Jurnal Ilmu Kehutanan
https://jurnal.ugm.ac.id/v3/jik/
ISSN: 2477-3751 (*online*); 0126-4451 (*print*)

Editorial

Sustainable Forest Management from Hydrology and Climate Change Mitigation Perspectives

(Pengelolaan Hutan Berkelanjutan Perspektif Hidrologi dan Mitigasi Perubahan Iklim)

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DOI: 10.22146/jik.v17i1.6904

ABSTRACT

The increasing number of hydrometeorological disasters induced by unsustainable landscape management has led to significant fatalities and economic loss. Forest ecosystem landscapes are strategic national capital that could contribute to climate change mitigation. The government had formulated policies on FOLU Net Sink 2030 through sustainable forest management, environmental and carbon governance, and a Nationally Determined Contribution (NDC) strategic approach using its natural infrastructure in the form of forest ecosystem landscapes. The government could establish attractive and integrated incentive and disincentive systems and mechanisms with sustainable forest management to achieve the targets.

KEYWORDS
sustainable forest management, hydrology, climate change, hydrometeorology

INTISARI

Maraknya bencana hidrometeorologi yang disebabkan oleh pengelolaan lansekap yang tidak berkelanjutan telah mengakibatkan korban jiwa dan kerugian ekonomi yang cukup besar. Padahal landsekap ekosistem hutan merupakan kekayaan nasional yang strategis, termasuk dalam mitigasi perubahan iklim. Pemerintah juga telah menyusun kebijakan FOLU Net Sink 2030 melalui pendekatan strategis pengelolaan hutan berkelanjutan, tata kelola lingkungan dan karbon, dan Nationally Determined Contribution (NDC) dengan menggunakan infrastruktur alam berupa landsekap ekosistem hutan. Pencapaian target dapat dilakukan dengan membangun sistem dan mekanisme insentif dan disinsentif yang terintegrasi dengan pengelolaan sumberdya hutan lestari.

KATA KUNCI
pengelolaan hutan lestari, hidrologi, perubahan iklim, hidrometeorologi.

Introduction

Mohammad Hatta, the founding father of Indonesia, highlighted the importance of maintaining the ecological functions of the forests. In 1950, his paper "Hutan Menyimpan Kapital Nasional Kita" stated, "*...If the trees in the mountain are felled, water will flow to the sea. This process will slowly drain the soils and creates barren lands. The water will wash away organic matter on its surface, creating barren mountain lands. These are the national capital we must maintain*" (Hariyadi Kartidihardjo 2022).

The increasing number of hydrometeorological disasters has led to substantial fatalities and economic loss. Hydrometeorological disasters include floods, landslides, erosion-sedimentation, and water shortages caused by natural phenomena such as rainfall and human activities. These disasters are induced by heavy rainfall, decreasing forest area, unsustainable land uses, and forest conversion into settlements, mining, and plantations such as large-scale oil palm plantations. Decreasing water retention (ponds, dams, wetlands) induced by economic development could also lead to hydrometeorological disasters.

As an illustration, La Nina induced the flash flood in South Kalimantan in 2021, creating heavy rainfalls in the tropics and massive land conversion. Between 1990-2019, South Kalimantan lost 63% of its forest, increased (legal and illegal) mining activities (33%), and expanded 77% of its oil palm plantations (Bappenas 2021). The disturbances of forest stands and unsustainable agricultural practices have induced flood events in many regions. Figure 1 indicates that landowners or farmers seldom practice agricultural production considering soil and water conservation. These unsustainable practices are not against any regulations. Therefore, the government should develop attractive economic incentive systems and mechanisms to encourage the farmers, especially those on land with steep slopes, to implement a conservative agricultural production system.

Responding to the increasing number of

Figure 1. Land uses that are prone to hydrometeorology disaster

hydrometeorological disasters and other current issues on global warming, the Ministry of Environment and Forestry (MoEF) focuses on improving forest and landscape governance. The basic premise of the selection was that Indonesian forests have a strategic position in the global climate landscape. In 2019, Indonesian agriculture, forests, and other land uses (AFOLU) contributed around 23% of global greenhouse gas (GHG) emissions (IPCC 2019). However, they could deliver up to 37% of the GHG emissions reductions needed to avoid two degrees of warming by 2030 (Griscom et al. 2017), indicating that good forest coverage outweighed the adverse effects of GHG emissions.

