Ecological Justice in Land Use Management: The Case Study of the Upstream Limboto Watershed in Indonesia

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ABSTRACT

The upstream Limboto Watershed (DAS Limboto) in Gorontalo Province is a critical ecological zone that regulates the hydrological flows and supports the biodiversity and community development. Unsustainable land use practices, including agricultural expansion, deforestation, and inadequate conservation measures, have accelerated environmental degradation. These practices lead to high erosion rates, reduced vegetation cover, decreased infiltration, and declining water quality. This study employs a mixed-methods approach to examine the biogeophysical and governance factors driving the land use change. The proposed approach integrates remote sensing and Geographic Information Systems (GIS) for spatial analysis with socio-economic surveys and institutional assessments. The findings of the study reveal that current land management practices, compounded by weak policy enforcement and limited community participation, exacerbate ecological vulnerability and threaten downstream hydrological stability. The study underscores the need for justice-oriented watershed management that integrates ecological justice principles, community-based conservation, and coordinated governance.

Keywords-upstream watershed management; ecological justice; land use governance; limboto watershed; biogeophysical vulnerability; community-based conservation; environmental sustainability

I. INTRODUCTION

Watersheds represent integral ecological systems where various natural and anthropogenic components interact, including climate, vegetation, landforms, water, and human activities. As dynamic hydrological units, watersheds regulate the flow of water from upland catchments to downstream outlets such as rivers, lakes, or seas. They serve as essential ecological infrastructure supporting biodiversity, water filtration, soil stabilization, and climate regulation [1, 2]. Holistic watershed management is therefore critical to maintain environmental sustainability and human well-being, particularly in regions experiencing increasing land pressure and population growth.

The upstream or headwater areas of a watershed are particularly vital, functioning as primary zones for water retention, infiltration, and forest-based carbon sequestration. The proper management of upstream lands can prevent soil erosion, flooding, and sedimentation that threaten downstream regions [3, 4]. The mismanagement of these areas—through deforestation, unsustainable agriculture, or poorly planned settlements—can create hydrological imbalances with cascading ecological and socio-economic impacts.

In the case of the Limboto Watershed in Gorontalo Province, Indonesia, studies and field assessments indicate significant environmental degradation [5]. The upper Limboto watershed experiences severe land cover loss, increased erosion, sediment accumulation in downstream areas, and reduced water availability during dry periods [6]. Data from BWS Sulawesi II and satellite imagery interpretation reveal that most upstream zones fall under high-risk ecological categories due to excessive land use conversion and limited conservation efforts [7, 8].

These conditions raise concerns regarding the sustainability of land and water governance in Indonesia's tropical ecosystems. The current policy implementation is often inadequate, the institutional coordination remains weak, and the ecological justice principles are insufficiently integrated. Traditional top-down approaches frequently overlook the local knowledge, community participation, and socio-cultural dimensions of land use, further exacerbating ecological degradation.

Previous studies on watershed management in Indonesia have largely focused on physical hydrology or downstream flood impacts [9, 10], often neglecting upstream socio-ecological interactions. The present research fills this gap by integrating spatial, ecological, and institutional analysis to provide a comprehensive understanding of upstream watershed degradation. In doing so, it aligns with global discourses on ecological justice, emphasizing the fairness in the distribution of environmental benefits and burdens [11, 12].

The primary objective is to evaluate the conditions of the upstream DAS Limboto, map land degradation patterns, and identify environmental and institutional drivers of change, with a focus on ecological justice and inclusive governance. Ultimately, it seeks to foster a paradigm shift in watershed management by embedding ecological justice in upstream land governance frameworks in Indonesia.

II. LITERATURE REVIEW

Watersheds are considered critical in water supply, erosion control, and habitat conservation operating as precipitation collectors [13]. Deforestation, agricultural expansion, and unplanned urban growth, attributed in human activities, disrupt hydrological cycles [14-16]. These activities reduce infiltration, increasing runoff, and accelerating soil erosion, compromising ecosystem services. Subsequently, effective watershed and land use management must be performed to sustain both environmental and human welfare [17].

