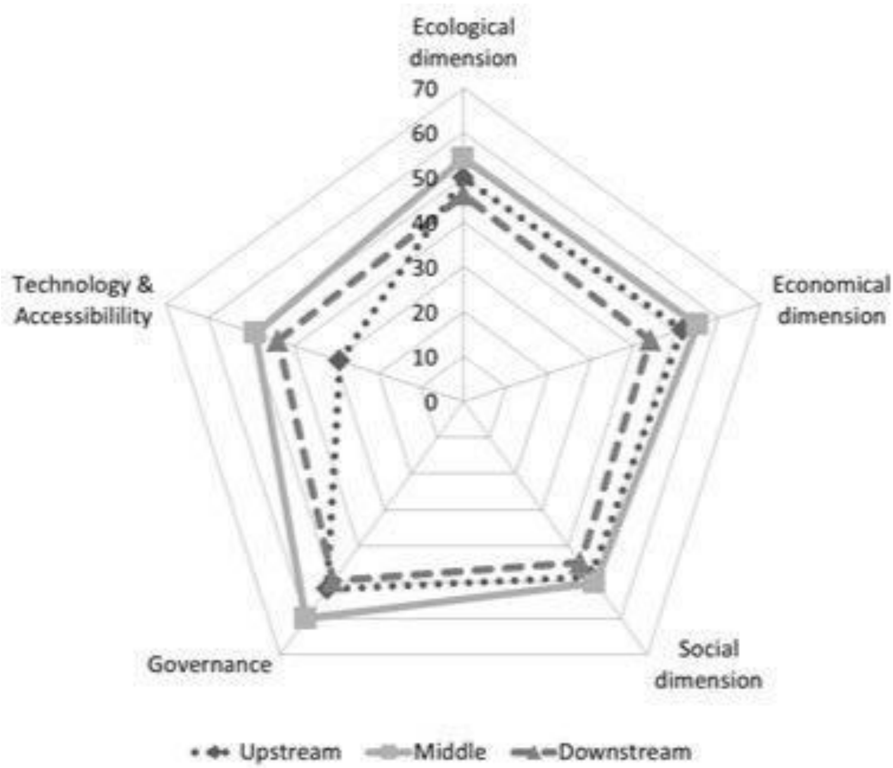


Figure 6: Multidimensional sustainability assessment

Table 3: Sustainability index in each regions (Upstream, Middle, Downstream) of AF watershed

No.	Region	Ecology	Economy	Social	Technology & Access	Institution & Governance
1	Upstream (Sustainability Index)	49.88	51.57	48.58	29.10	51.91
	Squared correlation (R^2)	94.15	95.37	93.77	93.57	94.87
	Stress values (%)	16.29	13,35	16.84	13.35	15.21
	Sustainability Status	Less Sustainable	Moderate Sustainable	Less Sustainable	Less Sustainable	Moderate Sustainable
2	Middle (Sustainability Index)	54.26	55.20	48.58	29.10	51.91
	Squared correlation (R^2)	94.15	95.37	93.77	93.57	94.87
	Stress values (%)	16.29	13.35	16.84	13.35	15.21
	Sustainability Status	Moderate Sustainable	Moderate Sustainable	Moderate Sustainable	Less Sustainable	Moderate Sustainable
3	Downstream (Sustainability Index)	46.07	44.06	44.59	43.71	49.72
	Squared correlation (R^2)	94.15	95.37	93.77	93.57	94.87
	Stress values (%)	16.29	13.35	16.84	13.35	15.21
	Sustainability Status	Less Sustainable	Less Sustainable	Less Sustainable	Less Sustainable	Moderate Sustainable

Looking at the R_2 value of all five sustainability dimensions tested in this study (Table 3), all dimensions showed R_2 value close to 1. This means that the five sustainability dimensions tested in this study are strongly linked to the sustainable assessment of AF watershed. Previous study by Yusuf *et al.* (2016) also reported that the same five dimensions (economic, ecology, social, technology and governance) were acceptable to be used in the sustainability assessment of watershed management.

