

Islamic Ecological Justice: A Comprehensive Islamic Approach Towards Peatland Sustainability

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Abstract.

Peatlands play a crucial role in maintaining the balance of the global ecosystem and the sustainability of local communities. However, various development policies, such as the One Million Hectare Peatland Development Project (PLG) and the Food Estate program, have demonstrated failure in sustainably managing peatlands, leading to environmental degradation, social conflict, and economic inequality. This article proposes an alternative approach based on Islamic Ecological Justice, integrating sharia principles—such as tawhīd, khalīfah, mīzān, and maṣlahah—into a Khilafah-based peatland governance system. This research employs a qualitative approach through a thematic literature review covering five focuses: peatland ecological characteristics and challenges, national policies and their failures, sensor-based environmental monitoring technology, Islamic ethical principles in natural resource governance, and community-based adaptive cultivation strategies. The findings indicate that technocratic approaches have not been able to address the ecological and social complexities of peatlands. In contrast, the application of monitoring technology developed by researchers, combined with a public funding system through the Baitul Mal (Islamic Baitul Mal), and adaptive cultivation based on Islamic bioeconomics, offers a holistic solution framework. This approach is not only technically and socially relevant but also confirms that Islam provides a paradigm for natural resource governance that is just, preventative, and sustainable.

Keywords : Islamic ecological justice; peatlands; monitoring technology and Islamic bioeconomics.

I. INTRODUCTION

Tropical peatlands serve vital ecological and hydrological functions in maintaining the balance of the Earth's systems. These ecosystems store approximately 550 gigatons of carbon, or about 30% of the world's total soil carbon, despite covering only 3% of the global land surface. (Page, Rieley, & Banks, 2011) In Indonesia, peatlands are spread across Sumatra, Kalimantan, and Papua, covering an area of approximately 13.4 million hectares, making it one of the countries with the largest tropical peat reserves in the world. (Ritung et al., 2018). In addition to their function as carbon storage, peatlands play a vital role in regulating water management, preventing seawater intrusion, and serving as habitats for biodiversity and sources of food, medicine, and building materials for local communities. However, peat ecosystems are currently under threat due to human activities that ignore their carrying capacity and ecological functions. The practice of converting peat forests into monoculture plantations such as oil palm and acacia, opening drainage canals, and massive land burning have caused severe degradation, including carbon oxidation, land subsidence, and biodiversity loss. (Murdiyarso, Hergoualc'h, & Verchot, 2010; Wahyunto, 2024; Wahyunto & Suryadiputra, 2016) Recurring peatland fires every dry season also trigger transboundary haze disasters and public health and education crises, as occurred in 2015 and 2019. (Omar et al., 2022; UN Environment Program (UNEP), 2017) (Omar et al., 2022; UN Environment Program (UNEP), 2017) This condition reflects the issue of natural resource governance, which has not only technical and ecological dimensions, but also political, social, and ethical ones.

The Indonesian government's efforts to restore peatlands, particularly through the establishment of the Peat Restoration Agency (BRG) in 2016, are an important step in addressing ecological degradation

caused by massive burning and land conversion.(PPID: BRGM, 2023)One of BRG's main approaches is the rewetting, revegetation, and revitalization program—often known as the 3Rs—which emphasizes hydrological restoration through rewetting canals to maintain land moisture and prevent fires.(Giesen & Nirmala, 2018). Although this program shows good intentions in integrating technical and ecological aspects, a number of studies show that its implementation still faces significant challenges, especially in terms of local community participation, socio-economic sustainability, and the neglect of cultural and spiritual values inherent in indigenous communities. (Novalia & Malekpour, 2020; Puspitaloka, Kim, Purnomo, & Fulé, 2019, 2021).Restoration policies that are overly technocratic and without considering ethical and value aspects can fail to address the root of structural problems, such as power relations in land ownership, unequal access to resources, and the weakening of local wisdom. Therefore, a more integrative and holistic alternative approach is needed, one that considers not only the ecological and technical dimensions but also the spiritual, moral, and social dimensions of sustainability. In this context, Islam, as a religion rich in creation cosmology and environmental ethics, offers an important paradigm through the concept of Islamic Ecological Justice (KEI).

KEI is based on the understanding that nature is a creation of Allah SWT that has intrinsic value and is not solely for human exploitation. The principle of *tawhīd* (the oneness of God) teaches the interconnectedness between humans and all creation; *mīzān* (balance) demands harmony in all aspects of life; *khalīfah* (leadership of humans on earth) carries a moral responsibility to protect and care for the earth; while *maṣlaḥah* (public benefit) encourages decision-making that considers the long-term benefits of all creatures.(Foltz, Denny, & Baharuddin, 2003; Naṣr, 1990). Within this framework, environmental degradation is not only seen as an ecological crisis, but also as a form of collective ethical failure.The KEI-based approach opens up space for a resource governance system that relies not only on legal and technological instruments, but also on ethical values derived from revelation, as well as respect for social justice and intergenerational sustainability. Thus, this approach can serve as a normative foundation for designing more sustainable and equitable peatland restoration policies. This article proposes a KEI-based systemic framework for equitable, sustainable, and contextual peatland management. This approach combines Islamic values with scientific and technological strategies such as an IoT sensor-based environmental monitoring system, adaptive irrigation, cultivation of local crops tolerant to peat conditions, and the integration of a sharia-based economic model. Using an interdisciplinary approach from the perspectives of instrumentation physics, public administration science, Islamic law, and plant science, this article aims to design a peatland management model that not only preserves ecological functions but also empowers communities and fosters a just and sustainable economy.