Concerning the crucial roles of the landscape, MoEF formulated policies and programs on FOLU Net Sink 2030 to reduce GHG emissions by up to 29% (unconditional) and up to 41% (conditional or with foreign aid). FOLU Net Sink 2030 will achieve its target through Sustainable Forest Management, Environmental and Carbon Governance, and Indonesia's Nationally Determined Contribution (NDC) strategic approach. The NDC is based on four principles as follows (MoEF 2021).

1. Implement a landscape terrestrial-coastal integrated approach by considering multi-sectoral climate mitigation and adaptation efforts.
2. Highlight existing best practices by recognizing the importance of collaboration in combating climate change, scaling up the diversity of traditional wisdom and innovation on climate change mitigation and adaptation efforts that involve governments, private sectors, and communities.
3. Mainstream climate change agenda into development, spatial, and budget plans and formulate development targets that conform with the key climate change indicators.
4. Promote climate resilience in the food, water, and energy nexus by recognizing its importance of fulfilling the needs of a growing young population and improving its natural resources management to enhance climate resilience by protecting and restoring critical terrestrial, coastal, and marine ecosystems.

However, some strategic plans need consistent follow-up. For example, how are these comprehensive strategies and programs implemented at the site level? What is the capacity of human resources in the regions for executing these strategic policies? How to internalize these policies into existing policies effectively? These questions on sustainability should become the direction of these policies' implementation in the field.

Natural Infrastructure

The natural infrastructure approach implements sustainable forest landscape management and mitigates climate change simultaneously. The natural infrastructures, such as landscapes and green open spaces, could strategically be used to conserve ecosystem functions and values and to support the implementation of sustainable forest landscape management policies (Allen 2012). Forest stands, wetlands, riparian areas, and other natural elements of landscapes are natural infrastructures when they are managed strategically, such as agricultural and forest land conservation activities, environmentally friendly development projects, and other activities to serve communities. These activities are often called watershed protection, soil conservation, or other traditional technical terms that are environmentally friendly. Natural infrastructures are similar to green infrastructures, although the latter is also associated with energy-saving technologies.

The incentive-based approach in the form of technical assistance could facilitate the development of natural infrastructures for farmers to preserve and implement environmentally-friendly land management, restore the ecosystem, and maintain ecosystem services within the watershed management scheme. Such investments often involve payment for environmental services mechanisms between the beneficiaries in the lowland and landowners in the uplands. This incentive mechanism could become an efficient and effective approach to securing natural infrastructures.

Landscape attributes should become the primary consideration in land use planning to design natural infrastructure networks, such as landscape ecology and conservation biology. The design of natural infrastructure networks consists of a system of core, corridor, and hub areas that provide essential habitats for endangered species. This system connects to the broader natural functions and processes at the ecosystem level.

The core area hosts natural ecosystems that meet the minimum size thresholds based on the landscape characteristics and provide habitats for endemic flora and fauna. The corridor area is a linear landscape feature that allows wildlife movement in the core area. The habitat preferences of umbrella species have become the primary consideration in designing natural infrastructure networks. Umbrella species are species whose habitats overlap with other species, while keystone species play critical roles in the ecosystem, such as pollinators or predators. The hub area aggregates the core area, other habitats, and other natural landscapes supporting endemic species. It interfaces between forest or ecological areas, landscapes, and built environments.

Implementing natural infrastructure networks at the landscape scale focuses on land acquisition and adaptive land management by public and private landowners to conserve critical habitats and ecosystem processes and functions. America's Longleaf Initiative is an example of landscape management that focuses on restoring the longleaf ecosystem functions for ecological, social, and economic benefits (Langridge et al. 2014; Bennett et al. 2016). This example indicates that the natural infrastructure could conserve forest landscapes while serving social and economic benefits for the communities. For these reasons, implementing sustainable forest management and ensuring forest stands and their functions are critical for soil conservation. The land covered with dense-stratified canopies could protect soils from erosion because the canopies will reduce the kinetic energy of the rainfalls (Falkenmark & Rockström 2004; Vanacker et al. 2007; Asdak & Supian 2018).

