Ecological performance of local initiatives on water resources management in Timorese communities, Indonesia

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Abstract. Indonesia is one of the countries under the threat of a water crisis. A total of 106 districts from 16 provinces, including East Nusa Tenggara, experienced drought and clean water crisis of 1.50 billion m³ year⁻¹. This involves ecological characteristics accumulation of semi-arid regions, degradation of forest resources, and increased critical land. Mitigation research on a watershed scale provides an understanding of the strong relationship between land degradation and water crisis. However, specific information on biophysical spring sources in semi-arid ecosystems is still very limited. This study aimed to obtain ecological performance based on rainfall, critical land, and land cover from a community-based water resource management model on the Timor island. This study was conducted through field observations at 63 units of water sources and structured interviews. The results showed that the characteristics vary from rainfall distribution, land cover, critical land, and utilization pressure. Furthermore, water source units have a limited carrying capacity of rainfall, the land conditions are generally critical, including the threat of land fires and community use of springs. Meanwhile, the variations of these characteristics determine the management interventions undertaken by the community. Therefore, through various management models of community-based water sources, local initiatives need to get support to preserve water sources for the people's livelihood.

1. Introduction

Water is a natural resource beneficial to humans but threatened by scarcity. Also, the quality and quantity are seriously affected due to environmental damage. This has prompted the emergence of a global community to focus on collective action to address the scarcity affecting humans [1] and decreased agricultural productivity, food security, and malnutrition [2-3]. According to predictions, 2.7 billion people are expected to experience a water crisis in 2025, and this number will increase to 6 billion in 60 countries by 2050 [4]. However, this can be controlled by mitigation of water use outside the agricultural sector, especially in dry areas, to control the scarcity level in 2050 [5].

Indonesia has a water potential of 3.9 trillion m³ year⁻¹, but only 691.3 million m³ year⁻¹ is used [6]. The geographic characteristics of an archipelago also influence the scarcity of clean water [7]. This is because most of the areas consist of small islands with limited water catchment areas. Due to this, 33 million people do not enjoy drinking water properly [8]. As an archipelago province, East Nusa Tenggara experiences a clean water deficit of 1.50 billion m³ year⁻¹. This deficit occurs in most regencies, including East Sumba, West Sumba, Central Sumba, Southwest Sumba, South Central Timor, North Central Timor, Malacca, Belu, Rote Ndao, Sabu Raijua, Alor, Lembata, East Flores, Ende, Sikka,
and Nagakeo. Furthermore, water scarcity occurs in Kupang City and Kupang Regency, which already have adequate facilities and infrastructure [9].

For a long time, water scarcity has occurred among people on Timor Island. Multi-dimensional implications in decreased agricultural production, livestock mortality, and public health have been recorded. The process of interaction and adaptation to water scarcity promoted community initiatives to manage and conserve land around water sources, both individually and by local institutions. [7] emphasized the importance of paying attention to local institutions. This is because they act as partners in conducting community-based water resource management. The initiative through local institutions reflects the values, culture, and norms practiced by the community in water management and utilization [10].

Local initiatives in water conservation have been practiced according to community capacity. Therefore, policymakers need to understand and integrate them in the formulation of policies for their development. Policy support can improve effective and adaptive management by strengthening and developing community-based water conservation [11]. A sturdy foundation is needed for this to happen on the ecological performance of a local initiative model in water resources management among the Timorese community. Therefore, this study aims to obtain information on ecological performance based on rainfall, critical land, and land cover from Timor Island's community-based water resource management model. It is expected that the results of this research could be helpful for policymakers, especially those related to water management in Indonesia, especially in Timorese communities.

2. Methodology

In the regency of Kupang, South-Central Timor and Belu, studies have been carried out on the environmental performance of local community-based water resources management initiatives. In addition, coordination was conducted with the Regional Environmental Agency and other related institutions to determine the distribution of springs managed by the community. The sample units of the spring, as many as 63, were determined, and a field observation was further conducted. Data and information were collected using questionnaires and interviews with the community managing and using the springs. The data types collected include the geographical position of springs, rainfall, critical land, land cover, and its management. Descriptive and qualitative analysis was used to process the collected data.