Conclusion

The sustainability assessment was done on the AF watershed management in the three different regions, and the results showed that both the upstream and downstream regions were categorized as less sustainable, and only the middle region was regarded as moderate sustainable. In overall, of the five sustainability dimensions tested in this study, the social and technological dimensions were fall into less sustainable category. The other three dimensions, namely economic, ecology and institution-governance were regarded as moderate sustainable. The MDS approach was able to provide further sensitivity analysis on attributes that influencing the sustainability status for each dimension in the AF watershed. The results from the sensitivity analysis emphasize the needs of community collaborative watershed management in the AF watershed that involving multiple stakeholders to be involved in the planning, action and monitoring of the watershed management.

Acknowledgments

The authors would like to acknowledge the Government of Ngada District, East Nusa Tenggara Province of Indonesia, in part of financially support this research. The authors would also to thank the regional Government Agencies in the Ngada and Nagekeo Districts for the help in the field studies, and also to the experts and all of the respondents that participate in the field observation studies.

References

Asdak, C. (2010). *Hidrologi dan pengelolaan daerah aliran sungai.* Gadjah Mada University Press.

BPDAS Benain Noelmina Balai Pengelolaan Daerah Aliran Sungai. (2013). *Rencana pengelolaan DAS terpadu DAS Aesesa provinsi NTT.* Kupang (ID). BPDAS Benain Noelmina.

Blomquist, W., & Schlager, E. (2005). Political pitfalls of integrated watershed management. *Society and Natural Resources*, 18(2), 101-117.

Fauzi, A., & Anna, S. (2002). Evaluasi status keberlanjutan pembangunan perikanan: aplikasi pendekatan rapfish. *Formulir Berlangganan Jurnal Pesisir dan Lautan,* 43.

Kavanagh, P., & Pitcher, T.J. (2004). Implementing Microsoft Excell Software for Rapfish: A Technique for The Rapid Appraisal of Fisheries Status. Vancouver (CA). University of British Columbia. Fisheries Centre Research Reports 12(2): 75 pages. ISSN : 1198-672.

Maan, Y., Polomaing, B., Suardika, P., Asmoro, P., Merza, M. A., & Joicey, P. (2006). Collaborative community-based management of the Aesesa Watershed, Indonesia. In 11th Biennial Conference of the International Association for the Study of Common Property, Bali, Indonesia (pp. 19-23).

Mebratu, D. (1998). Sustainability and sustainable development: historical and conceptual review. *Environmental Impact Assessment Review*, 18(6), 493-520.

Noywuli, N., Rachman L.M., Sapei, A., & Satriawan, H. (2017). Prasyarat Penyusunan Kebijakan Pengelolaan Terpadu dan Berkelanjutan DAS Aesesa Flores Propinsi NTT. *Prosiding Seminar Nasional Pengelolaan Daerah Aliran Sungai (DAS) Secara Terpadu 2017*. http://pslh.lppm.unri.ac.id/2018/02/06/ prosiding-seminar-nasional-pengelolaan-daerah-aliran-sungai-das-secara-terpadu-2017/.

Nurhayati, A., & Purnomo, A. H. (2014). A Case Study on Sustainability Analysis of Fisheries in Pangandaran, West Java Province. *Journal of Agricultural Science and Technology B,* 321.

Pitcher, T.J. (1999). Rapfish, a rapid appraisal technique for fisheries, and its application to the code of conduct for responsible fisheries. FAO Fisheries Circular No. FIRM/C: No. 947: 47pp.

Pitcher, T. J., & Preikshot, D. (2001). RAPFISH: a rapid appraisal technique to evaluate the sustainability status of fisheries. *Fisheries Research,* 49(3), 255-270.

Rahayu, A., Bambang, A. N., & Hardiman, G. (2013). Strategi Peningkataan Status Keberlanjutan Kota Batu Sebagai Kawasan *Agropolitan. Ekosains,* 5(1).

Rasul, G., & Thapa, G B. (2004). Sustainability of Ecologi and Conventional Agricultural Systems in Bangladesh: an Assessment Based and Environmental, Economic and Social Perspectives. Agricultural Systems 79 (2004):327-351.

WCED. (1987). Our Common Future. London: Oxford University Press.

Yusuf, M., Kusmana, C., Fahrudin, A., & Kamal, M. M. (2016). Analisis Faktor Penentu dalam Pengelolaan Berkelanjutan Estuaria DAS Tallo. *Jurnal Analisis Kebijakan Kehutanan*, 13(1), 41-51.