Challenges for the Watershed Management

Land covers, especially on agricultural lands, have gained low priority in the sustainability of the landscape ecosystem in many watersheds, leading to high run-offs and soil erosions (on-site), floods, and sedimentations (off-site).

Watershed management needs coherent efforts to ensure sufficient planning, implementation, monitoring, and evaluation. The lowlands' biophysical, social, and economic consequences should become the attribute of the erosion magnitude in the uplands (Gregersen et al. 2007; Asdak 2015). With this, the watershed managers could calculate the external costs of activities on the uplands and plan the ecosystem services schemes. Watershed landscape management is complex. Central and provincial governments play critical roles in accommodating stakeholders with various interests and facilitating cross-border collective actions from uplands to lowlands.

Forests and land covered with dense-stratified canopies are crucial in hydro-meteorological disaster management and climate change mitigation. Figure 2 indicates sedimentation rates at various vegetation cover fractions, while Table 1 illustrates the economic benefits of watershed forest landscape conservation. Vanacker et al. (2007) suggested that different types of land with different vegetation covers will produce different levels of sedimentation. The minimum vegetation cover of 40% has relatively low sedimentation, while a lower percentage of vegetation cover, such as 30%, still produces relatively high sedimentation. A watershed should have a minimum of 40% vegetation cover for climate change mitigation and optimum protection from hydrometeorological disasters. In addition, the collaboration between local governments and communities to increase forest land cover and to identify the hydrometeorological disaster-prone areas is crucial.

Watershed and forest managers encounter significant challenges, especially in the non-technical aspects, although they could also develop potential benefits. For example, why don't farmers plant trees and practice soil conservation? Why haven't decision-makers taken watershed management seriously? Why do cross-sectoral and cross-border remain unresolved? Research suggests that non-technical constraints in watershed management could be addressed through several efforts, as

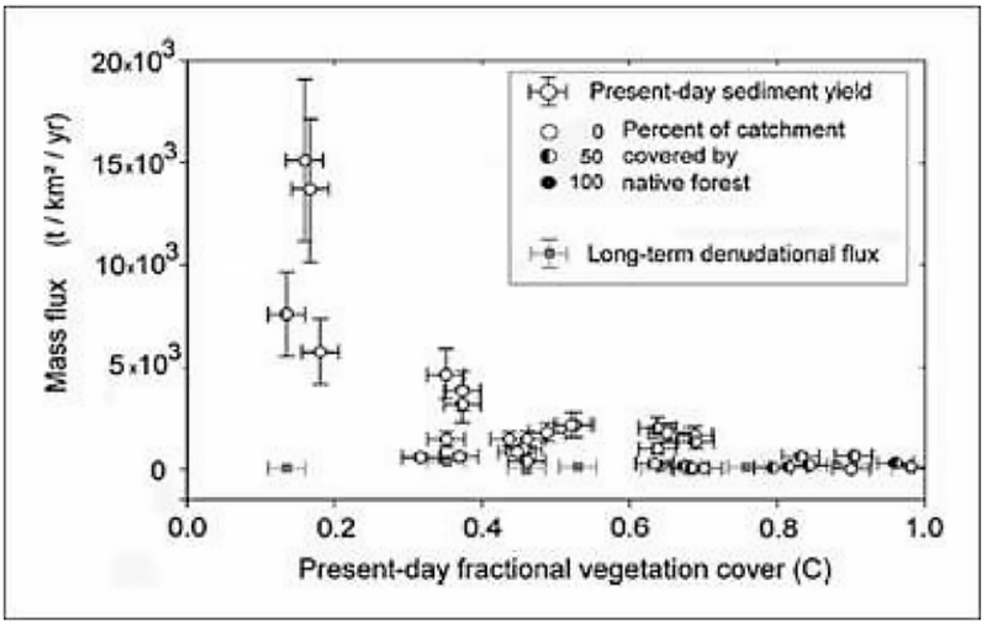

Figure 2. Sedimentation rates at various fractions of vegetation cover (Vanacker et al. 2007)

Table 1. Economic benefit from landscape conservation of 27 watersheds in the United States of America (WRI 2011)

