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Sustainability of Urban Watershed Management in Kendari City, Southeast Sulawesi, Indonesia

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Abstract

According to the tendency to decrease the carrying capacity of several urban watersheds in Kendari City, it is necessary to conduct research to evaluate the sustainability of the carrying capacity of urban watersheds based on its five dimensions and determine the sensitive attributes (leverage) that affect this sustainability, as well as test the accuracy of the model used. The analysis uses the Rapid Appraisal for Urban Watershed (RAPURWA) method, with Multidimensional Scaling (MDS) techniques, and validation tests on Monte Carlo, Stress, and the coefficient of determination (R2). The study results showed that the Anggoeya, Abeli, and Lemo watersheds were quite sustainable with sustainability status values of 56.31, 55.15, and 53.57 respectively. While the sustainability status of the Nokambu and Matanggonawe watersheds has a value of 42.70 and 45.75 respectively, so they are considered less sustainable. For the sustainability status of the watersheds dimension, land, hydrology, and regional spatial use have respective values of 53.84, 62.28, and 59.90 (quite sustainable). In contrast, socio-economic investment and water buildings have respective values of 46.51 and 39.96 (less sustainable). Furthermore, attributes that utilize all dimensions that require careful attention, namely vegetation cover, slopes, degraded land, floods, sedimentation, water utilization, income, and welfare, implementation of regulations, drainage channels, amount of investment in water development, clean water networks, flood control, ecotourism, mangrove forests, landslide-prone areas, flood-prone areas, and protected areas. The MDS method validation test is able to provide more accurate results.

Keywords: Carrying capacity; Leverage attributes; Multidimensional scaling; Sustainability; Urban watershed

1. Introduction

Kendari City has great potential for natural resources that are highly beneficial for the survival of living beings, including humans. These include several urban watersheds, namely Nokambu, Matanggonawe, Anggoeya, Abeli, and Lemo watersheds, which have been managed in a sustainable manner (Kiran *et al.,* 2014). Likewise, their roles in providing land, water, and plant resources are also vitally crucial for the continuous existence of the watershed ecosystem. However, the continuity of the watershed ecosystem can be disrupted due to land use change from vegetated land to open land due to the development of urban activities, which often cause hydrological problems such as flooding and inundation in residential areas (Grimley *et al.,* 2020). Intense economic activities of the community particularly can cause erosion, flooding, and sedimentation, all of which will ultimately harm the ecosystem and reduce the carrying capacity of the watershed.

Brooks *et al.* (2003) defined a watershed as an area bounded by topographic boundaries that collects rainwater and drains it through a river system to a certain point that functions as an outlet. Watershed is not only a hydrological unit (Wang *et al.,* 2016), but also a socio-economic unit (Rolia *et al.,* 2021) and a management unit for the sustainable development of available natural resources. In addition, watersheds can be used to assess and analyze causal relationships between upstream and downstream activities. As a unit with clear boundaries, watershed problems are easy to identify, measure and manage for their carrying capacity. The carrying capacity of the watershed is thus extremely important to understand in order to increase awareness and participation of the community and related agencies in increasing land productivity and realizing optimal quantity, quality and water sustainability for the achievement of sustainable watershed management (FAO, 2017).

A decrease in the carrying capacity of a watershed is generally the beginning of problems such as degraded land, reduced vegetation cover, erosion, surface runoff, sedimentation, decline in the income and welfare of the community, problems with infrastructure and water availability, and issues of regional spatial planning control (Narendra *et al.,* 2021). Urban watersheds in Kendari City have a function and role in regulating the water system and sediment system due to changes in land use and vegetation cover in the watershed, thus enabling the determination of its sustainability and carrying capacity (Hikmat and Marselina, 2021). According to Grimley *et al.* (2020), the occurrence of floods during the rainy season and drought during the dry season signifies a decrease in the function and carrying capacity of a watershed. Indicators of the carrying capacity of a watershed consist of several dimensions, including land, hydrology, socio-economics, water construction investment, and regional space utilization (Sriyana, 2018), which greatly determine the sustainability in the watershed management (Rolia *et al.,* 2021). On the other hand, the sustainability of watershed management is also a measurable indicator to determine the carrying capacity of the watershed in providing the land, water, and vegetation resources needed by the community (Maulana *et al.,* 2020). In this sense, high carrying capacity of a watershed in terms of the availability of land, water, and vegetation indicates the sustainability of a good watershed management. Conversely, a decline in the carrying capacity of the watershed is also determined by poor and less sustainable watershed management. Therefore, it is important and urgent to assess the sustainability of urban watershed management based on several dimensions that determine the carrying capacity of the watershed.

The sustainability of urban watershed management in Kendari City, based on the dimensions of their carrying capacity, namely the dimensions of land, hydrology, socio-economic, water construction investment, and regional spatial use, is examined using MDS (Multidimensional Scaling). Furthermore, to improve the sustainability of watershed management, the leverage attribute is analyzed based on the Root Mean Square (RMS) value. The results of the MDS analysis describe the sustainability status of urban watersheds in Kendari City and also the sustainability status of each dimension of watershed carrying capacity. While the results of the RMS analysis show several sensitive attributes that influence sustainability in the carrying capacity dimension in urban watershed management in Kendari City. This study aims to evaluate the sustainability of the carrying capacity of urban watersheds in Kendari City, and to determine the sensitive (leverage) attributes that affect this sustainability, as well as test the accuracy of the model used.

2. Materials and method

2.1 The study area

This study was conducted in five urban watersheds in Kendari City, Southeast Sulawesi, Indonesia, namely: Nokambu watershed with an area of 2,514.76 hectares, Matanggonawe watershed with an area of 2,022.10 hectares, Anggoeya watershed with an area of 898.45 hectares, Abeli watershed with an area of 1,610.26 hectares, and Lemo Watershed area of 649.13 hectares. The total area of the research locations is 7,694.70 hectares (Figure 1).

The study locations were chosen with the consideration that the five watersheds provide water for the needs of urban communities and experience flooding, sedimentation, and changes in land use that have an impact on the waters of Kendari Bay (Aswar Limi *et al.,* 2017). The watershed of Kendari City is at longitude 122° 31’ 20”E - 122° 37’ 10” E, latitude 03° 58’ 50” S - 04° 10’ 15” S, and an altitude of 0-200 m above sea level (BP DASHL Sampara, 2019). The largest land use is mixed dryland agriculture (32.59% of the total area of the urban watershed), followed by forest (29.01%), settlements (13.37%), ponds (6.06%), and shrubs (2.74%). Meanwhile, the topography is dominated by rather steep slopes (44.91%), followed by very steep slopes (31.14%) and flat slopes (23.95%) (BP DASHL Sampara, 2019).