Ecological justice indicates how the environmental benefits, risks, and responsibilities are distributed between human activity and nature. It additionally recognizes the intrinsic rights of ecosystems themselves and the ethical imperative to their protection [18]. Based on Schlosberg's framework, ecological justice encompasses three dimensions, including recognition, distribution, and participation. Political ecology highlights the way power relations, institutional governance, and socio-economic pressures lead to land use decisions, particularly in vulnerable upstream areas [19, 20]. In watersheds, this perspective implies equitable land management that balances immediate human needs with long-term environmental sustainability and intergenerational equity.

In Indonesia, upstream watersheds, such as Limboto in Gorontalo Province, are under intense pressure from land cover change, declining vegetation, and sediment inflow into Lake Limboto [21, 22]. Previous studies have focused on hydrological models or soil erosion, with limited attention to socio-cultural and institutional factors. This research aims to address this gap by integrating biogeophysical data, spatial analysis, field surveys, and governance mapping.

III. METHODOLOGY

The Limboto Watershed is located in Gorontalo Province, Indonesia, spanning across three administrative regions: Gorontalo Regency, Gorontalo Utara Regency, and the city of Gorontalo, spanning over a total area of approximately 89,385.60 ha. The watershed lies between 0°39'54.431" N to 0°45'55.348" N latitude and 122°52'42.408" E to 123°3'16.429" E longitude. Administratively, more than 96% of the watershed is situated within Gorontalo Regency, rendering it the most influential region in terms of land use and watershed management. The watershed ultimately drains into Lake Limboto, one of the most ecologically significant but increasingly threatened water bodies in Sulawesi.

This study employed a mixed-methods approach to analyze the biogeophysical and socio-institutional characteristics of the upstream Limboto Watershed. The primary data sources include high-resolution satellite imagery, such as Landsat 8 and ALOS PALSAR, for land cover classification. In addition, thematic maps are utilized—topographic, geological, and soil type maps—obtained from the Geospatial Information Agency (BIG) and the Ministry of Environment and Forestry. Secondary data, including rainfall records, population demographics, land use trends, and socio-economic indicators from 2018 to 2023, were collected from the Central Bureau of

Statistics (BPS), local government agencies, and the Balai Wilayah Sungai Sulawesi II.

GIS and remote sensing techniques are applied, in terms of spatial analysis, to interpret the land cover dynamics, watershed morphology, slope gradients, and hydrological flow patterns. Furthermore, the hydrological modeling involved estimating the surface runoff coefficients and calculating the peak discharge values using the Rational Method and Manning's equation, specifically adapted for small-scale sub-watersheds. Analysis utilizing Digital Elevation Models (DEM) generated elevation and slope maps. Morphometric parameters, such as drainage density, stream order, and basin shape, are extracted to assess the watershed health. Integrating these layers enables the spatial delineation of critical areas prone to erosion and degradation.

Qualitative methods are employed to capture the institutional and socio-cultural dimensions of watershed management. These included semi-structured interviews, while participatory discussions were conducted with 45 stakeholders, namely village leaders, farmers, customary authorities, and environmental officers. During the interviews, ecological justice concepts were utilized by examining perceptions of fairness in resource access, the distribution of environmental risks and benefits, and the inclusion of nature's rights in local decision-making. Moreover, institutional analysis focuses on governance gaps, policy implementation barriers, and the interaction between formal and informal organizations in land management. Its limitations include the five-year temporal scope, potential inconsistencies in official records, and challenges in capturing long-term ecological changes and informal land transactions in remote upland areas.

IV. RESULTS AND DISCUSSION

The Limboto watershed is characterized by steep slopes, a tropical monsoonal climate, and diverse geological formations. Volcanic and sedimentary rocks, including diorite, limestone, and volcanic breccias, are the most common types in the upstream region. Annual precipitation ranges from 1,160 mm to 1,700 mm, and soils are sandy loam to clay loam. The land cover includes agricultural fields, degraded forest patches, shrublands, and vegetation, which are significantly low due to the extensive farming and lack of conservation activities.

