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Degradation of Limboto Lake from an Environmental Ethics Perspective: A Critique of Anthropocentrism and the Relevance of Ecocentrism

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ABSTRACT

Environmental degradation is not only a technical problem; it also reflects how people value nature. Limboto Lake in Gorontalo, Indonesia, has undergone long-term shrinkage, shallowing, and sedimentation, yet the value orientations behind its use and management have rarely been examined. This study analyzes the degradation of Limboto Lake from an environmental ethics perspective by critiquing anthropocentrism and assessing the relevance of ecocentrism. A structured literature review with a descriptive-critical approach was applied to peer-reviewed studies of the lake and its watershed and to literature on environmental ethics, social-ecological systems, and governance, and analyzed through a three-stage thematic synthesis: descriptive social-ecological mapping, an anthropocentric reading, and an ecocentric reading. The results reveal a social-ecological chain linking agricultural expansion and deforestation, land and riverbank erosion, sedimentation, and conversion of the exposed lakebed, with impacts returning to communities through flooding, declining fisheries, and poor water quality. Anthropocentrism is not inherently destructive, but when human interests are defined narrowly and in the short term, it treats the former lakebed as a land reserve, sidelines non-monetary ecological values, and leaves future generations unrepresented. Ecocentrism offers a more adequate frame by treating the lake, rivers, and watershed as one system whose integrity underpins human well-being, with communities as part of that system. The novelty of this study lies in explicitly linking biophysical and social evidence on Limboto Lake to environmental ethics debates and translating them into operational management principles: ecological limits, integrated lake-watershed management, ecological indicators, community co-management, and intergenerational justice.

Keywords: *Anthropocentrism, Ecocentrism, Environmental Ethics, Limboto Lake, Social-Ecological System, Environmental Governance*

1. INTRODUCTION

Environmental degradation is commonly read through biophysical indicators such as declining water quality, habitat loss, or rising erosion rates. Such readings are essential, but they do not explain why damaging decisions continue to be made even when their consequences are known. Every decision about the use of land, water, and space involves value choices: whose interests are prioritized, which benefits are considered worth pursuing, and which limits are deemed worth respecting. Chan *et al.* [1] showed that conservation debates are often trapped in a dichotomy

between the instrumental and intrinsic values of nature, even though many human relationships with nature are relational. Kopnina *et al.* [2] added that worldviews placing humans at the center of value remain one of the roots of ecological problems, although their forms and effects vary. Environmental degradation is therefore also an ethical problem, that is, a problem of how humans perceive, value, and treat nature.

Lakes reveal this relationship clearly because their condition records the accumulated activities across their entire catchments. Studies of the world's large lakes show that lake degradation proceeds through human pressures accumulated over long periods, including nutrient enrichment, loss of catchment wetlands, shoreline modification, and excessive water abstraction [3], and freshwater ecosystems more broadly face persistent and emerging threats that make them among the most imperilled ecosystems on Earth [4]. Limboto Lake in Gorontalo Province faces a similar pattern of pressure in a distinctive form. The lake is recorded as one of Indonesia's critical lakes and is included among the fifteen national priority lakes [5], [6]. Its condition is marked by shrinking surface area, shallowing, sedimentation from the rivers that drain into it, the spread of water hyacinth, and declining water quality [6], [7]. These changes do not stop at the water body, as communities around the lake also experience declining fish catches, seasonal flooding, and shifting livelihoods [8].

Research on Limboto Lake has developed in several directions. Kimijima *et al.* [6] explained the mechanism of the lake's rapid shrinkage and showed that more than 70% of sedimentation during 2003–2017 originated from riverbank erosion. Alfianto and Cecilia [9] modeled potential erosion and sedimentation upstream of the lake and identified the rivers contributing the most sediment, whereas Bakari *et al.* [10] linked agricultural expansion, deforestation, and weak conservation practices in the upper Limboto Watershed to increasing ecological vulnerability. Umar *et al.* [11] mapped the conversion of the former lakebed into farmland, plantations, settlements, and tourism areas. Aquatic and fisheries aspects have been examined through water quality evaluation [7] and post-dredging fisheries management [12]. More recent studies have begun to address social and institutional dimensions, such as the cultural adaptation of lakeside communities [8], the relationship between socioeconomic status, knowledge, and community participation [13], and the direction of public policy in lake conservation [5].

This mapping reveals two bodies of literature that have developed separately. Research on Limboto Lake has explained in detail what has changed and through which processes, from riverbank erosion and conversion of the former lakebed to changes in fish habitat after dredging. Some studies have also touched on normative aspects, such as calls for watershed management oriented toward ecological justice [10], weak policy implementation [5], and residents' tendency to view the lake's problems as the government's responsibility [8]. However, these findings have not yet been analyzed as expressions of particular value orientations, namely how the lake and the former lakebed are valued, whose interests are counted, and what time horizon is used in decisions. Conversely, the literature on anthropocentrism and ecocentrism has largely been developed at conceptual and global levels and has not been applied to concrete tropical lake cases such as Limboto Lake. Consequently, no analysis yet explains the limitations of a narrow anthropocentric orientation in this case, assesses the relevance of ecocentrism for reading the lake as a social-ecological system, and translates both into operational management principles.