2.2 Data collection

Primary data collection was carried out using field surveys, questionnaires, and in-depth interviews with purposive sampling respondents consisting of lay respondents and expert respondents who empirically understand attribute data in the research dimension. Respondents in primary data collection were selected with a total of 30 respondents, because with the number of respondents the information obtained was saturated. Lay respondents are people who have long lived in the watershed. While the expert respondents in this study consisted of drinking water resource managers, local government, traditional leaders, youth organizations, watershed experts, forestry, agricultural, and environmental experts. Secondary data were obtained from literature studies, documents, and reports from various agencies that are relevant to this research topic. The dimensions or variables used in this study refer to the indicators of the carrying capacity of a watershed, namely land, hydrology, socio-economics, water building investment, and regional spatial use, which was adapted from the Regulation of the Minister of Forestry of the Republic of Indonesia Number 61

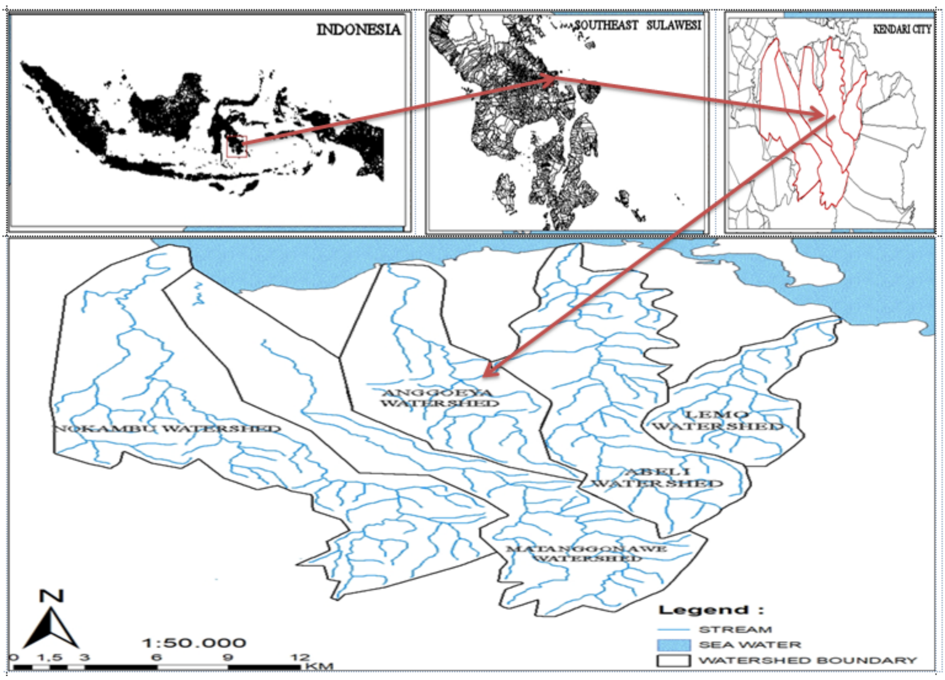


Figure 1. Study locations

of 2014 concerning monitoring and evaluation of management DAS (Sriyana, 2018). While the attributes for each dimension were adapted from Sriyana (2018) and Juniansyah *et al.* (2016).

The dimensions and attributes used in this study are: a) The land dimension consists of eight attributes, namely percentage of degraded land, vegetation cover, erosion index, river bank erosion, riparian conditions, vegetation and land management, infiltration rate, land conversion rate, and watershed slope; b) The hydrological dimension consists of six attributes, namely flow regime coefficient, annual flow coefficient, sediment load, flood frequency, water use index, and runoff coefficient; c) The socio-economic dimension has seven attributes, namely population pressure on land, level of community welfare, enforcement of regulations, rate of population growth, level of community income, community role in agricultural activities, and community role in maintaining watersheds; d) The investment dimension for water structures contains six attributes, namely watershed classification status, investment value for water structures, availability of irrigation networks, availability of raw water networks, availability of flood control, and availability of waste management; e) The spatial utilization dimension consists of six attributes, namely protected areas, cultivation areas, flood-prone areas, landslide-prone areas, ecotourism areas, and mangrove forest areas.

Each attribute in the dimension is translated into several indicators as the basis for compiling a questionnaire and determining the score for each of these indicators which is used as a guide in data collection. The scoring process is carried out by translating primary and secondary data into an ordinal measurement scale with a value of 0 to 4 according to the indicators for each attribute. The mean of an ordinal measurement scale was analyzed in the RAPFISH application in the ad-in to the Excel program.

2.3 Data Analysis

As proposed by Kavanagh and Pitcher (2004), the Rapid Appraisal for Urban Watershed (RAPURWA) method, adopted from the Rapid Appraisal for Fisheries (RAPFISH), with the Multi-Dimensional Scaling (MDS) technique consists of six stages as follows:

1. All attributes for each dimension were scored using an ordinal measurement scale by Arvidsson (2019), in which the scores are divided into five categories: 4 means "very good"; 3 means "good"; 2 means "moderate"; 1 means "bad"; and 0 means "very bad".

2. Ordinations of the Rapid Appraisal for Urban Watershed (RAPURWA) include: (a) assessing the main horizontal reference points for the "bad" (0%) and "good" (100%) categories; (b) determining the other main reference point or the "middle point", and a vertical reference point referred to as an "anchor", which is a useful stabilizer; (c) standardizing the scores on each attribute so as to have a uniform weight in order to eliminate differences in measurement scale; and (d) calculating the distance between reference points using the squared Euclidean distance (seuclied) method.

3. RAPFISH method which is used commonly in various countries (Pitcher and Preikshot 2001). These attributes serve as indicators of the dimensional conditions of each resource, then are translated and adapted to conditions in Indonesia. The sustainability index of the urban watershed management in Kendari City was estimated in the range of 0 - 100% and divided into four categories of sustainability status: bad or not sustainable (0 - 25.0%), less sustainable (25.01 - 50.0%), quite sustainable (50.1 - 75.0%), and good or very sustainable (75.1 - 100.0%).

4. The leverage attributes for each dimension were determined by selecting six to eight attributes with a high level of importance (leverage) based on the results of previous studies on the criteria for watershed management and its carrying capacity (Sriyani, 2018), as well as the logistics and processing of the watershed.