3. Results and Discussions

3.1. Ecological distribution based on rainfall

Rainfall is a source of water for agriculture, livestock, industry, and households in Timor Island. Generally, rural communities fulfill their needs from springs around the settlements. This high dependence becomes the basis for developing local initiatives in the conservation, rehabilitation, and protection of the surrounding spring ecosystem.

Community-based spring management units are classified into two clusters based on the rainfall factor (Figure 1). The first consists of 39 (62%) spring units with rainfall input ranging from 1501-2000 mm year⁻¹. Meanwhile, the second consists of 24 (38%) spring units with rainfall input ranging from 1001-1500 mm year⁻¹. Based on the above information, both groups show relatively small variations in rainfall input. This has implications for the amount of water produced, the choice of community use, and ecosystem protection efforts to increase water uptake in the soil.

The relatively small ecological variations have implications for soil and water conservation models in protecting the ecosystems. Water traps and terracings are general models used for the development of surrounding soil and water conservation. The application of terracing helps maintain land functions stability around the spring from the threat of erosion and landslides. On the other hand, there is a strong suspicion that soil and water conservation application has implications for discharge fluctuation level during the rainy and dry seasons.

Water discharge fluctuation in 13 samples of springs on Timor Island shows various changes ranging from 10-25% during the rainy and dry seasons [12]. Furthermore, relatively small fluctuation of water...
discharge is influenced by rainfall input, the application of soil and water conservation, as well as the performance of the management by the community. Optimal protection and management performance have implications for sustainable service functions. Therefore, attention to soil and water conservation and management and protection of the ecosystem needs to be increased to obtain better and sustainable benefit values.

![Figure 1](image_url)

**Figure 1.** Distribution of spring locations by annual rainfall in Timor Island.

3.2. *Ecological distribution based on critical land*

Critical land is considered unproductive since the management ignores the principles of soil and water conservation. This has resulted in erosion, physical, chemical, and biological damage, and a decrease in the function of water systems. A damaged land with loss or reduced function [13] is known as critical land. It is generally categorized as very critical, slightly critical, potentially critical, and uncritical. Based on the classification (Figure 2), most springs were located in the critical land class (47 out of 63 locations; equal to 75%). Furthermore, 2 (3%) springs were in potentially critical class land, and both slightly critical land and very critical land classes have 7 locations of spring (11%).

The community manages the land around the spring water units by developing various plants for various purposes. This is a driving factor for increased land cover and improved fertility. The initiative needs to be developed in the rehabilitation and conservation of springs using a vegetative approach. These efforts can be strengthened by integrating the community forest unit development and afforestation in the catchment area of springs. Also, it should further increase the diversity of plant species and land cover functions as well as their carrying capacity in soil and water conservation. Program intervention from the government is expected to control the decline in community awareness of the protection and management of agroforestry ecosystems developed around water sources [14-15]. The decrease is probably related to the production function through intervention from the government. This increases farmers’ initiatives in agroforestry management and development (15).
Conservation initiatives can be synergized in community-based forest development and reforestation. It is based on the nature and the characteristics of spring water. This is necessary since the forest development is in line with land rehabilitation initiatives around springs that synergize the interests of forests, gardens, agriculture, livestock, and environmental conservation [12]. The community places water resources as part of the management of land and environmental resources, with a multi-benefit orientation to the community. This manifestation is through the management of various plant species to conserve biological resources around water sources, reaching at least 112 species [16]. These include *Swietenia machrophylla* King., *Swietenia mahagony* L. Jacg., *Gmelina arborea* (Burm F.) Merr., *Tectona grandis* Lf., *Toona sureni* (Blume) Merr., *Timonius sericeus* (Desf) K. Schum., *Sterculia foetida* L., *Alstonia scholaris* R.Br., *Alstonia spectabilis* R.Br., *Artocarpus heterophyllus* Lamk., *Artocarpus integra* Merr., and *Acacia leucophloea* (Roxb.) Willd.

