Determinant of sustainable land resources management key factors in Musi Hydropower Plant Catchment Area of Bengkulu Province

Sukisno1,2, Widiatmaka3, M Y J Purwanto4, B P Noorachmat5 and K Munibah3
1Graduate Student of Natural Resources and Environmental Management, IPB University, Bogor, West Java, Indonesia.
2Department of Agriculture Cultivation, Faculty of Agriculture, University of Bengkulu, Bengkulu, Indonesia.
3Department of Soil Science and Land Resources, IPB University, Bogor, West Java, Indonesia.
4Department of Civil and Environment, IPB University, Bogor, West Java, Indonesia.
5Department of Agricultural and Bio-system Engineering IPB University, Bogor, West Java, Indonesia.

E-mail: suquisno@unib.ac.id

Abstract. The Subwatershed of Musi Hulu plays an essential role in Bengkulu Province and the South Sumatra region. In 2006, the establishment of the Musi Hydropower Plant increases the functional load of the area hence, there is a need for sustainable land resources management. Therefore, this study aims to identify the key factors that affect sustainable land resources management in the Musi Hydropower Plant catchment area in Bengkulu Province. This research was conducted in the Musi Hydropower Plant catchment area in Rejang Lebong and Kepahiang Regency, Bengkulu Province, Indonesia. The method used was an Interpretive Structural Modelling (ISM) with four criteria, namely objectives, programs, barriers, and stakeholders of land resources management. The results showed that limited budget and weakness of coordination among stakeholders are the main barriers to sustainable land resources management in the catchment area. Meanwhile, non-governmental organization plays significant roles in supporting land resources management. Therefore, with the limited budget of land resources management, it is recommended to improve the coordination among stakeholders to maintain sustainability in the Musi Hydropower Plant catchment area in Bengkulu Province.

1. Introduction
The subwatershed of Musi Hulu plays an essential role in Bengkulu Province and the South Sumatra region. It serves as the upstream of Musi River and artificial watershed of the Hulu-Air Lemau, which was formed by changing the flow direction of water from the upstream to Lemau River. This change in the direction of water flow is due to the establishment of the Musi Hydropower Plant in 2006, using the water from Musi River and spilling it out to Lemau River [1, 2].
In the past decade, land resources in the Musi Hydropower Plant catchment areas have degraded significantly. Also, the sedimentation rate of the Musi Hydropower Plant reservoir has interfered with the water supply to the power and dredged reservoir [3, 4]. Moreover, the sedimentation rate is closely related to land resources management, especially with land-use changes.

As the catchment area of Musi Hydropower Plant, the sustainability of land resources in the subwatershed of Musi Hulu is very important. Therefore, sustainable land resources management related to its capacity to support activity in the watershed is required. Meanwhile, sustainable land resources management is defined as a knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet the requirements of a growing population, while sustaining ecosystem services and livelihoods. In contrast, improper land management leads to degradation and a significant reduction in the productive and service (biodiversity, hydrology, and carbon sequestration) functions of watersheds and landscapes [5]. To determine an appropriate land resources management model, the interrelationships among support systems of the area need to be considered [6, 7, 8, 9]. Moreover, the support systems of sustainable land resources management are stated to be the key factors that affect the area’s sustainability.

Interpretive structural modeling (ISM) is an appropriate method to identify and analyze the relationships and the interacting position among variables [10, 11, 12]. This method is widely used in various fields to identify variables for effective customer involvement in implementing the green concept in the supply chain and prioritize the identified variables [13]. In addition, it is applied in the analysis of key performance indicators for sustainable rubber industry [14], barriers of uptake and implementation of nature-based solution [15], biomass related sustainability [16], and identify critical success factors for safety management in subway construction [17].

Therefore, this study aims to identify key factors that affect sustainable land resources management in the Musi Hydropower Plant catchment area in Bengkulu Province, Indonesia.

2. Material and Methods

2.1. Research Location
This study was conducted from September 2020 to February 2021 in the Musi Hydropower Plant catchment area in Rejang Lebong and Kepahiang Regency, Bengkulu Province, Indonesia.

2.2. Research Method
The interpretive structural modeling (ISM) method is used to identify the relationships among specific elements of a system and structure them into a comprehensive systematic model [9, 12, 15]. Therefore, the method was used to identify the relationships among sub-elements of sustainable land resources management in the Musi Hydropower Plant catchment area.