5. Sensitivity analysis was performed to find out the attributes that dominantly influence changes in the sustainability of urban watershed management in Kendari City. The sensitivity level of each attribute can be seen from its "Root Mean Square" (RMS) value on the X axis, formulated as follows:

$$\text{RMS}=\sqrt{\sum_{i=1}^{n}\left(\frac{Vf_i\_Va_i}{n}\right)^2} \quad (1)$$

where *Vai* is the value of the actual data, *Vfi* is the estimated value, and *n* is the number of attributes. Leverage attributes that require special attention are those that have the highest RMS value or whose value exceeds the average RMS value.

6. Three tests were done to validate the scoring and the results of the Rapid Appraisal Procedure for Urban Watershed (RAPURWA), namely: stress, coefficient of determination (R^2), and Monte Carlo simulation. The value of the standardized residual sum of the square (stress) is calculated using the following formula from Pitcher and Preikshot (2001):

$$\text{Stress}=\sqrt{\frac{1}{m}\sum_{k_i}^{m}\left[\frac{\left(\Sigma_i\Sigma_j\left(d_{ijk}^2-o_{ijk}^2\right)^2\ \right)}{\Sigma_i\Sigma_j\, o_{ijk}^4}\right]} \quad (2)$$

where *dijk* is the square of the distance; *oijk* is the origin in dimension (i, j, k); and *m* is the number of dimensions.

The results of the analysis are valid and accurate if the "stress" value is less than 0.20 (< 20%), the coefficient of determination (R^2) is > 50%, and the results of the Monte Carlo simulation obtain narrow interval values that are almost the same as those of the Multi-Dimensional Scaling (MDS).

Apart from being used to estimate the error rate of the model, Monte Carlo simulation can also explain several things from Kavanagh and Pitcher (2004): a) the effect of scoring errors due to lack of information on research site conditions or misunderstandings about attributes and assessment procedures, b) the effect of variation in judgments due to differences or judgments from different people, c) indicating the stability of the MDS method for successive operations (iterations), d) incomplete convergence (high stress), d) data entry errors or missing data, and e) ambiguous (reversed or rotated) solutions. In this study, Monte Carlo simulation was used to determine the random errors of all dimensions. A comparison of the results of the Monte Carlo simulation with the MDS analysis obtained a degree of confidence of 95% with a difference of about 5%. This means that the MDS results are relatively good to apply if there is a difference of < 5% with the Monte Carlo results. Thus, the scoring and the results of the RAPFISH procedure have fulfilled the statistical requirements for the leverage attribute which were built and applied to research on the sustainability of urban watershed management in the city of Kendari.

3. Results and discussion

3.1 Sustainability index and leverage attribute on each dimension

3.1.1 Land dimension

The index value of the land dimension in Nokambu and Matanggonawe watersheds are 41.25 and 46.27, respectively, meaning that both are less sustainable. Meanwhile, Anggoeya, Abeli, and Lemo watersheds are considered quite sustainable in terms of the land dimension with index values of 64.35, 58.94, and 53.36, respectively (Figure 2A). These findings indicate that the management of Nokambu and Matanggonawe watersheds is experiencing land problems, with several attributes that need close attention being a decrease in vegetation cover (RMS = 3.20), slopes (RMS = 2.60), and an increase in degraded land (RMS = 2.33), as seen in Figure 2B. Of the five watersheds in Kendari City, the highest decline in vegetation cover occurred in Nokambu and Matanggonawe watersheds, reaching 20% and 30% of their area, respectively.

Reduced vegetation cover may result in various other problems, including increased degraded land, erosion (Sukiyah *et al.,* 2020), and deforestation in the watershed (Mengistu *et al.,* 2022). Nokambu and Matanggonawe watersheds are located in the center of Kendari City, thus having a tendency for the area of degraded land to increase due to changes in land use from mixed gardens to settlements and open land (Gashaw *et al.,* 2018). Meanwhile, Abeli, Anggoeya, and Lemo watersheds are situated on the outskirts of Kendari City, with relatively high vegetation cover (Brontowiyono, 2022), small area of degraded land (Kane *et al.*, 2016), and less sloped watershed (Wubie and Assen, 2020). Therefore, the three watersheds are less damaging to environmental resources (Anggalini *et al.*, 2021).