![Figure 2. Distribution of spring locations by critical land classes in Timor Island.](image)

3.3. Ecological distribution based on landcover

The land cover has an impact on the protection of spring ecosystems. Based on this (Figure 3), about 22 (35%) are spring water units with secondary dryland forest cover category. As many as 20 (32%) were in areas with the shrub category, while the other 14 (22%) were in the dry land agriculture category. A small distribution of 5 (8%) is in areas with the mixed dryland agricultural category, and 2 (3%) is in the paddy field (wetland).

The land cover showed that most distribution of spring water management units is in a well-managed condition. The investigation results showed that the spring water units located in secondary dryland forest, dryland agriculture, and mixed dryland agriculture were agroforest units developed by the community. They cultivate various plant species beneficial to socio-economy, culture, and food. The food-producing plants were: *Ananas comosus* Merr., *Anona muricata* L., *Artocarpus communis* Forst., *Artocarpus heterophyllus* Lamk., *Artocarpus integra* Merr., *Canna edulis* Ker., *Carica papaya* L.,
Citrus maxima (Burm) Merr., Colocasia esculenta Schott., Cocos nucifera L., Dioscorea hispida Dennst., Dioscorea acucata Linn., Dioscorea alata Linn., Ipomoea batatas Poir., Mangifera indica L., Manihot utilissima Pohl., Musa parasidiaca Linn., Persea gratissima Gaertn., and Solanum torvum Swartz. Others include the development of non-timber forest products species such as areca nut (Areca cathecu L.), tamarind (Tamarindus indica L.), and hazelnut (Aleurites moluccana (L.) Willd. The community maintained plant species beneficial for conservation, including banyan (Ficus benjamina L.), pulai (Alstonia scholaris (L.) R.Br. to increase biodiversity, support land conservation efforts and reforest the area around springs. The role of the community in protecting spring water sources is quite fundamental, especially in avoiding the risk of possible threats such as land fires.

The initiatives of the local communities for the spring water units management are quite sustainable and are part of the economic activities. Water is used for basic needs such as irrigation of vegetable crops, livestock needs, and raising fish. Periodically, several community groups initiate the sales services to outsiders using tank cars at competitive prices. These benefit values encourage protection and conservation efforts by using cultural attributes such as traditional ceremonies. The limited water resources are optimally used since there are direct and indirect benefits through the cultivation of vegetables, animal husbandry, irrigation of small agricultural areas and honey beekeeping, one of which is in Loli Village. Also, spring water is managed using an agroforest-customary approach. They maintain some plant species, including hive trees and honey bee forage trees. This supports the production of honey for the livelihoods of the community.

Cultural institutions support local initiatives for spring resource management by applying the "Banu" ceremonial tradition. It regulates the use of resources such as the spring ecosystem. Various types of fruits produced from ecosystems of spring water are also counted as valuable resources with high social and economic benefits for the community. The time-frame and procedures for utilization to ensure the
sustainable function of the spring ecosystem are also regulated. Regulation through the Banu tradition has positive implications, such as providing opportunities for ecosystem recovery through natural regeneration processes. It increases the quality and quantity of natural resource production in spring ecosystems and disciplines communities not to overuse natural resources. The consequences of each violation are customary fines with several materials agreed upon collectively.

4. Conclusion
Local initiatives in the management of springs have lasting value to aid conservation efforts. The application of the conservation of soil and water increase groundwater input in conditions of limited rainfall. Furthermore, the initiatives to develop various types of plant biodiversity in spring ecosystems increase ecological function, conserve biodiversity, control critical land, increase land cover, and diversify livelihood sources for the community.

The implication of this research is to promote the development of community-based spring management as a specific water resources conservation model in semi-arid ecosystems. Social, economic, and ecological benefits are the basis for encouraging local governments to initiate development. This is conducted through scale-up at the local level since a superior community-based water resources management model is applied to local ecosystems.