Share of watershed forested	Treatment costs per 3,785 m^3	Costs increase of less than 60% of forest cover	Average annual treatment cost
60%	$37	$297,110	-
50%	$46	$369,380	24%
40%	$58	$465,740	57%
30%	$73	$586,190	97%
20%	$93	$746,790	151%
10%	$115	$923,450	211%

follows (Hanson & Yonavjak 2011; Asdak & Supian 2017):

1. Implement appropriate catchment area management with attractive incentives and disincentive systems.
2. Control the rate of surface run-off through dense vegetation cover, retention ponds, and maintaining wetlands as a water park.
3. Combine river naturalization and normalization approaches as needed.
4. Improve the welfare of dryland farmers in the upper lands of the watershed.
5. Enhance community capacity and their institution in coping with hydrometrical disaster through support on disaster planning and control strategies, early warning systems, and preparation for hydrometeorological disaster and climate change mitigation.

Sea Level Rise

In the future, part of the Indonesian Archipelago will experience increased and extreme rainfall. The MoEF predicts that the probability of rainfall of more than 350 mm/month, which lead to extreme rain, will increase (MoEF 2017). In general, rainfall will decrease in the dry season and increase in the rainy season. In addition, glaciers in permafrost are increasingly melting, leading to global sea level rise, including in Indonesia. Figure 3 indicates that the Indonesian sea level has been rising around 62.3 mm by 11 Mei 2022 (Sadya 2022). Sea level rise will increase acidity, intrusion, coastal abrasion, and tidal floods that could interfere with the mangrove ecosystem's flora and fauna and threaten coastal villages.

The government has realized that coastal ecosystems have deteriorated and has set a target to improve the environmental performance in its

Figure 3. Indonesia's sea level changes from 1994 to 2022 (Sadya 2022).

strategic plan for 2020-2024. The policies on NDC and FOLU Net Sink 2030 will also contribute to reducing the environmental hazard in the coastal areas. The government has allocated 12.7 million ha of land and given access to 6,620 farmer groups to request social forestry licenses. This land distribution has created 7.31 small-medium business groups in the forestry sector. In addition, 66 indigenous groups in Sumatra, Sulawesi, Kalimantan, Java, and Bali gained government recognition to manage 44,629.34 ha of land.

The government has established an additional 1.02 million ha High Conservation Value Forest outside the state forest areas and 24.67 million ha peat/wetland ecosystems. The wetland ecosystems are distributed in Sumatra (9.60 million ha), Kalimantan (8.40 million ha), Sulawesi (63.29 thousand ha), and Papua (6.59 million ha). These wetland ecosystems will contribute to harboring rainwater and controlling floods effectively. However, the land conversion rate is still higher than its recovery rate. The restoration efforts the central government has done are insufficient. Therefore, it needs a penta-helix-approach that involves local governments, communities, the private sector, academicians, and mass media.

The Roles of Forest Ecosystems in Controlling the Impacts of Climate Change

Why do forests play essential roles in controlling the impacts of climate change? Forests become crucial in the landscapes because they have dense and robust root systems that prevent soil erosion and landslides (Asdak 2023). Forests have stratified canopies that can reduce the velocity of rainwater, reduce its kinetic energy when it collides with the soil surface, and decrease surface run-offs and erosions. However, evapotranspiration also occurs in the forest stands, leading to a decrease in soil moisture content. Therefore, the focus of research on forest hydrology has been looking for evidence on the magnitude of infiltration and evapo-transpiration of forest stands.

Forests could reduce sedimentation, improve water quality by more than 90%, and become the buffer zone for prone areas (Ice 1999). Riparian forests could prevent 80% of sediment debris into river water (Avril & Barten 2007). The structure