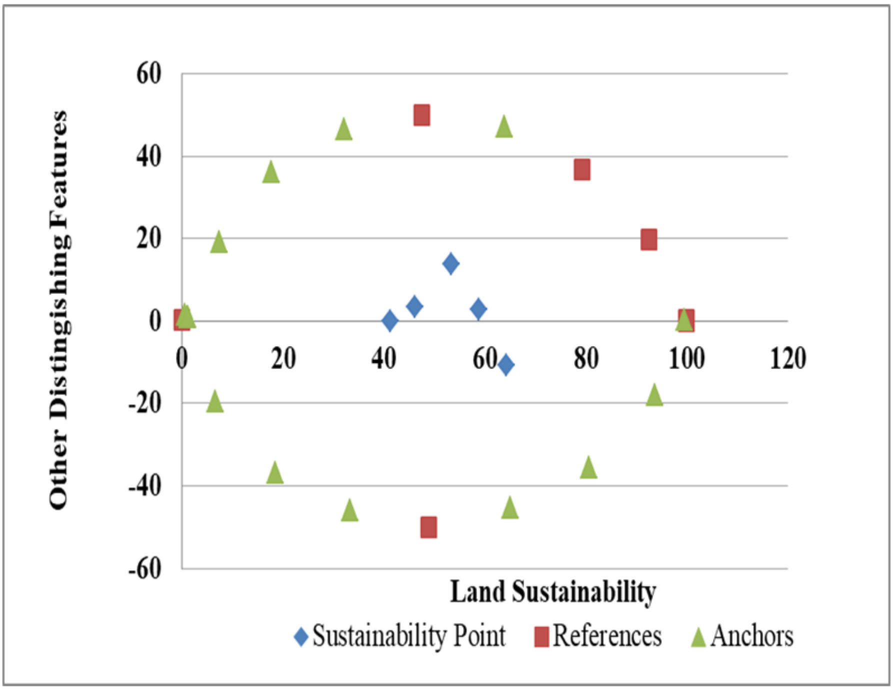


Figure 2A. Sustainability index for the land dimension

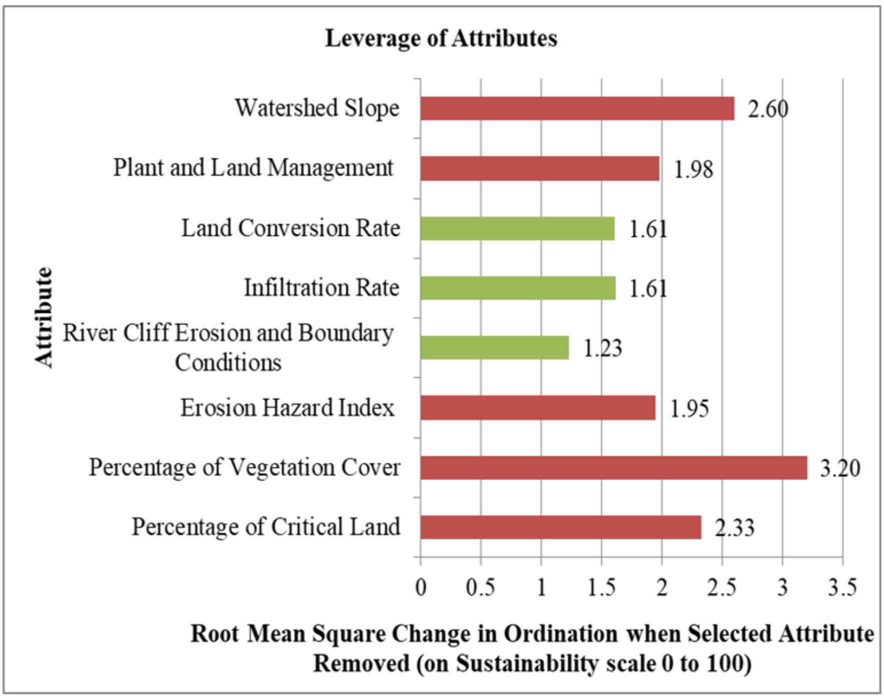


Figure 2B. Leverage attribute on the land dimension

3.1.2 Hydrology dimension

Hydrological conditions in the urban watersheds are related to fluctuations in river water discharge, as well as the quality and quantity of river water needed by the community. In terms of the hydrological dimension, Nokambu Watershed has an index value of 49.07 (less sustainable), while the other four watersheds, i.e., Matanggonawe, Anggoeya, Abeli, and Lemo watersheds, are quite sustainable with index values of 51 - 75 (Figure 3A). The reduced sustainability of the carrying capacity of Nokambu Watershed is caused by hydrological problems, especially floods that occur more than once a year. As seen in Figure 3B, attributes for the hydrological dimension to be considered in the management of urban watersheds in Kendari City include the frequency of flooding (RMS = 5.96), sediment load (RMS = 5.68), annual water consumption coefficient (RMS = 5.62) and water use index (RMS = 5.11).

According to Pambudi (2022), flooding is a hydrological issue in a watershed that needs to be addressed and managed properly. Peak discharge can be caused by reduced vegetation cover which brings about changes in hydrological characteristics of the watershed (Zhang *et al.,* 2022). Both Nokambu and Matanggonawe watersheds are located in the center of the city with numerous houses, office buildings, and shopping center buildings that have the potential to reduce water absorption (Grimley *et al.,* 2020). Furthermore, growing residential activity as a result of urbanization may also increase the risk of flooding due to increased discharge and peak volume (Salazar-Briones *et al.,* 2020). Likewise, the rate of change in land use in urban watersheds that tends to change from agricultural land to settlements can have an impact on the water catchment function that can increase the risk of flooding and has implications for poor management of watersheds in the future (Dan-Jumbo *et al.,* 2018). The after-effects of flooding can carry floating sediments to the lower reaches of the watershed and even to the sea, causing silting of the riverbed and reduced carrying capacity of the rivers as well as high sediment levels in sea waters (Chen *et al.,* 2022).

3.1.3 Socio-economics dimension

The socio-economic dimension of the carrying capacity of urban watershed is closely related to activities to increase community income and welfare (Yaebiyo *et al.,* 2015) which significantly affect the environmental sustainability of the watershed. The results of the analysis reveal that the sustainability index