This study was conducted to identify the key factors that affect sustainable land resources management in the Musi Hydropower Plant catchment area. The four criteria of elements used as key factors include the objectives, programs, barriers, and stakeholders of sustainable land resources management. Meanwhile, the matrix of elements and sub-elements of sustainable land resources management is shown in Table 1.

Purposeful sampling was used to select the experts, which consist of 6 academics, three governmental officials, and one user (The Musi Hydropower Plant). There are three main steps to the ISM methods, namely, identifying the representative elements which are relevant to the key factors. Secondly, establish contextual relationships between elements by examining their connection, which can be transferred into an initial reachability matrix, and convert into a final reachability matrix. Thirdly, partition the reachability matrix into different levels and present the result for expert modification [18]. The analysis procedures in this study are shown in Figure 1.
Table 1. The matrix of elements and sub-elements of sustainable land resources management

| Elements | Pairwise Relationships | Sub Elements |
|----------|------------------------|--------------|
| The objectives of sustainable land resources management | V => the objective i contribute to the achievement of the objective j | 1. Erosion and sedimentation rate reduction |
| | A => the objective j contribute to the achievement of the objective i | 2. Increasing land productivity |
| | X => the objectives i and j contribute to each other | 3. Increasing generating income |
| | O => the objectives i and variable j are unrelated | 4. Increasing efficiency of Musi Hydropower Plant management |
| The programs of sustainable land resources management | V => the program i more important than the program j | 5. Decreasing deforestation |
| | A => the program j more important than the program i | 6. Creating jobs |
| | X => the program i equal to the program j | 1. Forest rehabilitation |
| | O => the programs i and j are unrelated | 2. The development of agroforestry on the Area for other land uses (APL) |
| The barriers to sustainable land resources management | V => the barrier i affects the barrier j | 3. Implementation of conservation system |
| | A => the barrier j affects the barrier i | 4. Creating check dams |
| | X => the barrier i and j affects each other | 5. Payment of environmental services |
| | O => the barriers i and j are unrelated | 6. Education and supervision of community programs |
| The stakeholders of sustainable land resources management | V => the stakeholder i supporting the stakeholder j | 1. Limited budget |
| | A => the stakeholder j supporting the stakeholder i | 2. Sectoral programs |
| | X => the stakeholder i and j supporting each other | 3. Absence of specific programs |
| | O => the stakeholders i and j are unrelated | 4. Weakness of coordination among stakeholders |
| | | 5. Lack of community involvement |
| | | 6. Community education rate |
| | | 7. Land physical factors |
| | | 1. The Central Government |
| | | 2. The Musi Hydropower Plant |
| | | 3. The non-governmental organization |
| | | 4. The academics/researcher |
| | | 5. The regional/local government |
| | | 6. The farmer |
3. Results and Discussions

3.1. The Objectives of Sustainable Land Resources Management

The objectives of sustainable land resources management consist of 6 sub-elements, namely the erosion and sedimentation rate reduction, increase in land productivity, generate more income, increase the efficiency of Musi Hydropower Plant management, decreasing deforestation, and creating jobs. Meanwhile, the result showed that the hierarchy structure of the objectives consists of five levels, namely decreasing deforestation at level 5, erosion and sedimentation rate reduction at level 4, increasing land productivity and creating jobs at level 3, increasing generating income at level 2, and increasing efficiency of Musi Hydropower Plant management at level 1. This structure showed the priority of the elements. The relationships among sub-elements of objectives are shown in Figure 2.

Figure 1. The flow chart of analysis for key factors of sustainable land resources management with ISM.
Figure 2. The hierarchy structure of elements the objectives of sustainable land resources management.

Figure 2 shows that decreasing deforestation is the priority of the objectives of sustainable land resources management. Therefore, achieving this objective contributes to erosion and sedimentation rate reduction, which also contributes to increasing land productivity and creating jobs. Furthermore, creating jobs and increasing land productivity contribute to the increasing generating income. Hence, the increase in Musi Hydropower Plant management efficiency is gained after the other objectives are achieved.

The driving power-dependence diagram showed that decreasing deforestation and erosion and sedimentation rate reduction is in the Independent Quadrant (Figure 3). These objectives have intense driving and weak dependence power and are the main priority of sustainable land resources management in the Musi Hydropower Plant catchment area.

In the linkage quadrant, there are creating jobs and increasing land productivity. These objectives have both intense driving as well as dependence power and are sensitive because any alterations have effects on the dependence elements. In addition, there is a feedback effect since they are interrelated.