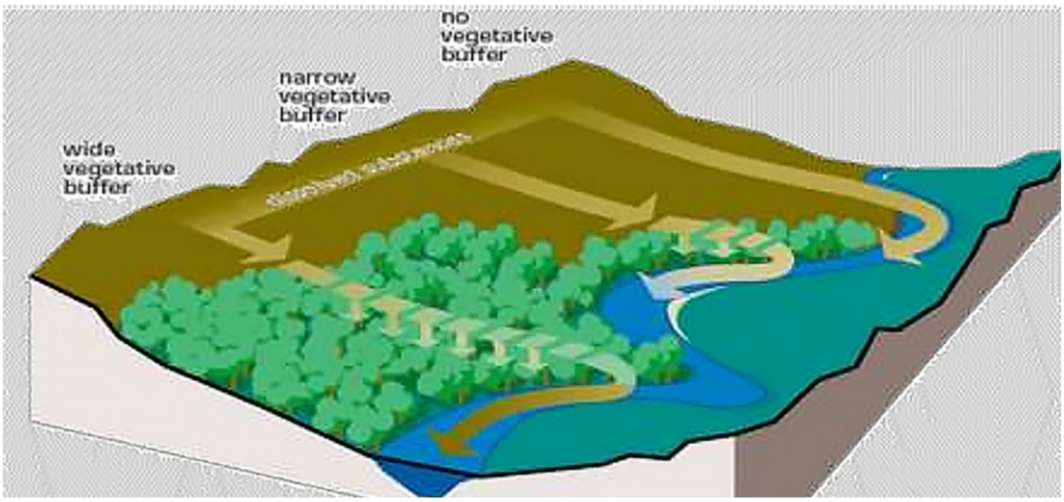

Figure 4. The structure and function of the forest buffer (riparian) ecosystem play essential roles in reducing runoff, increasing infiltration, preventing seawater intrusion, and preventing sedimentation

Figure 4. The structure and function of the forest buffer (riparian) ecosystem play essential roles in reducing runoff, increasing infiltration, preventing seawater intrusion, and preventing sedimentation

and function of riparian forest ecosystems are crucial in reducing surface run-off and seawater intrusion, preventing sedimentation, and increasing infiltration (Figure 4). As natural infrastructures, forest stands could contribute to controlling the impacts of climate changes, including hydrometeorological disasters.

Cloud forests will become the future of watershed forest landscape management (Figure 5). However, more knowledge about cloud forests and their potential contribution to landscape management and increasing rainfall must be available. Cloud forests in the tropics are commonly uphill, with altitudes more than 1000 m above sea level (Tanaka et al. 2011). However, they are also found in altitudes lower than 500 m above sea level (Mulligan 2010). Cloud forests differ from other forest stands because they have different species compositions and hydrological and biogeochemical behavior (Bruijnzeel et al. 2010). Their canopy often or within a long period has been in contact with the clouds (Bruijnzeel & Scatena 2011).

The crucial role of cloud forests is to produce occult precipitation or horizontal rain when the stand canopy is in contact with clouds at the temperature that allows the condensation process. The horizontal rain could increase surface run-off on the forest floor. Because of the structure of the forest stands and the undergrowth covering the forest floor, the run-off would not adversely impact the soil. Horizontal rains could occur due to low transpiration rates, low radiation, and high humidity. In Honduras, the cloud forests of La Tigra National Park contributed around 40% of the water supply for the city (Lawton et al. 2001). In addition, the cloud forests in the watershed's upper lands could prevent soil erosion, floods, and landslides and improve water quality (Jarvis & Mulligan 2011). Cutting the cloud forests will reduce the potential capacity of horizontal rain to supply water for the lower lands of the watersheds and increase the risks of hydrometeorological disasters.

Those considerations could become part of the payments for environmental services schemes, such as payments for water utilization in the lower lands of the watersheds and compensation for landowners or cloud forest owners in the upper lands of the watersheds. To ensure the hydrological function sustainability of the cloud forests, the government needs to identify and map the cloud forests and ensure no conversion of those cloud forests into other land uses.

Conclusion

The description above emphasizes five integrated approaches for sustainable forest management and climate change mitigation. First, implement sustainable forest management and environmental and carbon governance approaches through landscape-based forest restoration. Second, create attractive economic incentives for farmers who practice agroforestry, involve in the payments for environmental services schemes, micro-hydro power, and small to medium-scale timber-based industries, especially using fast-growing species. Third, establish multi-collaboration networking at local, national, and international levels. Fourth, build human resources capacity, including curricula that fit the forest landscape restoration approach. Fifth, implement micro watershed management at the village level that could use village funds or village enterprises (BUMDes) to ensure the landscape function sustainability.

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