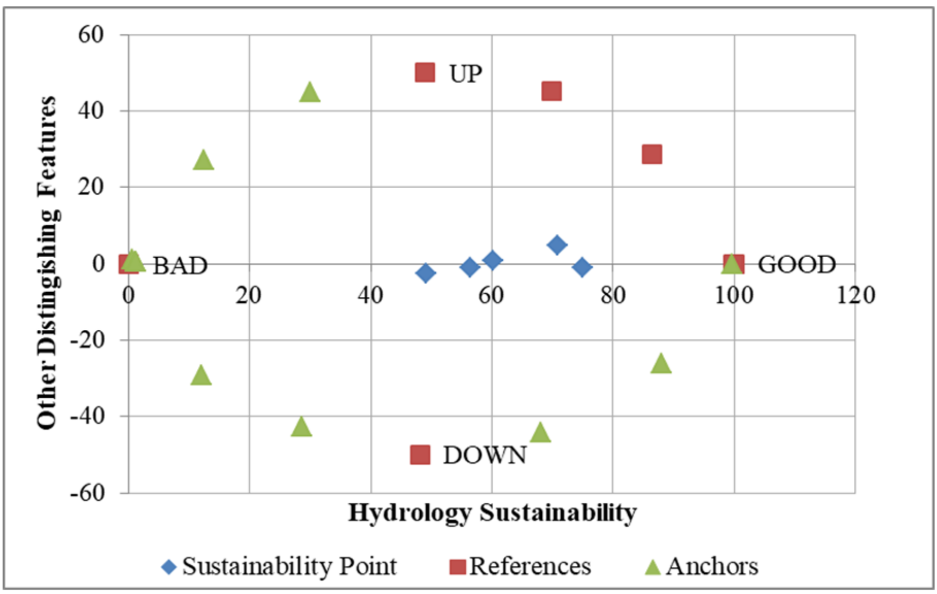


Figure 3A. Sustainability index for the hydrological dimension

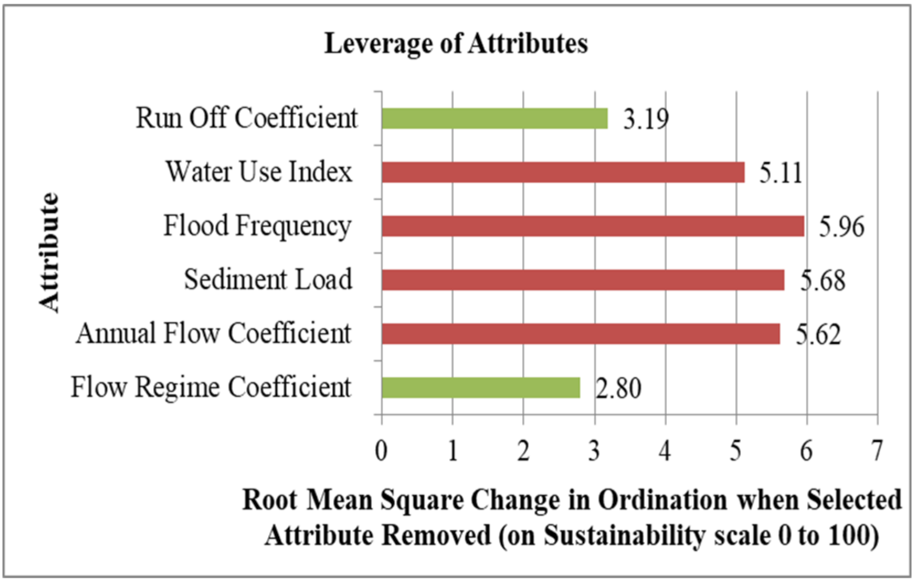


Figure 3B. Leverage attribute on the hydrological dimension

of Nokambu and Matanggonawe watersheds in terms of the socio-economic dimension are 28.83 and 33.26, respectively, meaning that both are less sustainable. On the other hand, Anggoeya, Abeli, and Lemo watersheds have index values of 58.15, 59.78, and 52.52, respectively, with sustainability status of quite sustainable (Figure 4A.).

Leverage attributes for the socio-economic dimension that need special attention are community income (RMS = 6.24) and welfare level (RMS = 4.96), as well as application of regulations (RMS = 4.01).

Successful and sustainable watershed management is determined by the socio-economic conditions of the community living in the watershed (Taufik *et al.,* 2021). As stated by Ojha *et al.* (2021), the level of community income and welfare may be inversely related to environmental conditions. In this case, good community welfare results in changes in land use and can also exploit natural resources for expansion of settlements, offices, and other activities, thus affecting the sustainability of urban watershed management (Hikmat and Marselina, 2021). In addition to community income and welfare, another cause of damage to natural resources in the watershed is the lack of strict law enforcement (Pambudi, 2022).

3.1.4 Water construction investment dimension

The dimension of water construction investment refers to infrastructure buildings made for the needs of the community in terms of water utilization while simultaneously controlling environmental damage caused by erosion, landslides, sediments, and flooding in the watershed. The results of the MDS analysis for this dimension indicate a sustainability index of 41.64 for Nokambu Watershed, 42.55 for Matanggonawe Watershed, 40.89 for Anggoeya Watershed, 31.82 for Abeli Watershed, and 42.90 for Lemo Watershed, as shown in Figure 5A. This signifies that all five watersheds are less sustainable. Furthermore, Figure 5B shows that the attributes for this dimension which require careful attention include irrigation and drainage channels (RMS = 5.11), the amount of water construction investment (RMS = 4.83), and clean water networks (RMS = 4.61).

Ishiwatari and Sasaki (2021) argue that water construction investment in the watershed is crucial in determining the carrying capacity of the environment. The assets and investment value of water constructions in watersheds indicate the amount of artificial resources provided to protect against environmental damages from floods, landslides, sedimentation, and drought (Dottori *et al.,* 2023). The greater the investment value, the more important and prioritized the management of land conservation and rehabilitation in the watershed (Jongman, 2018) and the better the watershed is in repairing environmental damages (Ishiwatari and Sasaki, 2021). Common water constructions include check dams, ponds, and other soil and water conservation structures (Gao *et al.,* 2020; Dashora *et al.,* 2022).

3.1.5 Regional space utilization dimension

Utilization of regional space in an urban watershed is vital for the condition of both