People in the watershed practice primarily subsistence and small-scale commercial agriculture, producing crops such as corn, rice, and peanuts. The rural communities depend on the natural resources for their livelihoods, with limited access to information on sustainable land management or infrastructure. The education level in the upstream villages is relatively low, which influences decision-making on land use. However, poor institution coordination, inadequate enforcement of land use policy, and low levels of community participation in conservation increase land degradation and socio-environmental vulnerability. The land use transformation and environmental degradation over the past 10–20 years can be observed through ecological and spatial analysis. Temporal and spatial visualizations demonstrate how disproportionately upstream areas suffer from ecological stressors like erosion, deforestation, and sediment entry.

The upstream region of the Limboto watershed possesses specific biogeophysical characteristics that directly impact its hydrological performance and ecological function. These factors make the area prone to erosion, runoff, sedimentation, and land degradation. The land use policies are inconsistent with prevailing national and local regulations, such as Indonesia's Environmental Protection and Management Law and regional spatial planning policy. An examination of the access rights and tenure over land indicates that indigenous people, small farmers, and customary landowners have limited decision-making and tenure. These are structural imbalances and result in unsustainable land conversion and enhanced ecological vulnerability.

Based on data obtained from six stations within the watershed, the annual values range between 1,160.8 mm and 1,700.3 mm per year, which is categorized at the lower percentile of annual rainfall. These low levels limit the availability of the surface water and reduce the groundwater recharge, especially in steep areas with low infiltration capacity. Furthermore, the daily rainfall intensity remains below 13 mm/day, which may lead to localized surface runoff and erosion due to poor vegetative cover and fragile soils. Table I presents the annual rainfall and intensity in the upstream Limboto watershed.

TABLE I. ANNUAL RAINFALL AND INTENSITY IN THE UPSTREAM LIMBOTO WATERSHED

Station name	Annual rainfall (mm)	Rainfall category	Daily intensity (mm/day)	Intensity category
Isimu Raya	1,240.1	Very low	8.16	Very low
Biyonga	1,162.8	Very low	9.75	Very low
Dulamayo	1,160.8	Very low	10.83	Very low
Iloponu	1,435.1	Very low	8.76	Very low
Tabongo Timur	1,516.9	Low	11.83	Very low
Liyodu	1,700.3	Low	12.68	Very low

More than 70% of the land area of the watershed exhibits a gradient above 8%, classifying it as a critical conservation zone according to Indonesian watershed classification standards. These conditions increase the area's vulnerability to surface runoff and soil erosion, especially during the rainy season. The morphological configuration promotes rapid water discharge, reducing the infiltration opportunities and increasing the sediment transport downstream, as shown in Table II.

TABLE II. SLOPE CLASSIFICATION IN THE UPSTREAM LIMBOTO WATERSHED

Slope class	Gradient range	Description	Area coverage
I	0%– 8%	Flat to gentle	29.7%
II	8% – 15%	Moderately sloped	21.4%
III	15% – 25%	Sloped	18.8%
IV	25% – 45%	Steep	17.3%
V	≥ 45%	Very steep	12.8%

From a geological perspective, the upstream region primarily comprises diorite bone, volcanic breccias, limestone, and alluvium. These rock types influence the water retention and permeability, with impermeable volcanic formations contributing to higher surface runoff and more permeable

sedimentary rocks allowing greater infiltration. However, the presence of diorite and volcanic rocks in the area exacerbates the runoff and erosion potential, particularly on steep terrains. Additionally, the soils in the upstream area are composed of sandy loam, clay loam, and volcanic-derived soils, each with differing infiltration and erosion characteristics. Sandy soil provides higher infiltration capacity, although it is vulnerable to wind and water erosion. On the other hand, clay-rich soils can retain moisture and are more prone to compaction and surface runoff during high precipitation events.

The hydrological dynamics include surface runoff, infiltration, and erosion, while the sedimentation processes ultimately affect both the upstream ecological stability and downstream water bodies. In the upstream zone, where vegetation has been significantly reduced and steep slopes are present, the water infiltration capacity is low, while the surface runoff and erosion are intensified. Deploying the rational method, runoff coefficients (*C*) for various land use types ranged from 0.50 to 0.85, indicating that 50–85% of rainfall becomes direct runoff, minimizing infiltration and reducing groundwater recharge. This, in turn, increases peak discharge during rainy periods, as presented in Table III. Climate change further enhances these dynamics, as more intense storms and longer dry spells increase the frequency and severity of floods, erosion, and sedimentation.