Addressing this gap, this study aims to analyze the degradation of Limboto Lake from an environmental ethics perspective through four interrelated steps: (i) synthesizing the forms and

drivers of Limboto Lake degradation as a social-ecological problem; (ii) critiquing the anthropocentric worldview operating in the use of the lake and the former lakebed; (iii) assessing the relevance of ecocentrism as a framework for understanding the integrity of the lake-watershed system; and (iv) formulating the implications of environmental ethics for the management of Limboto Lake. The expected contribution, and the novelty of this study, is to bridge the biophysical and social evidence on Limboto Lake with environmental ethics debates so that management recommendations rest on an explicit normative foundation.

2. LITERATURE REVIEW

2.1 *Environmental Ethics*

Environmental ethics examines the moral relationship between humans and the natural world, including who or what deserves moral consideration and on what grounds. A central debate concerns the kinds of value attributed to nature. Instrumental values regard nature as a means to human ends, intrinsic values hold that nature has worth independent of its usefulness, and relational values locate worth in the relationships, identities, and responsibilities that connect people with places and other beings [1]. Batavia and Nelson [14] showed that attempts to accommodate intrinsic value within the ecosystem services framework, which values nature for its benefits to humans, often rest on misunderstandings, leaving non-anthropocentric concerns unanswered. The valuation approach of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) likewise recognizes that the values of nature are plural and cannot be reduced to monetary or instrumental terms alone [15].

Environmental ethics also intersects with debates on justice. Theories of environmental justice have expanded from concerns about the distribution of environmental harms to include recognition, participation, and capabilities, and some strands extend justice to the functioning of nonhuman nature itself [16]. Ecological degradation thus raises questions about who bears its costs, who participates in decisions, and whether ecosystems themselves are owed consideration. These questions provide the normative lens through which the empirical evidence on Limboto Lake is read in this study.

2.2 *Anthropocentrism and Ecocentrism*

Anthropocentrism places humans at the center of moral consideration so that nature is valued primarily for its usefulness to people [2]. Norton [17] distinguished strong anthropocentrism, grounded in felt preferences, from weak anthropocentrism, grounded in considered preferences subjected to rational scrutiny, and argued that the latter can support environmental protection. Critics respond that human-centered motives protect the environment effectively only when their benefits to humans are clearly visible, and that anthropocentrism remains a deep driver of ecological crises rather than a misunderstood label [2].

Ecocentrism extends moral consideration to all life and to ecosystems, including their abiotic components, and views humans as part of nature [18]. Proponents argue that conservation science originated in ecocentric values and should re-embrace them [19], that ecocentrism is needed for effective biodiversity conservation [20], and that ecological justice for nonhuman nature should be foregrounded alongside social justice

rather than traded against it [21]. The concept of ecological integrity, measurable through the biological condition of water bodies, shows that ecocentric considerations are not merely philosophical but can be translated into management goals and indicators [22]. Ecocentric considerations have also been institutionalized through legal rights for rivers and other natural entities in several countries [23], although their effectiveness depends on the legal force that accompanies them [24]. For Limboto Lake, this debate determines whether the lake is understood as a source of benefits that can be exchanged for other land uses or as an ecological system whose continued functioning is a precondition for human well-being.

2.3 *Social-Ecological Systems and Environmental Governance*

The social-ecological systems (SES) framework connects these ethical debates to empirical analysis. Ostrom [25] showed that the sustainability of resources depends on interactions among resource systems, resource units, users, and governance systems. The framework has since been refined as a diagnostic tool [26] and widely applied, although its operationalization across cases remains challenging [27]. Folke *et al.* [28] emphasized that human and natural systems are intertwined and embedded in the biosphere, and that social-ecological resilience is the capacity to adapt or transform in the face of change. Shallow lakes illustrate why resilience matters: when resilience is eroded, ecosystems can shift abruptly to alternative states that are difficult to reverse [29]. At a global scale, the planetary boundaries concept similarly frames ecological limits as the safe operating space for human development [30].

Environmental governance refers to the regulatory processes, mechanisms, and organizations through which actors influence environmental actions and outcomes, including hybrid and collaborative arrangements between the state, markets, and communities [31]. Its quality can be assessed by its effectiveness, equity, responsiveness, and robustness [32]. The temporal dimension raises a further ethical issue, as intergenerational justice requires the present generation to treat the environment as a trust for future generations [33], and recent work argues that Earth system boundaries should be defined with intragenerational, intergenerational, and interspecies justice in view [34]. Together, this literature provides the conceptual tools to read Limboto Lake not merely as a shrinking water body but as a social-ecological system shaped by value choices.

3. METHODS

This study is a structured literature review with a descriptive-critical approach. The descriptive approach was used to map the conditions, processes, and drivers of Limboto Lake degradation based on published research, whereas the critical approach was used to examine the value assumptions embedded in patterns of lake use and management through the perspectives of anthropocentrism and ecocentrism. No primary data were collected through field measurements, surveys, or experiments; all empirical data discussed are drawn from the cited publications. The literature comprised two groups: empirical studies of Limboto Lake and its watershed, and conceptual works and reviews on environmental ethics, social-ecological systems, environmental governance, and sustainability. Searches were conducted through academic search engines, official journal publisher websites, and open-access journal directories using Indonesian and English keywords, including “Danau Limboto,” “Limboto Lake,” “DAS Limboto,” “sedimentasi,” “erosi,”

"perubahan penggunaan lahan," "lake degradation," "anthropocentrism," "ecocentrism," "intrinsic value," "ecological integrity," "social-ecological systems," "environmental governance," and "intergenerational equity."