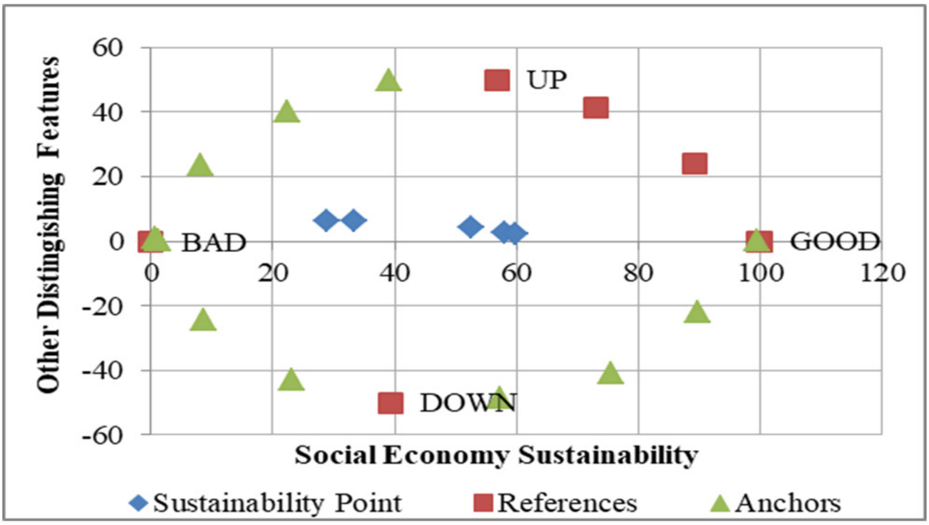


Figure 4A. Sustainability index for the socio-economic dimension

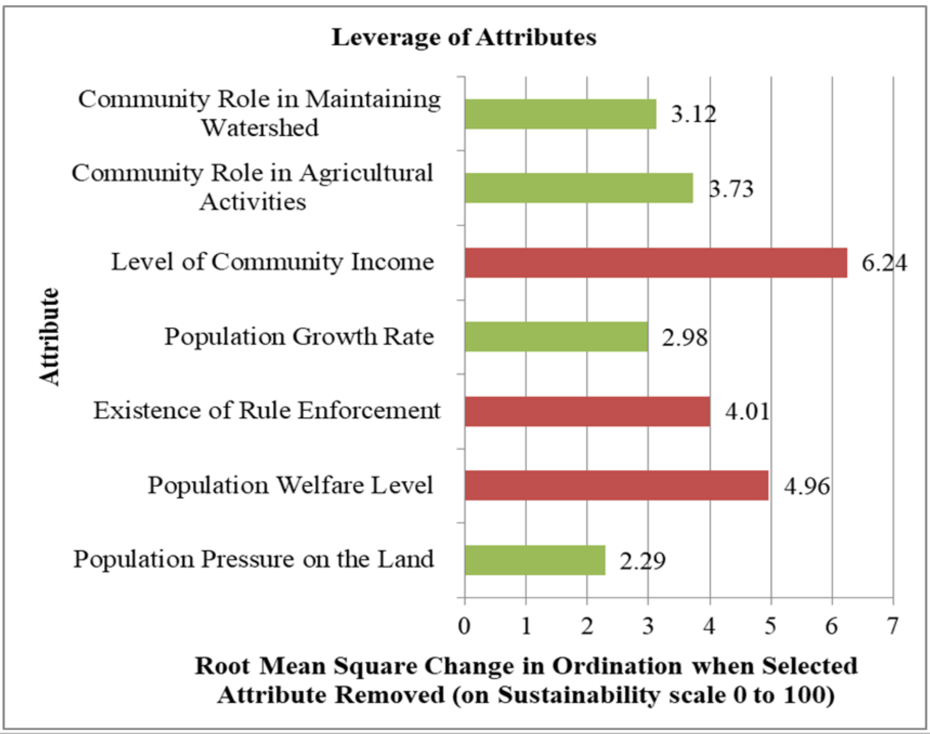


Figure 4B. Leverage attribute on the socio-economic dimension the community and the watershed ecosystem itself (Senik and Uzun, 2022). Utilization of regional space by the community for settlements causes changes in land use and land cover due to human development and urbanization (Lagrosa, *et al.,* 2018). Although green areas act as a buffer for the watershed from vulnerability to disasters, it is not fully effective in preventing environmental damage due to high urbanization which results in large numbers of people living in the watershed (Thorne *et al.,* 2018).

The results of the MDS analysis for the dimension of regional space utilization reveal that Nokambu and Anggoeya watersheds have a sustainability index value of 47.70 and 47.26, respectively. This means that both watersheds are less sustainable. Meanwhile, the sustainability index values of Matanggonawe, Abeli, and Lemo watersheds are 50.24, 50.33, and 58.95, respectively, meaning that their sustainability status is quite sustainable (Figure 6A). For this dimension, the leverage attributes that need better management are ecotourism areas (RMS = 6.36), mangrove forest areas (RMS = 5.00), and landslide-prone areas (RMS = 4.61), as presented in Figure 6B.

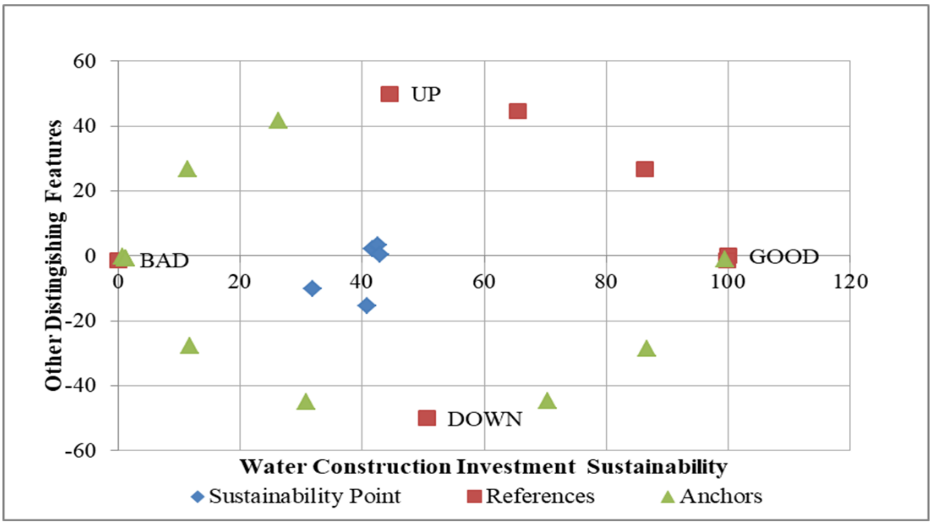


Figure 5A. Sustainability index for the dimension of water construction investment