The increasing generating income and efficiency of Musi Hydropower Plant Management are in the dependent quadrant. These elements have strong dependence and low driving power, therefore, it is achieved after the other objectives are reached. The driving power-dependence diagram of the objectives of sustainable land resources management is shown in Figure 3.

Figure 3. The driving power-dependence diagram of elements of the objectives of sustainable land resources management.
3.2. The programs of sustainable land resources management

The programs of sustainable land resources management consist of 6 sub-elements, namely forest rehabilitation, agroforestry development on the area for other land-uses, implementation of conservation system on agricultural land, creating dams, payment of environmental services, and education as well as supervision of the community. Meanwhile, the result showed that the hierarchy structure of the programs of sustainable land resources management consists of two levels, which are forest rehabilitation at level 2 and the other programs at level 1 (Figure 4).

Furthermore, the program's hierarchy structure showed that forest rehabilitation is the priority of sustainable land resources management which contributes to the other programs. The programs of development agroforestry on the area for other land-uses, implementation of conservation system on agricultural land, creating dams, payment of environmental services, as well as education and supervision of the community programs are interrelated.

The diagram of driving power-dependence showed that the forest rehabilitation is in the independent quadrant, while the other programs are in the linkage quadrant. This indicated that the forest rehabilitation program has strong driving and weak dependence power. Therefore, this objective is the main priority of the program (Figure 5).

Figure 4. The hierarchy of elements of the program of sustainable land resources management.

Figure 5. The driving power-dependence diagram of element program of sustainable land resources management.
3.3. The barriers to sustainable land resources management

The seven barriers to sustainable land resources management in the Musi Hydropower Plant catchment area include limited budget, sectoral programs, absence of specific programs, weakness of coordination among stakeholders, lack of community involvement, education rate, and physical land factors. The result showed that the hierarchy structure of the barriers consists of 6 levels, namely limited budget at level 6, the weakness of coordination among stakeholders at 5, the absence of specific programs at 4, the lack of community involvement at 3, and the physical land factors, and community education rate at level 1 (Figure 6).

The hierarchy structure of elements barriers showed that limited budget is the priority of the barrier that needs to be solved because it affects the others. Furthermore, the weakness of coordination among stakeholders also required solutions. Therefore, limited budget and weakness of coordination among stakeholders are the general problem of environmental management in Indonesia.

Moreover, the diagram of driving power-dependence showed that limited budget and weakness of coordination among stakeholders are in the independent quadrant (Figure 7). These barriers have strong driving power as well as weak dependence power. They are the main priority of the barriers of sustainable land resources management of the Musi Hydropower Plant catchment area. With the limited budget, it is suggested to improve the coordination among stakeholders to maintain the sustainability of the Musi Hydropower Plant catchment area in Bengkulu Province.

The absence of specific and sectoral programs is in the dependent quadrant, while lack of community involvement, education rate, and physical land factors are in the autonomous quadrant. Meanwhile, the absence of specific and sectoral programs has strong dependence and low driving power. In contrast, the aspect lack of community involvement, education rate, and physical land factors have low dependence and driving powers.

Figure 6. The hierarchy structure of elements barriers of sustainable land resources management.
Figure 7. The driving power-dependence diagram of element barriers of sustainable land resources management.

3.4. The stakeholders of sustainable land resources management

The six stakeholders involved in sustainable land resources management in the Musi Hydropower Plant catchment area include the central government, Musi Hydropower Plant, non-governmental organizations, academics/researchers, regional/local government, and farmers. The result showed that the hierarchy structure of stakeholders consists of 2 levels. The academics/researchers and non-governmental organizations are at level 2, while the central government, Musi Hydropower Plant, regional/local government, and farmers are at level 1 (Figure 8).

Figure 8. The hierarchy structure of stakeholders of sustainable land resources management.

The hierarchy structure of stakeholders showed that the academics and non-governmental organizations have essential roles in supporting the other for sustainable land resources management in the Musi Hydropower Plant catchment area. This indicated that the roles of academics and non-governmental organizations need to be optimized and supported by a study as well as community assistance capacity.
Figure 9. The driving power-dependence diagram of stakeholders of sustainable land resources management.

The driving power-dependence diagram of stakeholders showed that academics and non-governmental organizations are in the independent quadrant. These stakeholders have strong driving power and low dependence. Meanwhile, the other stakeholders, such as the central government, Musi Hydropower Plant, regional/local government, and farmers are in the linkage quadrant. These stakeholders have strong driving and dependence (Figure 9). From the driving power-dependence diagram, it is deduced that optimizing the roles of academics and non-governmental organizations is the priority.