Publications were selected using the following inclusion criteria: peer-reviewed journal articles that directly address the condition of Limboto Lake or the ethical and governance concepts used in the analysis, and whose bibliographic identity could be verified through a DOI or the publisher's official website. For conceptual literature, priority was given to publications from the last ten years, while older works were retained only when they constitute foundational references for a concept, such as the distinction between strong and weak anthropocentrism and the social-ecological systems framework. Exclusion criteria comprised non-peer-reviewed sources such as news, blogs, and unpublished documents; sources whose identity or content could not be verified; duplicate publications; and publications that mention Limboto Lake without relevant data or analysis. Selection involved title and abstract screening, reading of abstracts and accessible full texts, and matching each article's metadata against its DOI record. The selection yielded a core corpus of 21 publications, consisting of nine studies on Limboto Lake and its watershed and twelve conceptual and supporting publications. Information from each publication was extracted into a matrix covering focus, method, main findings, quantitative data with their periods and measurement methods, drivers, and management implications. Numerical data from different sources were not merged when their periods, methods, or delineation boundaries differed; instead, they were presented side by side with their sources. To situate the analysis within broader theoretical debates, further conceptual and synthesis works on environmental values, ecocentrism, social-ecological systems, regime shifts, governance, and justice were consulted; these supplementary sources inform the literature review and discussion but were not part of the extraction matrix.

The analysis was conducted through a three-stage thematic synthesis. The first stage was descriptive, arranging the forms of degradation and the causal chain linking human activities, changes in spatial use, watershed processes, sedimentation, lake conditions, and impacts returning to communities, using the social-ecological systems framework [25]. The second stage read these findings through the perspective of anthropocentrism using four analytical questions: whose interests are counted, which benefits serve as the measure, what time horizon is used, and which ecological values are neglected. This reading distinguishes narrow, short-term anthropocentrism from the broadened anthropocentrism formulated by Norton [17] and critiqued by Kopnina *et al.* [2]. The third stage read the same findings through the perspective of ecocentrism by assessing whether the integrity of ecological processes, the connectivity of the lake–river–watershed system, and the position of humans as members of the ecological community had been considered [18], [22]. The results of the three stages were then synthesized into management principles and implications with reference to a governance framework that is effective, equitable, responsive, and robust [32]. Each finding was compared with previous studies to identify similarities and differences, so that the argument does not rest on a single source.

4. RESULTS AND DISICUSSION

4.1 Conditions and Forms of Limboto Lake Degradation

The degradation of Limboto Lake is most evident in the long-term shrinkage of its surface area. Available sources agree on the direction of change but not entirely on its magnitude. A report by the Sulawesi II River Basin Agency (Balai Wilayah Sungai, BWS) cited by Kimijima et al. [6] recorded an area of about 6,000 ha and a depth of about 30 m in 1930, whereas Umar et al. [11] reported an area of about 7,000 ha around 1932 without specifying their data source. Differences also appear in satellite-derived data: for 1991, the Landsat classification by Kimijima et al. [6] yielded 23.02 km² (2,302 ha), whereas Landsat digitization by Umar et al. [11] yielded 3,644.5 ha. This discrepancy is likely related to different delineation boundaries, as spectral classification tends to capture open water, whereas visual digitization may include swamps and vegetated waters.

Therefore, data from both sources are presented side by side in Table 1 rather than combined into a single time series.

Table 1. Area and Depth Data of Limboto Lake by Source and Method

Year	Area	Depth	Data basis/method	Source
1930	±6,000 ha	±30 m	2009 BWS Sulawesi II report (secondary data)	Kimijima et al. [6]
±1932	±7,000 ha	–	Not specified	Umar et al. [11]
1978	31.50 km²	–	Landsat image classification	Kimijima et al. [6]
1991	23.02 km²	–	Landsat image classification	Kimijima et al. [6]
1991	3,644.5 ha	–	Landsat image digitization	Umar et al. [11]
1999	1,900–3,000 ha	2–3 m	2009 BWS Sulawesi II report (secondary data)	Kimijima et al. [6]
2003	23.39 km²	2.99 m (mean)	Regression of 1993–2012 field survey data	Kimijima et al. [6]
2015	19.65 km²	–	Landsat image classification	Kimijima et al. [6]
2017	19.60 km²	1.88 m (mean)	Regression of 1993–2012 field survey data	Kimijima et al. [6]
2017	2,693.9 ha	–	Landsat image digitization	Umar et al. [11]
2019	20.44 km²	–	Landsat image classification	Kimijima et al. [6]

Note: 1 km² = 100 ha. BWS = Balai Wilayah Sungai (River Basin Agency). Data obtained with different methods or delineation boundaries are not directly compared.
Source: Compiled from Kimijima et al. *[6] and Umar* et al. *[11].*

Table 1 shows that shrinkage is consistent across sources. Based on the same Landsat series, the lake area declined from 31.50 km² in 1978 to 20.44 km² in 2019, leaving 64.9% of the 1978 area [6]. The data series of Umar *et al.* [11] shows a loss of about 950 ha over the 26 years between 1991 and 2017. The decline in area was accompanied by shallowing, with the mean depth estimated to have fallen from 2.99 m in 2003 to 1.88 m in 2017 [6]. The slight increase in area in 2019 compared with 2015 in the same series indicates that surface area also fluctuates with hydrological conditions, so long-term trends are more informative than comparisons between adjacent years. Several studies project that the lake could become land within a few decades, for example by 2031 according to expert projections cited by Alfianto and Cecilia [9] or by 2035 according to Djafar and Akibu [5]. These projections differ in their assumptions and baseline periods but point in the same direction.