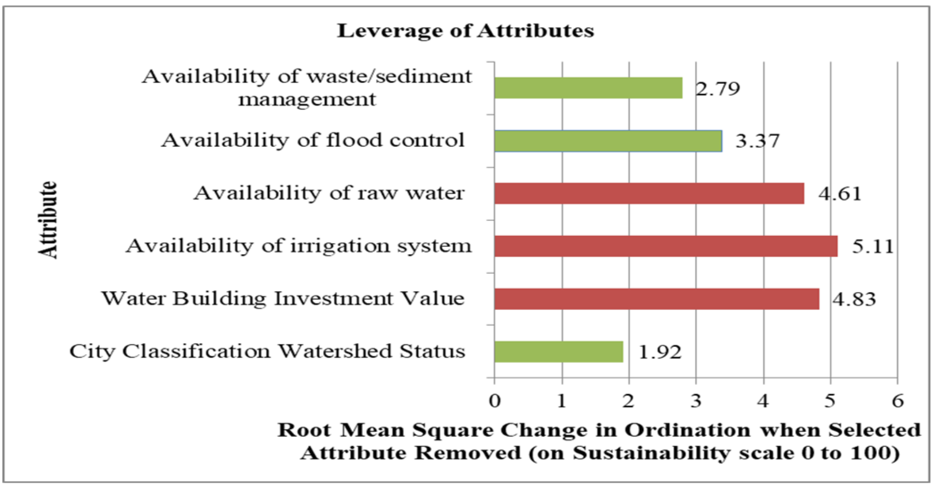


Figure 5B. Leverage attribute on the dimension of water construction investment

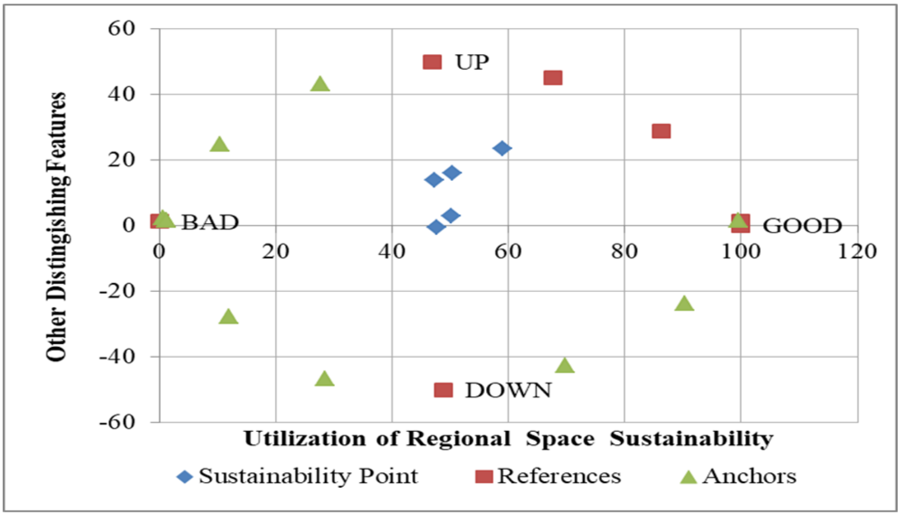


Figure 6A. Sustainability index for the dimension of regional space utilization

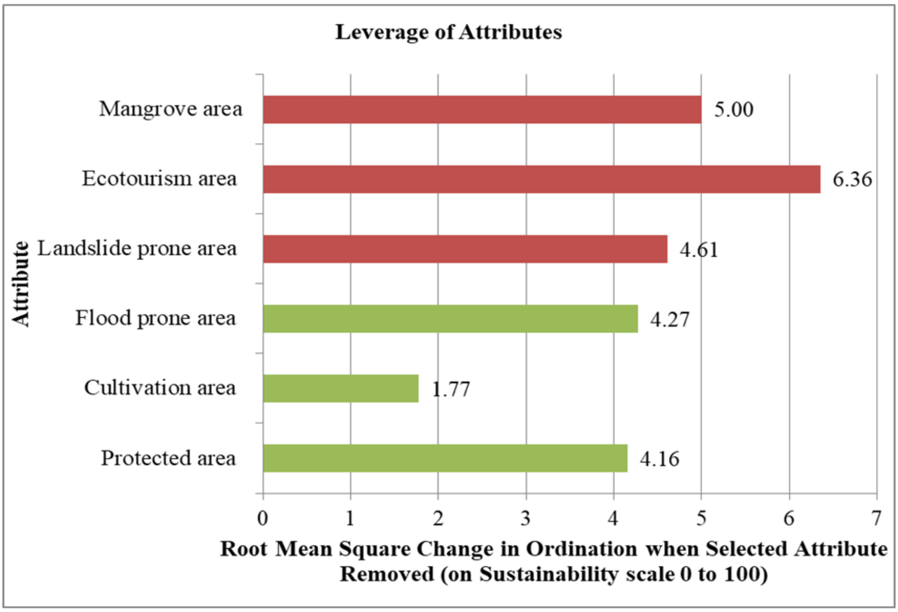


Figure 6B. Leverage attribute on the dimension of regional space utilization

Spatial planning by the community, public institutions, and the government, including in watersheds, is a positive way of making effective interventions, for example by maintaining protected areas (Mahamba *et al.,* 2022). Conservation of vegetation cover, especially in protected forest areas, is extremely important in preserving the ecological and hydrological integrity of the watershed (Maru *et al.,* 2023). However, in several watersheds, these protected areas have changed to agriculture areas and settlements, resulting in these areas being prone to flooding and landslides (Geldmann *et al.,* 2015). Changes in the utilization of regional space without applying soil and water conservation techniques will lead to an increase in degraded land, erosion, and surface runoff rates (Atharinafi and Wijaya, 2021). Therefore, we propose to maintain protected areas, especially forest areas in upstream watersheds, and promote the concept of agroforestry systems as part of land use policies to increase vegetation cover through biodiversity as well as function to restore high surface run-off and conserve resources soil and water (Hoffmann, 2022).

3.2 The validation test for the accuracy of the model used

The validation test based on the results of the Monte Carlo analysis and the MDS analysis at the 95% confidence level with 25 repetitions showed that there was no significant difference between the sustainability indices from the MDS analysis and the Monte Carlo analysis in the five urban watersheds in Kendari City (shown in Figure 7).

In the five urban watersheds, the difference in the value of the MDS analysis and the Monte Carlo analysis for each dimension of sustainability ranges from 0.01 percent to 3.59 percent. This value is considered to still have a small difference with a tolerance limit of below 5 percent (Nandini *et al.,* 2017; Ozhaer and Putuhena, 2017; Kahirun *et al.,* 2020). This proves that the level of accuracy in the MDS analysis and Monte Carlo analysis will determine the accuracy of the sustainability index value of each dimension, so as to avoid errors. Therefore, errors in scoring on each attribute have relatively small errors, scores from expert opinions and assessment results have relatively small variations, repeated data analysis is relatively stable, and input errors and missing data can be avoided (Kavanagh and Pitcher, 2004). This means that the resulting MDS analysis model can be used to quickly and objectively evaluate the sustainability index of urban watershed management in Kendari City.

In the RAPURWA analysis of five urban watersheds in Kendari City, the Stress value and the coefficient of determination (R^2) were obtained which determine the accuracy of the MDS method and the quality of the analysis results (shown in Table 1). In this study, each dimension has a stress value of 0.16 to 0.18, where the value is less than 0.25 or 25 percent. This means that the stress on the MDS analysis obtained is suitable for assessing the sustainability index of urban watershed management in Kendari City. The coefficient of determination (R^2) in each dimension of this study is close to 1 or in the range of 0.92 - 0.94. In general, if the value of R^2 is close to 1, it means that the quality of the analysis results is getting better. According to Santosa *et al.* (2016), the results of the analysis are accurate and can be accounted for if the stress value is less than 0.25 or 25 percent. The smaller stress value and coefficient of determination (R^2) > 0.50 (close to 1), the better quality of the MDS analysis results.

The stress values range from 0.16 - 0.18 (less than 0.25 or 25 percent), while the R^2 values range from 0.92 - 0.94 (close to 1 or 100 percent). This implies that the Stress and R^2 parameters can justify the assumption that all dimensions examined in the sustainability analysis of the urban watersheds in Kendari City have higher accuracy (goodness of fit). Based on the sustainability index data for each urban watershed in Kendari City according to their respective dimensions, it can be seen the average of the five dimensions of each watershed to determine the order of good to bad watershed management sustainability performance, seen in Figure 8.

Figure 8 shows that the order of the average sustainability index values in each watershed, where the Nokambu and Matanggonawe watersheds are classified as having less sustainable management. The sustainable management of these two watersheds is proven by the frequent occurrence of floods due to the high rate of change of land cover from vegetated land to residential land. The sustainability of a watershed is determined by land conditions, especially changes in land use and protected areas (Dero *et al.,* 2021), as well as socio-economic conditions, especially the high rate of urbanization which requires residential land. This has an impact on the lack of water catchment areas due to soil compaction, disrupting hydrological conditions (Rentachintala *et al.,* 2022). Unlike the other two watersheds mentioned above, the Anggoeya, Abeli, and Lemo watersheds are considered sustainable. The three watersheds have good vegetation cover and fairly good hydrological conditions. The condition of three watersheds still has extensive vegetated land cover with the social conditions of the people still practicing a mixed garden farming system culture so this needs to be maintained and improved management so that the watersheds are even more sustainable