TABLE III. RUNOFF COEFFICIENTS BY LAND USE TYPE

Land use type	*C*
Forest	0.30 – 0.45
Mixed agroforestry	0.50 – 0.60
Agricultural land	0.65 – 0.75
Bare/degraded land	0.75 – 0.85
Settlements/roads	– 0.95

Erosion is considered one of the most severe hydrological issues in the upstream Limboto watershed. The combination of high rainfall intensity, steep topography, and lack of proper soil conservation practices leads to high surface erosion. The estimated erosion rate, calculated using the Universal Soil Loss Equation (USLE), varies between 15 to 460 tons/ha/year, with the highest erosion levels occurring on unprotected agricultural slopes and bare lands. These values indicate an annual topsoil loss and degrading land productivity while contributing to sedimentation downstream, as displayed in Table IV.

TABLE IV. EROSION HAZARD CLASSIFICATION

Erosion class	Soil loss (tons/ha/year)	Area condition
Very low	< 15	Forested, stable slopes
Low	15 – 60	Mixed land use
Moderate	60 – 180	Agricultural on mild slopes
High	180 – 460	Steep cultivated areas
Very high	> 460	Bare land, critical zones

The Sediment Yield (SY) in the upstream Limboto region is closely linked to erosion severity and the region's low sediment retention capacity. Sediments generated through surface erosion are carried by runoff into downstream areas, contributing to lake shallowing, water quality degradation, and loss of aquatic habitats. The Sediment Delivery Ratio (SDR) is calculated between 0.20 and 0.30. For instance, a Gross Erosion (GE) of 200 tons/ha/year with an SDR of 0.25 results in 50 tons/ha/year sediment entering the hydrological network.

The land use changes are also affected by a complex set of socio-economic factors, including population pressure, agricultural dependency, poverty, limited education, and weak institutional control. To better understand these dynamics, this study incorporates a stakeholder-focused approach, examining the roles and perspectives of local communities, indigenous groups, farmers, government agencies, and private actors. Population growth is one of the most dominant drivers directly increasing the demand for land. Villages, such as Dulamayo Selatan, Iloponu, and Buhu in the upstream region, have experienced a steady population growth, forcing communities to convert forest and shrubland into farmland to meet subsistence needs. According to BPS Gorontalo data in 2023, over 70% of the local workforce is engaged in agriculture, with corn and paddy cultivation being the primary activities, as illustrated in Table V.

TABLE V. 2023 DEMOGRAPHICS IN UPSTREAM VILLAGES OF DAS LIMBOTO

Village	Population	Population percentage in agriculture	Dominant crops
Dulamayo Selatan	2,342	78%	Corn and cassava
Iloponu	1,980	74%	Corn and paddy
Buhu	2,215	71%	Corn and peanuts
Tabongo Timur	2,412	68%	Paddy and banana

Furthermore, the high levels of rural poverty and limited alternative livelihood sources lead residents to natural resources for survival. Consequently, environmental degradation triggers social exposure to poverty, health risks, as well as potential displacement. Surveys and interviews reveal that few land managers have extensive knowledge of modern conservation principles. Therefore, Traditional Ecological Knowledge (TEK) guides practices such as contour planting, selective cutting, and water control on the watershed. However, the widespread farming practices on slopes of more than 25% demonstrate economic pressures and insufficient support for TEK. Institutional research reveals that poor governance structures and weak enforcement of land use regulations support the unsustainable land conversion. In addition, misalignments between district, provincial, and national governance further complicate decision-making and exacerbate ecological injustice. Formal planning procedures marginalize customary land tenure (hak ulayat), resulting in land conflict and limited accountability. Adopting a multi-level governance perspective can identify opportunities for more coherent, inclusive, and justice-oriented management approaches that align ecological sustainability with social equity.