The shrinkage is driven primarily by sedimentation. Kimijima *et al.* [6] estimated the volume of sediment accumulated in the lake during 2003–2017 at about 4.23 million m³, while the volume of riverbank erosion over the same period reached about 3.28 million m³. Thus, more than 70% of the sedimentation causing the shrinkage originated from riverbank erosion, with the Alo and Rambongan Rivers as the largest contributors. This erosion is accelerated by the fine-grained deposits of an ancient bay that are easily scoured, together with tectonic uplift, land-use change, and deforestation. WaTEM/SEDEM modeling by Alfianto and Cecilia [9] reinforces the picture that sediment sources are dispersed across many upstream rivers, with the Batulayar, Biyonga, and Alo Rivers among the largest contributors. These findings shift the focus from surface land erosion alone to the river corridors that connect the watershed to the lake.

Degradation is also visible in the ecological functions of the waters. Water hyacinth cover increased from about 0.0027 km² in 1991 to 4.3 km² in 2015 before declining to 3.31 km² in 2019, and its growth has been linked to eutrophication and accelerated shallowing [6]. Lihawa and Mahmud [7] found that the lake and the rivers flowing into it were polluted, with nitrate, phosphate, and hydrogen sulfide concentrations exceeding quality standards. Dredging, which began in 2013, increased depth, but the dredged material used to build embankments also removed mud habitats and covered the spawning grounds of migratory fish [12]. This pattern is consistent with global findings that human-induced nutrient enrichment reduces water clarity and triggers anoxic conditions, while shallow lakes are strongly affected by sediment resuspension [3]. The difference is that the degradation of Limboto Lake is dominated by riverine sediment supply, so the recovery of water quality cannot be separated from sediment control.

The impacts of degradation return to the communities. Baga *et al.* [8] reported that many lake fish species have declined or disappeared, catches are low, and some fishers have moved to Gorontalo Bay or shifted to farming, transport services, and other occupations. Rainy-season floods can inundate settlements for months, especially houses built on the former lakebed. Kimijima *et al.* [6] also noted reduced lake storage capacity, increased vulnerability to disasters, and changing community livelihoods. These findings show that the degradation of Limboto Lake is not merely a morphometric change but a change in ecological function that directly affects the safety and livelihoods of communities. This becomes the starting point for tracing how human activities, spatial decisions, and ecological processes reinforce one another.

4.2 Human Activities and Social-Ecological Pressures

The literature synthesis shows that the degradation of Limboto Lake forms through an interconnected social-ecological chain, as summarized in Figure 1. In the upstream area, agricultural expansion, deforestation, and weak conservation practices reduce vegetation cover and soil infiltration capacity and increase erosion [10]. At the provincial level, the maize planting area increased 3.5-fold during 2001–2015, and Kimijima et al. [6] linked population growth to over-cultivation and deforestation that trigger erosion. Material eroded from land and riverbanks is carried into the lake, settles, and expands the land along the lakeshore. This new land is then used for rice fields, dry fields, coconut plantations, settlements, and tourism areas [11]. The use of the former lakebed narrows the space that functions as a water storage zone and habitat, so that its impacts return to communities as flooding, declining fisheries, and deteriorating water quality.

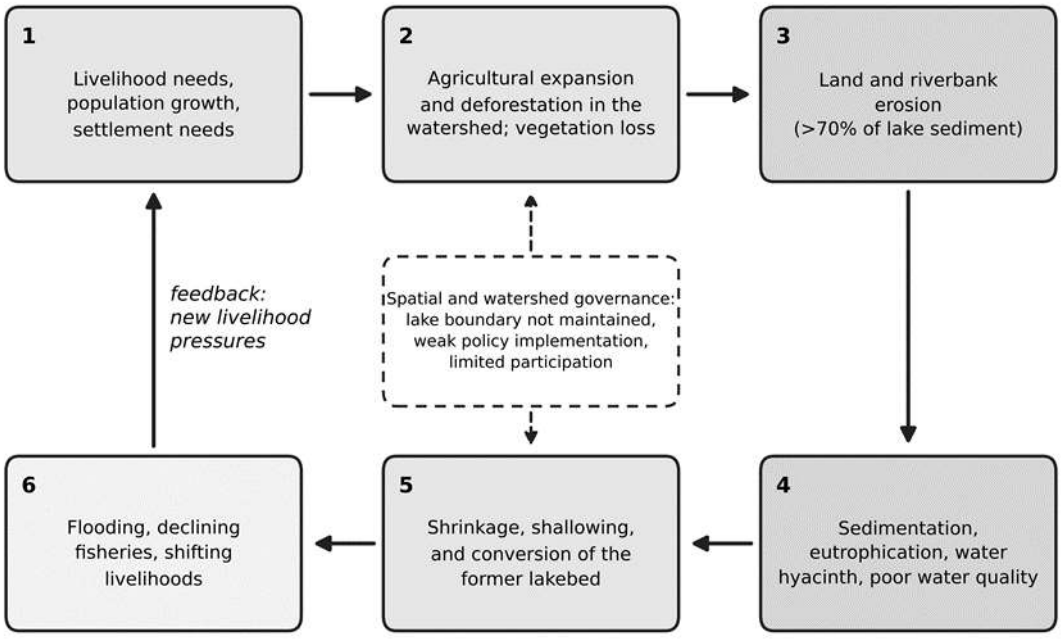


Figure 1. Social-Ecological Chain of Limboto Lake Degradation
Source: Synthesized from Bakari et al. [10], Baga et al. [8], Kimijima et al. [6], and Umar et al. [11].