4. Conclusion
Based on the results, sustainable land resources management in the Musi Hydropower Plant catchment area is vital for enhancing and sustaining the eco-hydrological function. Therefore, the strategies for sustainable land resources management are as follows:
1. The priority objectives of sustainable land resources management include a decrease in deforestation rate as well as reducing the erosion and sedimentation rate. This is followed by increasing land productivity and creating jobs as well as increasing generating income and efficiency of Musi Hydropower Plant management.
2. The priority program of sustainable land resources management is forest rehabilitation. Meanwhile, other programs such as the development of agroforestry for other land-uses, implementation of conservation system on agricultural land, creating dams, payment of environmental services, together with education and supervision of community programs, are interrelated.
3. The main barriers to sustainable land resources management are limited budget and weakness of coordination among stakeholders. Therefore, with the limited budget, an improvement in the coordination among stakeholders is recommended.
4. Academics and non-governmental organizations have important roles in supporting sustainable land resources management, especially through study and community assistance.
Acknowledgment

The authors are grateful to the Head of LPPM University of Bengkulu, Herry Suhartoyo, Ph.D., Vice Dean I Faculty of Agriculture University of Bengkulu, Yansen, Ph.D., Lecturer of University of Bengkulu, Faiz Barchia, Ph.D., Kanang S. Hindarto, M. Fajrin Hidayat, Gunggung Senoaji, Ph.D., Head of Bengkulu Provincial Environmental and Forestry Service (DLHK), Sorjum Ahyan, Section Head of Program the BPDAS Ketahun, Yumi Lestari, Section Head of Infrastructure and Territory of Regional Planning and Development Agency (BAPPEDA) Bengkulu Province, Agus Saptaji, and Manager of Musi Hydropower Plant, Martin Wahyunus.

References

[1] [PLN] Perusahaan Listrik Negara 2015 Studi Kekritisan dan Analisis Tata Air Daerah Tangkapan Air PLTA Musi dan PLTA Tes (Bengkulu : LPPM Universitas Bengkulu dan PLN)
[2] Tang S, Chen J, Sun P, Li Y, Yu P, Chen E 2019 Energy Policy 129 239-249
[3] Amri K, Halim A N, Ngudiantoro, Barchia M F 2014 APCBEE Procedia 10 235-240
[4] Amri K, Halim A N, Ngudiantoro, Barchia M F 2014 IPCBEE Procedia 63 83-87
[5] World Bank 2006 Sustainable Land Management Challenges, Opportunities, and Trade-off World Bank (US: Washington)
[6] Marimin, Maghfiroh N 2010 Aplikasi Teknik Pengambilan Keputusan dalam Manajemen Rantai Pasok (Bogor: IPB Pr)
[7] Muhammadi, Aminullah E, Soesilo B 2001 Analisis Sistem Dinamis Lingkungan Hidup, Sosial, Ekonomi, Manajemen (Jakarta: UMJ Pr)
[8] Hartrisari H 2007 Sistem Dinamik Konsep Sistem dan Permodelan untuk Industri dan Lingkungan (Bogor: SEAMEO BIOTROP)
[9] Eriyatno, Larasati L 2013 Ilmu Sistem Meningkatkan Integrasi dan Koordinasi Manajemen. Jilid 2 (Surabaya: Guna Widya)
[10] Warfield J N 1974 IEEE Transaction in Systems, Man, and Cybernatic 4 81-87
[11] Panahifar F, Heavey C, P Sontamino, and Byrne P J 2016 J. of Advanced Management Science 4 1-8
[12] Sushil 2012 Global Journal of Flexible Systems Management 13 87-106
[13] Kumar S, Luthra S, and A Haleem 2013 Journal of Industrial Engineering International Springer 9 1-13
[14] Amrina E and Yulianto A 2018 IOP Conf Ser.:Mater. Sci. Eng 319 012055
[15] Sarabi S, Qi Han, George A, Romme L, Bauke De Vries, Varlkenburg L, and Elke den Euden 2020 J. of Environmental Management 270 110749
[16] Azevedo SG, Sequeira T, Santos M, and Mendes L 2019 Energy 171 1107-1125
[17] Liu P, Li Q, Bian J, Song L, and Xiahou X 2018 Int. J. Environ. Res. Public Health 15 1359
[18] Cai Y and Xia C 2018 Sustainability 10 786