The upstream Limboto watershed has been classified into five degradation levels based on the integration of slope gradient, land cover, erosion rate, vegetation index, and land use intensity. A critical area map is generated to identify the zones that require urgent conservation or rehabilitation through spatial overlay techniques in GIS along with support from

erosion hazard assessments from the Ministry of Forestry classification (1986). The analysis reveals that approximately 62.8% of the upstream watershed area falls into the moderate to very critical categories, primarily located in sub-watersheds with steep slopes and intensive agricultural land use, such as Dulamayo, Iloponu, and Tabongo. Table VI shows the classification of land degradation in the upstream Limboto watershed, with the total area reaching 42,951 ha.

TABLE VI. CLASSIFICATION OF LAND DEGRADATION IN THE UPSTREAM LIMBOTO WATERSHED

Degradation level	Area (ha)	Percentage (%)	Dominant characteristics
Not critical	3,168.80	7.34%	Forested, flat slopes, and high infiltration
Potentially critical	10,540.34	24.42%	Mixed land use, moderate slopes, and partial degradation
Moderately critical	13,474.55	31.25%	Agricultural areas, steep slopes, and erosion observed
Critical	11,377.31	26.37%	Bare/degraded land, minimal vegetation, and high runoff
Very critical	4,390.00	10.20%	Severe erosion, landslide-prone, and sediment source zones

The critical and very critical zones are concentrated in areas where the slope exceeds 25%, combined with low vegetation cover and intense land use without conservation structures. These zones are prone to accelerated erosion, landslides, and sediment delivery to downstream catchments, significantly contributing to sedimentation in Lake Limboto. The field validation in villages, such as Buhu and Dulamayo Selatan, confirmed visible signs of land degradation, including exposed soil surfaces, rill erosion, and seasonal gully formation. The dominant land uses in these zones are non-terraced agriculture and unregulated clearing for seasonal crops.

The results of this study are consistent with prior findings in other tropical catchments both in Indonesia and Southeast Asia [23, 24]. Moreover, agricultural expansion on steep slopes in the upstream Limboto watershed has led to high rates of surface runoff, soil erosion, and sediment transport. Comparable studies in Java, Sulawesi, and Southeast Asia indicate that unregulated headwater land conversion reduces infiltration, disrupts hydrological cycles, and generates long-term ecological imbalances [25, 26]. Field observations and stakeholder interviews revealed fragmented control with conflicting mandates between forestry and agriculture agencies, along with weak regulation of the conservation regulations. This institutional deficiency is observed in other Indonesian watersheds, where decentralized government has struggled to turn policy frameworks into collective action [25]. However, community forest schemes and participatory land-use planning systems, successfully implemented in West Java and Central Kalimantan, can also be applied to improve upstream management in Limboto.

The current land use practices in the upstream Limboto watershed also reveal misalignments with Sustainable Development Goals (SDGs), including clean water and sanitation (SDG 6), climate action (SDG 13), life on land (SDG 15), reduced inequalities (SDG 10), and peace, justice, and strong institutions (SDG 16). Similar challenges have been observed across Southeast Asia, where top-down approaches often fail to incorporate the local ecological and socio-institutional contexts [26].

However, effective intervention will require not only technical solutions but also strengthened governance, community participation, and sustainable financing mechanisms. To achieve intergenerational equity, governance must integrate ecological justice, recognize customary land rights, and balance socio-economic resilience with environmental stewardship. By drawing on international and regional best practices while adapting them to Gorontalo, integrated and justice-oriented watershed management can support long-term sustainability, equitable resource distribution, and the protection of the ecological rights of future generations.

The spatial delineation of the degraded areas provides a key input for targeted rehabilitation planning. By delineating such areas, policymakers can prioritize interventions including reforestation, agroforestry, terracing of slopes, and controlled land conversion. However, improved governance, community participation, and sustainable funding mechanisms must also be present.

V. CONCLUSIONS

The Limboto upstream watershed is degraded environmentally by biogeophysical vulnerability, unsustainable land use with steep slopes, degraded soils, and uncontrolled farming encroachment, encouraging runoff, erosion, and sedimentation. Over 60% of the upstream catchment is moderately to severely degraded, threatening ecological equilibrium and downstream hydrological functions.