This chain cannot be reduced to the fault of communities around the lake. Umar *et al.* [11] showed that the conversion of the former lakebed was driven by livelihood needs, the housing needs of fishing households wishing to live near their source of income, tourism development, and a fishers' housing program built on former lake land in 2015. The same study recorded that the physical boundary of the lake has not been maintained since the 1990s and that spatial-use control around the lake has not been effective. Djafar and Akibu [5] judged existing strategic policies to be

inadequate and weakly implemented, while Bakari *et al.* [10] found that weak policy enforcement and limited community participation increase ecological vulnerability. These findings indicate that household decisions take place within economic, policy, and institutional structures that allow, and in certain cases facilitate, the use of the former lakebed. In other words, pressure on the lake results from interactions among population needs, the expansion of agricultural commodities, and spatial governance.

The relationship between people and the lake is reciprocal. Communities that use the former lakebed for farming and settlement are precisely those most exposed to flooding and prolonged inundation [8]. Fishers who have lost their catches change occupations or adjust their activities seasonally, fishing in the rainy season and farming in the dry season, a form of resilience that, according to Baga *et al.* [8], is difficult to sustain when floods and droughts alternate. Melo *et al.* [13] found that socioeconomic status and knowledge of the lake ecosystem are positively correlated with participation in sustainable management, meaning that the community's capacity to engage is also shaped by its socioeconomic conditions. This finding is consistent with Ostrom's framework [25], in which the behavior of resource users is influenced simultaneously by user characteristics, the resource system, and governance rules. From an ethical standpoint, the key question is not who should be blamed but how human needs can be met without eroding the lake's capacity to maintain its ecological functions.

4.3 Anthropocentrism Critique in Limboto Lake Management

Anthropocentrism places humans at the center of moral consideration, so the value of the lake is measured mainly by its benefits to people [2]. In the case of Limboto Lake, these benefits include fish, water, flood control, recreational space, and, after the lake shrank, new land for farming and settlement. This worldview is not entirely mistaken, because the losses suffered by fishers, farmers, and flood-affected residents are strong moral reasons to restore the lake. Norton [17] even argued that carefully considered human interests can provide an adequate basis for environmental ethics. The critique of anthropocentrism in this case is therefore directed not at the recognition of human interests but at how those interests are defined. Problems arise when human interests are understood narrowly, limited to direct benefits, and measured over a short time horizon.

This narrow orientation is most evident in how the former lakebed is treated. From the standpoint of direct benefits, land emerging from sedimentation is productive land ready for rice fields, coconut plantations, or houses, so keeping it as part of the lake ecosystem appears irrational. Umar *et al.* [11] recorded that about 936.56 ha of former lake land was converted into farmland and plantations, 14.29 ha into settlements, and 0.35 ha into tourism areas during 1991–2017. The fishers' housing program built on former lake land shows that this logic of direct benefit operates not only at the household level but also at the policy level [11]. In this way, a symptom of degradation is treated as an opportunity for spatial use. The choice is rational in short-term calculations but ignores the functions of the former lakebed as water storage, habitat, and flood buffer.

A similar logic can be read in some technical interventions. Dredging and the construction of embankments from dredged material were aimed at restoring storage capacity, the function most directly related to human interests [12]. However, these interventions also altered mud habitats and covered the spawning grounds of migratory fish, disrupting other ecological functions. Baga *et al.* [8] also noted that barrier embankments created inundation and swamps in residential areas. These findings do not show that dredging is wrong; rather, they show that interventions designed for one function of use value can have consequences for other, less considered functions. Kopnina *et al.* [2] argued that human-centered motives protect the environment effectively only when their direct benefits are clearly visible to people. The Limboto case reveals the other side of that argument: ecological functions whose benefits are not directly visible tend to be excluded from planning.

The short-term orientation is also evident in the distribution of benefits and costs. The benefits of land use upstream and on the former lakebed are direct and enjoyed by users, whereas the costs of sedimentation, flooding, and declining fisheries are delayed, dispersed, and borne by

others, including future generations. Baga *et al.* [8] found that many residents recognize that the lake is shrinking but are not prepared for it and regard the problem as the government's responsibility. This attitude can be read as a separation of responsibility that readily arises when the lake is understood as a public facility rather than a system shaped by everyday actions. The critique is not intended to blame residents, as Baga *et al.* [8] also noted that residents rarely receive information about government plans.

Taken together, the analysis identifies four limitations of narrow anthropocentrism. The first concerns who is counted. In decisions about upstream land and the former lakebed, the interests represented are those of current users, while future generations have no voice even though they will inherit a shallower or vanished lake. Spijkers [33] explained that intergenerational equity positions each generation as both trustee and beneficiary of the environment, yet this principle has not been explicitly formulated in the Sustainable Development Goals. The Limboto case illustrates the local consequences of that absence: projections that the lake could become land within a few decades, though differing in magnitude, indicate that present decisions may permanently close options for future generations [5], [9].