References
[1] Gittins J R, Hemingway J R and Dajka J C 2021 How a water-resources crisis highlights social-ecological disconnects J. Watres. 194 116937
[2] Dinar A, Tieu A and Huynh H 2019 Water scarcity impacts on global food production J. GFS 23 212-26
[3] Gebre B, Ayenew H Y and Biadgilign S 2021 Drought, hunger, and coping mechanism amongst rural households in Southeast Ethiopia Heliyon 7 e06355
[4] Sanim B 2011 Sumber daya air dan kesejahteraan publik (Suatu tinjauan teoritis dan kajian praktis) Bogor
[5] Huang Z, Liu X, Sun S, Tang Y, Yuan X and Tang Q 2021 Global assessment of future sectoral water scarcity under adaptive inner-basin water allocation measures J. Sci. Tot. Env. 783 146973
[6] BPS-Statistics of Indonesia 2017 Statistik air bersih Indonesia Badan Pusat Statistik Jakarta
[7] Máněz K Z, Husain S, Ferse S C A and Costa M M 2012 Water scarcity in the Spermonde Archipelago, Sulawesi, Indonesia: Past, present and future J. Env. Sci 23 74-84
[8] Cameron L, Chase C, Haque S, Joseph G, Pinto R and Wang Q 2021 Childhood stunting and cognitive effects of water and sanitation in Indonesia J. EHB 40 100944
[9] Messakh J J, Sabar A, Hadihardaja I K and Chalik A A 2015 Kajian pemenuhan kebutuhan air minum untuk masyarakat di kawasan semi arid Indonesia Jurnal Manusia dan Lingkungan 22(3) 271-80
[10] Borthakur A and Singh P 2020 Indigenous knowledge systems in sustainable water conservation and management, Editor(s): Pardeep S, Yulia M, Kangming T, Deepak G, João P B, Water conservation and wastewater treatment in BRICS Nations Elsevier 321-28
[11] Thakur R, Rane A V, Harris G and Thakur S 2020 Government initiatives and policies for water conservation and wastewater treatment in South Africa and indigenous knowledge, Editor(s): Pardeep S, Yulia M, Kangming T, Deepak G, João P B, Water conservation and wastewater treatment in BRICS Nations Elsevier 285-93
[12] Njurumana G N, Victorino B A and Pratiwi 2008 Potensi pengembangan mamar sebagai model hutan rakyat dalam rehabilitasi lahan kritis di Timor Barat J.PHKA 5(5) 473-84
[13] Peraturan Menteri Kehutanan Republik Indonesia No. P.32/Menhut-II/2009 tentang tata cara penyusunan rencana teknik rehabilitasi hutan dan lahan aerah Aliran Sungai, Kementerian LHK RI
[14] Suek J, Hartono S, Irham and Waluyati L R 2017 Environmental awareness in mamar, a small
scale farmers' traditional agroforestry in Timor Indonesia *Int. J. App. Env. Sci.* 12(7) 1261-79
[15] Suek J 2020 Behavior of farmers responding to risks of mamar traditional agroforestry production in Timor, East Nusa Tenggara *Pros. Sem. Nas. PolBangTan Yogyakarta Magelang* ISBN 978 623-95866-0-3
[16] Njurumana G N 2012 Agroforestry mamar dan konservasi keanekaragaman hayati tumbuhan di *Nusa Tenggara Timur. Pros. Sem. Nas. Agroforestry III* 29 Mei 2012

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**Authors’ contribution**
Conceptualization and research design; construction of research variables, indicators and instruments; primary and secondary data collection; review references; data analysis; manuscript development; revision and final editing was done by Gerson N. Njurumana (main contributor). Primary data collection, GIS analysis and map provision were made by Eko Pujiono. Primary data collection was also conducted by Mariany M. da Silva & Oskar K. Oematan.