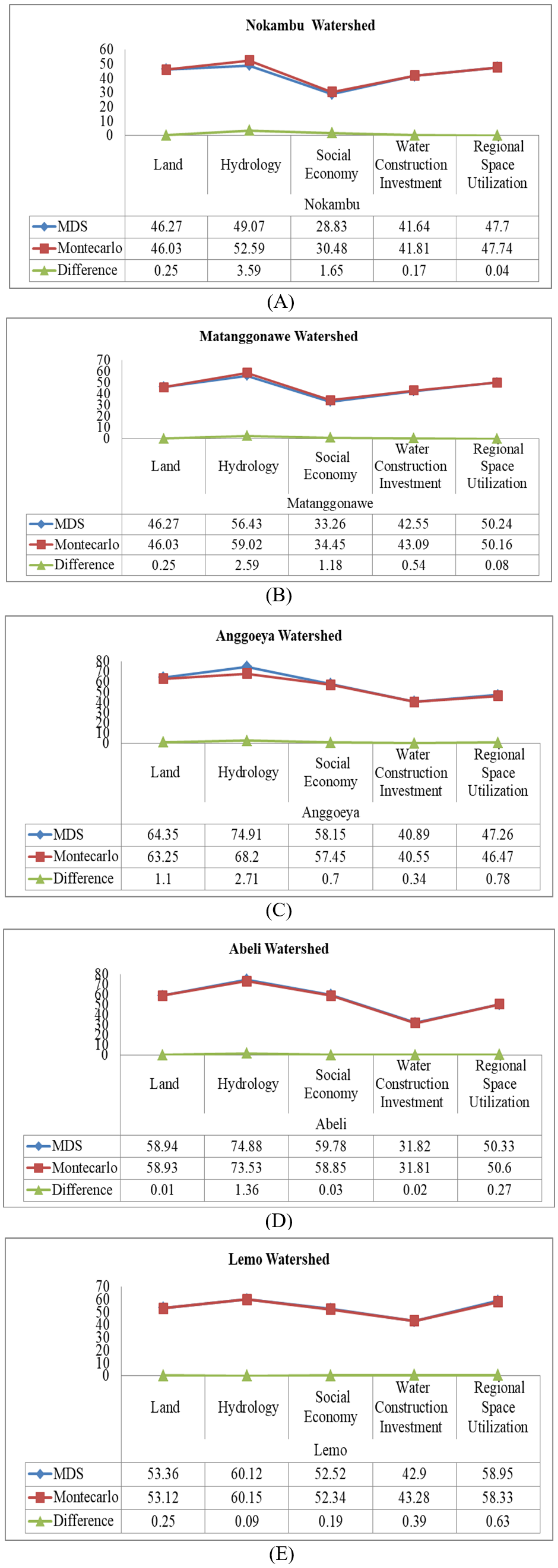
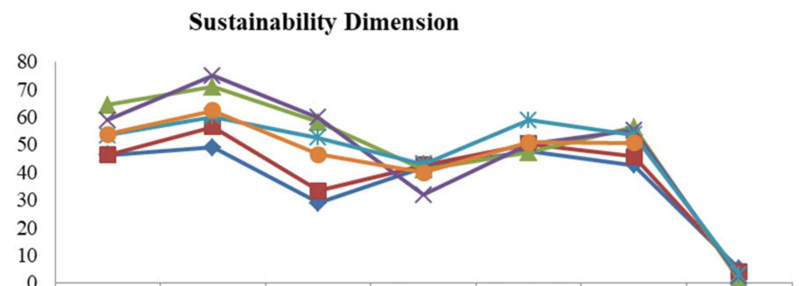


Figure 7. Differences between the results of the MDS analysis and Monte Carlo simulation for (A) Nokambu Watersheed (B) Matanggonawe Watersheed (C) Anggoeya Watersheed (D) Abeli Watersheed (E) Lemo Watersheed

Table 1. Stress and coefficient of determination value

Sustainability Dimension	Stress	R^2
Land	0.16	0.94
Hydrology	0.17	0.94
Social Economy	0.17	0.93
Water Constructions Investment	0.18	0.92
Regional Space Utilization	0.17	0.93



	Land	Hidrology	Social Economy	Water Building Investment	Regional Space Utilization	Mean	Ranking
Nokambu	46.27	49.07	28.83	41.64	47.7	42.7	5
Matanggonawe	46.27	56.43	33.26	42.55	50.24	45.75	4
Anggoeya	64.35	70.91	58.15	40.89	47.26	56.31	1
Abeli	58.94	74.88	59.78	31.82	50.33	55.15	2
Lemo	53.36	60.12	52.52	42.9	58.95	53.57	3
Mean	53.84	62.28	46.51	39.96	50.9	50.7	

Figure 8. Sustainability index of each watershed according to MDS ordination

(Li *et al.,* 2016; Sörensen *et al.,* 2015). Nonetheless, in general, the conditions of the five urban watersheds in Kendari City mentioned above, have an average sustainability index that is entirely sustainable, with an average value of 50.70. In the five watersheds in Kendari City, all dimensions show the same sustainability status, which is entirely sustainable, except for the investment dimension in-water construction. The 'less sustainable' status of this dimension is indicated by the lack of water management infrastructure in all watersheds.

4. Conclusion

The sustainable management of watersheds in the five urban watersheds in Kendari City, namely the Nokambu and Matanggonawe watersheds, has unsustainable management, while the Anggoeya, Abeli, and Lemo watersheds have fairly sustainable management. Overall, of the five dimensions of watershed carrying capacity studied in this study, the socio-economic and investment dimensions of water structures fall into the less sustainable category. Meanwhile, the dimensions of the land, hydrology, and dimensions of regional spatial use are considered quite sustainable.

Leverage attributes that require special attention in urban watershed management in Kendari City are vegetation cover and slopes which can increase the area of degraded land for the land dimension; flooding and sedimentation, as well as the use of water in the watershed for the hydrological dimension; and the level of income and welfare of the community, as well as the application of land and resource conservation regulations for the socio-economic dimension. For the investment dimension of water buildings, the attributes that must be improved are water infrastructure that is more able to control floods and provide sufficient water for community needs. Finally, the spatial utilization dimensions that need to be developed are the management of flood-prone and landslide-prone areas in a sustainable manner, as well as protected forest and mangrove forest areas that produce environmental resources.

The validation results of the MDS analysis on RAPURWA were able to provide statistical accuracy. This is shown by the value of Stress, R^2, and Monte Carlo analysis, which is at the appropriate value. So that the results of this study need to be carried out in accordance with the RAPURWA method by taking into account several dimensions and the same attributes in the broader watershed research.

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