The second limitation concerns values that are not easily monetized. The functions of the former lakebed as a flood storage zone, fish spawning habitat, and water quality buffer have no market price comparable to crop yields or building values. Following Batavia and Nelson [14] and Chan *et al.* [1], many such values are intrinsic or relational rather than exchangeable benefits. The cultural relationship of communities with Limboto Lake, which, according to Baga *et al.* [8], is regarded as home and as a space of sacred meaning, is an example of a relational value that economic benefit calculations do not capture. When management counts only what can be measured economically, these values are excluded from consideration.

The third limitation concerns ecological limits. Sedimentation sourced from fine-grained riverbank erosion and reinforced by tectonic uplift is a process that is difficult to reverse on policy time scales [6]. Each additional increment of sediment and each hectare of former lakebed that is built upon reduces the remaining space for recovery. Under such conditions, short-term benefit calculations may continue to justify additional use, even as their accumulation pushes the system beyond its functional limits. Folke *et al.* [28] emphasized that systems that lose resilience can shift rapidly to alternative states when facing shocks, and Scheffer *et al.* [29] showed that such shifts in shallow lakes may be difficult to reverse. Jenny *et al.* [3] documented a similar pattern in the world's large lakes, where pressures accumulated over long periods produce degradation that is difficult to remedy.

The fourth limitation lies in the conflict between economic benefits and ecosystem integrity, which shapes how success is measured. The expansion of agricultural commodities upstream increases production and income but also reduces vegetation cover and increases erosion [6], [10]. Within a narrow anthropocentric framework, this conflict tends to be resolved by prioritizing the most visible benefits, namely agricultural production and land availability. As a result, management success risks being measured by the physical outputs of interventions rather than by the recovery of ecological processes. Alfianto and Cecilia [9] noted that data on sediment control structures (sabo dams) need to be reviewed on a scheduled basis because upstream sediment loads are dynamic, indicating that monitoring of ecological processes is not yet a permanent part of management. Karr *et al.* [22] showed that biological integrity can be measured and has become a legal objective in water management, so the absence of ecological indicators is not due to a lack of methods. The limitations of narrow anthropocentrism in Limboto Lake thus lie in the scope of interests, the types of value, the time horizon, and the measures of success it employs.

4.4 Ecocentrism as an Alternative Environmental Ethics Framework

Ecocentrism places the whole ecosystem, including its abiotic components and the processes that connect them, as an object of moral consideration [18]. Applied to Limboto Lake, this perspective shifts the management question from “what are the lake's benefits to the community” to “what is

needed for the lake to continue performing its ecological processes." This shift changes the unit of analysis from the water body to the lake–river–watershed system. The finding of Kimijima *et al.* [6] that most sediment originates from riverbank erosion, and that the area of river channels roughly doubled during 2003–2017, shows that the condition of the lake is determined by the condition of the rivers that feed it. Lihawa and Mahmud [7] likewise found nutrient pollution in both the lake and its inflowing rivers. Restoring the lake without improving the system that supplies sediment and nutrients will therefore address only the symptoms.

The concept of ecological integrity gives this perspective an operational form. Karr *et al.* [22] view ecological integrity as a condition measurable through the biological state of a system, which has been widely applied to rivers and other waters. For Limboto Lake, ecosystem integrity means maintaining the connections among upstream soil and vegetation, riverbank stability, water quality, spawning habitats, native fish diversity, and the seasonal water-level fluctuations that sustain the floodplain. The stability and resilience of the ecosystem depend on these connections, as Folke *et al.* [28] stressed that social-ecological resilience is the capacity of a system to adapt or transform in the face of change. The decline in fish species, the spread of water hyacinth, and habitat changes after dredging are signs that these connections have been disrupted [6], [8], [12]. An ecocentric perspective makes these signs a primary management consideration rather than side effects.

Comparison with previous studies shows that this direction is already emerging but has not yet been articulated explicitly. Bakari *et al.* [10] proposed managing the Limboto Watershed with an orientation toward ecological justice, based on community conservation and inter-agency coordination. This proposal is close to an ecocentric perspective because it treats the upper watershed and the lake as one system, but the study focused on upstream land management and did not address the moral status of the lake or the former lakebed. Internationally, granting legal status to rivers in Australia, New Zealand, and India shows that ecocentric considerations can be realized institutionally, although O'Donnell and Talbot-Jones [24] stressed that such instruments are meaningful only when they carry adequate legal force. The lesson for Limboto Lake is not to copy these instruments directly but to place the integrity of the lake system as a non-negotiable limit in spatial planning. Table 2 summarizes the comparison of the two perspectives in the context of Limboto Lake management.

Table 2. Comparison of Anthropocentric and Ecocentric Perspectives in Limboto Lake Management

Aspect	Anthropocentrism (narrow orientation)	Ecocentrism
Moral focus	Human interests, especially those of current users	Integrity of the lake–river–watershed system, including the humans within it
View of the lake	Source of fish, water, recreational space, and a land reserve as the lake shrinks	Ecological system connected to rivers, soil, vegetation, and the watershed
Time orientation	Direct and short-term benefits	Long term, including the interests of future generations
Measure of success	Physical outputs of interventions and socioeconomic benefits	Recovery of ecological processes: sedimentation rate, water quality, habitat, and native fish
Management approach	Technical interventions on the lake body, such as dredging and embankments	Control of sediment and nutrient sources in the watershed, protection of buffer zones, and habitat restoration
Position of communities	Users and beneficiaries, as well as parties to be regulated	Members of the social-ecological system: users, affected parties, holders of local knowledge, managers, and restoration agents