The present study proposes strengthening land use planning, recognizing community land rights, integrating local knowledge, promoting participatory governance, and providing incentives for sustainable means such as terracing and agroforestry. The findings regarding the Limboto watershed reveal how the land use pressure at the local level, institutional deficit, and social relations sharpen ecological justice frameworks by highlighting the interplay between biophysical vulnerability, social justice, and multi-level governance.

Future research could examine these insights through longitudinal studies, comparative watershed analyses, and integrated socio-ecological modeling, contributing to both practical interventions and theoretical advancement in justice-oriented watershed management.

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REFERENCES

[1] Z. Cao, S. Wang, P. Luo, D. Xie, and W. Zhu, "Watershed Ecohydrological Processes in a Changing Environment: Opportunities and Challenges," *Water*, vol. 14, no. 9, May 2022, Art. no. 1502, https://doi.org/10.3390/w14091502.

[2] P. J. Edwards, K. W. J. Williard, and J. E. Schoonover, "Fundamentals of Watershed Hydrology," *Journal of Contemporary Water Research & Education*, vol. 154, no. 1, pp. 3–20, July 2015, https://doi.org/10.1111/j.1936-704X.2015.03185.x.

[3] I. W. S. Dharmawan *et al.*, "Implementation of Soil and Water Conservation in Indonesia and Its Impacts on Biodiversity, Hydrology, Soil Erosion and Microclimate," *Applied Sciences*, vol. 13, no. 13, June 2023, Art. no. 7648, https://doi.org/10.3390/app13137648.

[4] B. H. Narendra *et al.*, "A Review on Sustainability of Watershed Management in Indonesia," *Sustainability*, vol. 13, no. 19, Oct. 2021, Art. no. 11125, https://doi.org/10.3390/su131911125.

[5] M. Ramdhan Olii and I. Ichsan, "Assessment of critical land using geographic information systems - a case study of Limboto watershed, Gorontalo," in *IOP Conference Series: Earth and Environmental Science*, Malang, Indonesia, Oct. 2019, vol. 437, Art. no. 012053, https://doi.org/10.1088/1755-1315/437/1/012053.

[6] O. Sumule, R. F. Sitompul, S. Sriharti, and H. W. Retno, "Strategies on Degraded Lake Management for Sustainable Environmental Ecosystem in Lake Limboto, Gorontalo," in *IOP Conference Series: Earth and Environmental Science*, Aug. 2022, vol. 1175, Art. no. 012017, https://doi.org/10.1088/1755-1315/1175/1/012017.

[7] S. S. Eraku and A. P. Permana, "Erosion Hazard Analysis in the Limboto Lake Catchement Area, Gorontalo Province, Indonesia," *News of the National Academy of Sciences of the Republic of Kazakhstan*, vol. 3, no. 441, pp. 110–116, 2020, https://doi.org/10.32014/2020.2518-170X.61.

[8] G. G. Hidayat and H. Kakizawa, "Development Process of Watershed Partnership: A Case Study of Limboto Watershed – Gorontalo, Indonesia," *Indonesian Journal of Forestry Research*, vol. 1, no. 1, pp. 9–20, Apr. 2014, https://doi.org/10.59465/ijfr.2014.1.1.9-20.

[9] H. M. Rizal, M. Hariadi, Y. M. Arif, and E. Warni, "Enhancing Flood Prediction in Urban Areas: A Machine Learning Approach for Makassar City," *Engineering, Technology & Applied Science Research*, vol. 15, no. 2, pp. 21678–21684, Apr. 2025, https://doi.org/10.48084/etasr.9402.

[10] A. B. Supangat *et al.*, "Sustainable Management for Healthy and Productive Watersheds in Indonesia," *Land*, vol. 12, no. 11, Oct. 2023, Art. no. 1963, https://doi.org/10.3390/land12111963.

[11] D. Gottschlich and L. Bellina, "Environmental justice and care: critical emancipatory contributions to sustainability discourse," *Agriculture and Human Values*, vol. 34, no. 4, pp. 941–953, Dec. 2017, https://doi.org/10.1007/s10460-016-9761-9.

[12] C. Okereke and M. Charlesworth, *Advances in International Environmental Politics*. London, UK: Palgrave Macmillan London, 2014.

[13] S. S. Kumar, O. A. Wani, S. Kumar, and K. Devi, *Ecological Solutions to Agricultural Land Degradation*. Singapore, Singapore: Springer Nature, 2025.

[14] T. H. Oliver and M. D. Morecroft, "Interactions between climate change and land use change on biodiversity: attribution problems, risks, and opportunities," *WIREs Climate Change*, vol. 5, no. 3, pp. 317–335, Feb. 2014, https://doi.org/10.1002/wcc.271.

[15] T. Kortetmäki, *Justice in and to nature : an application of the broad framework of environmental and ecological justice*. Jyväskylä, Finland: University of Jyväskylä, 2017.

[16] B. S. Wiwoho, S. Phinn, and N. McIntyre, "Two Decades of Land-Use Dynamics in an Urbanizing Tropical Watershed: Understanding the Patterns and Drivers," *ISPRS International Journal of Geo-Information*, vol. 12, no. 3, Feb. 2023, Art. no. 92, https://doi.org/10.3390/ijgi12030092.

[17] T. P. Tomich, D. E. Thomas, and M. van Noordwijk, "Environmental services and land use change in Southeast Asia: from recognition to regulation or reward?," *Agriculture, Ecosystems & Environment*, vol. 104, no. 1, pp. 229–244, Sept. 2004, https://doi.org/10.1016/j.agee.2004.01.017.

[18] H. Mishra, *Sustainable Urban Environment and Waste Management*. Singapore, Singapore: Springer Nature, 2025.

[19] M. W. Parkes *et al.*, "Towards integrated governance for water, health and social–ecological systems: The watershed governance prism," *Global Environmental Change*, vol. 20, no. 4, pp. 693–704, July 2010, https://doi.org/10.1016/j.gloenvcha.2010.06.001.

[20] M. Falkenmark and C. Folke, "The ethics of socio-ecohydrological catchment management: towards hydrosolidarity," *Hydrology and Earth System Sciences*, vol. 6, no. 1, pp. 1–10, Feb. 2002, https://doi.org/10.5194/hess-6-1-2002.

[21] W. Leal Filho, U. M. Azeiteiro, and A. F. F. Setti, Eds., *Sustainability in Natural Resources Management and Land Planning*. Cham, Switzerland: Springer International Publishing, 2021.

[22] S. Y. Siswanto and F. Francés, "How land use/land cover changes can affect water, flooding and sedimentation in a tropical watershed: a case study using distributed modeling in the Upper Citarum watershed, Indonesia," *Environmental Earth Sciences*, vol. 78, no. 17, Aug. 2019, Art. no. 550, https://doi.org/10.1007/s12665-019-8561-0.

[23] A. C. Guzha, M. C. Rufino, S. Okoth, S. Jacobs, and R. L. B. Nóbrega, "Impacts of land use and land cover change on surface runoff, discharge and low flows: Evidence from East Africa," *Journal of Hydrology: Regional Studies*, vol. 15, pp. 49–67, Dec. 2017, https://doi.org/10.1016/j.ejrh.2017.11.005.

[24] C. G. K. Boongaling, D. V. Faustino-Eslava, and F. P. Lansigan, "Modeling land use change impacts on hydrology and the use of landscape metrics as tools for watershed management: The case of an ungauged catchment in the Philippines," *Land Use Policy*, vol. 72, pp. 116–128, Dec. 2017, https://doi.org/10.1016/j.landusepol.2017.12.042.

[25] I. S. Astuti, "Impact of land use land cover change on runoff and water quality of an increasingly urbanized tropical watershed in java, indonesia," PhD Dissertation, University of Georgia, 2017.

[26] N. Naharuddin, A. Wahid, G. Golar, I. Rachman, A. Akhbar, and S. D. Massiri, "Soil Infiltration in Various Areas as a Basis for Hydrlogical Alterations in the Toboli Watershed, Central Sulawesi, Indonesia," *Water Conservation & Management*, vol. 6, no. 2, pp. 76–80, 2022, https://doi.org/10.26480/wcm.02.2022.76.80.