Aspect	Anthropocentrism (narrow orientation)	Ecocentrism
Implications for sustainability	Risks accelerating shrinkage because delayed ecological costs are not accounted for	Maintains lake functions as a precondition for long-term well-being

Source: Synthesized from Kopnina et al. *[2], Norton [17], Washington* et al. *[18], and the analysis in Subsections 4.1–4.3.*

Table 2 shows that the difference between the two perspectives lies not in the recognition of humans but in the starting point of reasoning. Narrow anthropocentrism starts from human needs and treats ecological limits as negotiable constraints, whereas ecocentrism starts from the integrity of the system and places the fulfilment of human needs within those limits. In the case of Limboto Lake, this starting point determines whether the former lakebed is treated as a land reserve or as a recovery space, and whether success is measured by project outputs or by the recovery of ecological processes. Because the degradation of Limboto Lake stems from processes accumulated across the entire watershed, an ecocentric starting point provides a more adequate framework for capturing the whole problem.

Ecocentrism is often misunderstood as a rejection of human interests, whereas Washington *et al.* [18] emphasized that humans are part of nature and that ecocentrism is not opposed to social justice; ecological justice and social justice can be pursued together [21]. In the case of Limboto Lake, this affirmation is important because part of the community depends for its livelihood on the lake and its surroundings. Conservation policies that ignore socioeconomic conditions risk losing legitimacy and shifting the burden of recovery onto the most vulnerable groups. Baga *et al.* [8] noted that lakeside communities have coexisted with the lake for centuries, including through stilt houses adapted to changing water levels. Such knowledge shows that communities are not merely a source of pressure but also hold adaptive experience that can serve as a basis for recovery. An adequate ecocentric perspective positions communities as members of the ecological community with both needs and responsibilities.

The synthesis identifies at least five roles of communities in the social-ecological system of Limboto Lake. Communities are resource users who draw on fish, water, and land; parties affected by flooding and declining fisheries; and holders of local knowledge about lake dynamics [8], [11]. They also have the potential to become management actors and agents of restoration, particularly through community-based conservation upstream, as proposed by Bakari *et al.* [10]. Melo *et al.* [13] showed that participation increases with socioeconomic status and knowledge of the lake ecosystem, so capacity building and knowledge are prerequisites for participation rather than complements to it. This reinforces Ostrom's framework [25], in which successful resource management depends on users' knowledge, their stake in the resource, and the rules they recognize. These five roles affirm that communities are part of the social-ecological system, not objects outside it.

Positioning communities as part of the system must be translated into collaborative governance. The finding of Baga *et al.* [8] that residents rarely receive information about revitalization plans indicates that management still tends to be top-down. Bennett and Satterfield [32] emphasized that environmental governance should be effective, equitable, responsive, and robust, and these four goals are difficult to achieve without the involvement of those most affected. Adaptive co-management, which combines collaboration with iterative learning, offers one way to organize such involvement in complex social-ecological settings [35]. Participation needs to be present throughout the management cycle: planning that considers local needs and knowledge, oversight of the use of riparian buffers and the former lakebed, maintenance of sediment control structures and riverbank vegetation, and evaluation using ecological and social indicators. Djafar and Akibu [5] also emphasized the need for political commitment, resource allocation, and community participation in the conservation of Limboto Lake. People become part of the solution when their participation is substantive and sustained rather than merely formal.

4.5 Implications for Sustainable and Just Lake Management

The analysis shows that the problems of Limboto Lake require management that does not rely solely on technical interventions but also has an explicit ethical basis. Each of the following implications is derived from the findings in the preceding subsections and is summarized in Table 3. The first implication is the establishment of ecological limits as the basis of management, in line with the broader notion that human development should operate within a safe operating space [30]. The finding that the former lakebed has continued to be converted since the lake's physical boundary ceased to be maintained [11] points to the need to designate and enforce lake buffer zones, including treating undeveloped parts of the former lakebed as recovery zones rather than land reserves. These limits should also include minimum vegetation cover upstream and along river corridors, because the main sediment sources lie outside the lake body [6], [10]. Ecological limits function as the framework within which socioeconomic needs are met, not as negotiable constraints.

The second implication is integrated lake and watershed management. Because more than 70% of the sediment originates from riverbank erosion, sedimentation control should prioritize bank stabilization and the restoration of riparian vegetation along the largest contributing rivers, such as the Alo, Rambongan, Batulayar, and Biyonga [6], [9]. Dredging can still play a role, but without controlling sediment sources it merely postpones the problem and may disrupt fish habitats [12]. Water quality protection should likewise target nutrient sources in the inflowing rivers, given that nitrate and phosphate pollution occurs at both locations [7]. Water hyacinth control will be more effective when combined with reductions in nutrient loads, since its growth is associated with eutrophication [6]. This approach treats the lake, rivers, and watershed as a single management unit, consistent with an ecocentric perspective.

The third implication is habitat restoration and the use of ecological success indicators. The decline in fish species and the loss of migratory fish spawning grounds show that biodiversity should be an explicit restoration target [8], [12]. Management success should be measured by indicators that reflect ecosystem condition, such as sedimentation rate, mean depth, water quality, water hyacinth cover, the presence of native fish, and the condition of riparian vegetation, alongside socioeconomic indicators. Karr *et al.* [22] showed that assessments of biological integrity have been tested across various aquatic systems and can therefore be adapted for Limboto Lake. The need for periodic monitoring is also underscored by the finding of Alfianto and Cecilia [9] that the performance of sabo structures should be reviewed on a scheduled basis. Ecological indicators shift the measure of success from project outputs toward the recovery of lake functions.

The fourth implication is participatory social-ecological governance. Communities should be involved as co-managers in planning, oversight, maintenance, and evaluation, supported by knowledge and economic capacity building, which Melo *et al.* [13] found to be associated with participation. For households dependent on the former lakebed, restoration should be accompanied by alternative livelihoods and a just transition scheme, as restoration that shifts burdens onto vulnerable groups contradicts the principle of equity in governance [32]. Kimijima *et al.* [6] also pointed to opportunities for developing sustainable alternative economic activities with local stakeholders. Coordination across agencies and administrative jurisdictions is needed because the watershed and the lake cross different jurisdictions, given that about 70% of the lake area lies within Gorontalo Regency [10], [11]. Such governance translates the position of communities as part of the system into concrete institutional arrangements.

The fifth implication is mainstreaming intergenerational justice. Limboto Lake should be treated as a trust to be passed on in functioning condition, in line with the intergenerational trust model discussed by Spijkers [33] and with calls to define environmental limits with justice across generations in view [34]. Operationally, this principle can be realized by requiring long-term impact assessments for every spatial-use plan around the lake and in the watershed, and by restricting irreversible decisions such as permanent construction on the former lakebed. Together, these five implications indicate that the most relevant approach is not to replace anthropocentrism entirely but to position ecocentrism as the determinant of limits and a broadened anthropocentrism as the basis

for choosing fair and efficient forms of use within those limits. This position accommodates Norton's [17] argument about the potential of weak anthropocentrism while taking into account the critique of Kopnina *et al.* [2] that human interests alone are insufficient to guarantee the protection of nature. In this way, environmental ethics does not remain a normative discourse but becomes a basis for setting priorities, indicators, and the division of roles in the management of Limboto Lake.

Table 3. Implications of Environmental Ethics for Limboto Lake Management

Analytical finding	Ethical principle	Management implication	Example success indicators
Former lakebed converted after the lake's physical boundary ceased to be maintained	Protection of ecological limits	Designation and enforcement of buffer zones; undeveloped former lakebed designated as recovery zones	Area of protected buffer zone; no new construction on the former lakebed
More than 70% of sediment from riverbank erosion; nutrients also originate from rivers	Integrity of the lake–watershed system	Bank stabilization, riparian vegetation restoration, and erosion and nutrient control in priority rivers	Sedimentation rate; mean depth; nitrate and phosphate concentrations
Fish species declining, spawning grounds covered, and water hyacinth spreading	Ecological integrity and biodiversity	Restoration of spawning habitats; water hyacinth control combined with nutrient load reduction	Presence of native fish; water hyacinth cover; habitat condition
Residents rarely involved; participation associated with socioeconomic status and knowledge	Equity and participation	Co-management, capacity building, alternative livelihoods, and cross-jurisdictional coordination	Resident involvement in planning and monitoring; availability of livelihood transition schemes
Projected disappearance of the lake within a few decades	Intergenerational justice	Long-term impact assessment; restriction of irreversible decisions	Trends in lake area and depth; number of new permanent buildings in the lake zone

Source: Analysis in Subsections 4.1–4.4.

This study has several limitations. As a literature review, the analysis depends on the availability and quality of data from previous studies, including differences in methods for measuring lake area and projecting its future. The analysis also did not directly measure the values and attitudes of stakeholders, so the anthropocentric orientations discussed are interpretations of documented patterns of use and policy. Non-peer-reviewed documents, such as government planning documents, were excluded to maintain the verifiability of sources, although they could enrich the policy analysis. Nevertheless, this study contributes an explicit link between the biophysical and social evidence on Limboto Lake and the framework of environmental ethics.

5. CONCLUSION

This study shows that the degradation of Limboto Lake is a social-ecological problem formed through a chain of agricultural expansion and deforestation in the watershed, land and riverbank erosion, sedimentation, conversion of the former lakebed, and impacts that return to communities as flooding, declining fisheries, and deteriorating water quality. This chain cannot be explained solely as the fault of communities, because spatial-use decisions are shaped by livelihood needs, development programs, and weak spatial control. From an environmental ethics perspective, anthropocentrism is not inherently destructive, since the interests of affected people are themselves strong reasons to restore the lake; its limitations emerge when human interests are defined narrowly and in the short term, so that the former lakebed is treated as a land reserve, ecological values that are difficult to monetize are sidelined, and the interests of future generations go unrepresented.

Ecocentrism is more relevant for reading Limboto Lake because it treats the lake, rivers, and watershed as one system whose integrity, stability, and resilience are preconditions for human well-being, without excluding communities as members of the ecological community. Accordingly, the management of Limboto Lake should establish ecological limits as the basis of planning, integrate lake management with sediment and nutrient control in the watershed, restore habitats using ecological success indicators, involve communities as co-managers, and mainstream intergenerational justice; by positioning ecocentrism as the determinant of limits and a broadened anthropocentrism as the basis for choosing forms of use, management can move from reactive technical interventions toward sustainable social-ecological management.

Future research is suggested to test these findings empirically through surveys or interviews on the value orientations of communities, government officials, and policymakers, and to link them with population dynamics and land-use change in the Limboto Watershed. Further studies could also analyze government planning documents and develop locally calibrated ecological integrity indicators for Limboto Lake that can be used to monitor management performance over time.

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