II. METHODS

This research was conducted as an interdisciplinary literature review integrating environmental science and instrumentation technology, public administration, and Islamic normative principles. The goal is to formulate a framework for Islamic Ecological Justice in the context of sustainable tropical peatland management.

2.1 Literature Search and Selection Strategy

Literature was collected through national and international scientific databases such as Google Scholar, Scopus, ScienceDirect, SpringerLink, DOAJ, and Garuda. Keywords used included: sustainable peatland management, peatland monitoring, Islamic ecological ethics, caliph and environment, and Islam and sustainability. Classical and contemporary references from Islamic studies, such as thematic environmental interpretations, ecological hadith, and environmental fiqh literature, were also used.

Selection criteria include:

1. Thematic relevance to peatland management, monitoring technology, and Islamic values;
2. Publications in the last 15 years (2008–2023), except for classical Islamic literature;
3. Journal articles, research reports, and academic books that have undergone a peer-review process.

2.2 *Analysis Techniques*

The analysis in this study was conducted descriptively and qualitatively using a thematic approach, namely identifying, grouping, and synthesizing the literature based on major themes relevant to the study's objectives. The analysis process began with systematic reading and review of all selected literature sources, then classifying them into five main focuses as follows:

1. Characteristics and Ecological Challenges of Peatlands
2. National Policy and Restorative Approach to Peatlands
3. The Role of Sensor-Based Environmental Monitoring Technology
4. Islamic Values and Principles in Environmental Governance
5. Adaptive Cultivation Strategies and Community-Based Sustainability

All the results of these thematic classifications and interpretations are synthesized to develop an integrative conceptual framework for peatland management, a model that combines scientific and technological approaches, public policy strategies, and Islamic spiritual and ethical values. This framework is expected to provide both theoretical and practical contributions to promoting more equitable, inclusive, and sustainable peatland ecosystem governance.

2.3 *Empirical Validation: Monitoring System Development Experience*

Although no direct experimental tests were conducted in this article, the author has empirical experience in developing a technology-based peatland monitoring system. This system uses soil moisture, temperature, and peat water level sensors, controlled by an ESP32 microcontroller and communicated wirelessly over a LoRa network. Data is sent in real time to a web-based dashboard and used for land fire risk monitoring. This system was designed for energy efficiency through solar panels and tested on a limited scale on peatlands in Central Kalimantan. This experience provides a practical basis for assessing the feasibility of integrating technology utilization with Islamic principles of ecological justice.

III. RESULT AND DISCUSSION

3.1 *Challenges and Potential of Peatland Ecosystems*

3.1.1 *Physical, ecological, and social characteristics of peatlands*

Peatlands in Indonesia, which cover approximately 24.6 million hectares, have challenging physical characteristics, such as low nutrient content, high acidity, low bulk density, and poor soil structure stability. (Hidayat, Mizuno, Said, & Herdiansyah, 2023) This condition limits root development, hinders nutrient availability and absorption, and reduces plant productivity. Ecologically, peatlands play a crucial role in maintaining environmental balance, such as storing carbon reserves and regulating water management. Meanwhile, socially, peatlands have long been utilized by the indigenous peoples of Kalimantan to grow local food crops such as corn, cassava, fruits, and spices, reflecting traditional knowledge in sustainable natural resource management. (Afentina et al., 2021).

3.1.2 *Threats of fire, land subsidence, and oil palm conversion*

Poor peatland management, including unsustainable modern agricultural practices, has led to environmental damage such as soil degradation, nutrient depletion, and increased greenhouse gas emissions due to peat oxidation and drainage. (Afentina et al., 2021; Hidayat et al., 2023) This practice can trigger further degradation, such as land subsidence, and increase the risk of peatland fires. Peatlands in Indonesia are highly susceptible to fire, especially during the dry season. Dry, flammable peat can cause widespread fires, damage ecosystems, and threaten public health due to the resulting smoke. (Qamariyanti, Usman, & Rahmawati, 2023). In addition, the conversion of peat forests into oil palm plantations is also a serious threat. (Handayani, Idris, Sabiham, Juniwati, & Noordwijk, 2009) Every year, around hundreds of thousands of hectares of peat swamp forest are converted to oil palm plantations, which contributes significantly to greenhouse gas emissions in Indonesia. (Wibowo, 2010).

3.1.3 *Economic and ecological potential if managed based on sharia*

The use of organic materials such as manure can improve soil structure, support microbial activity, and increase the efficiency of nutrient absorption. (Anthony, Stover, James, & Silver, 2024; Rayne & Aula, 2020) This approach aligns with the principles of sustainability and environmental balance, which can be

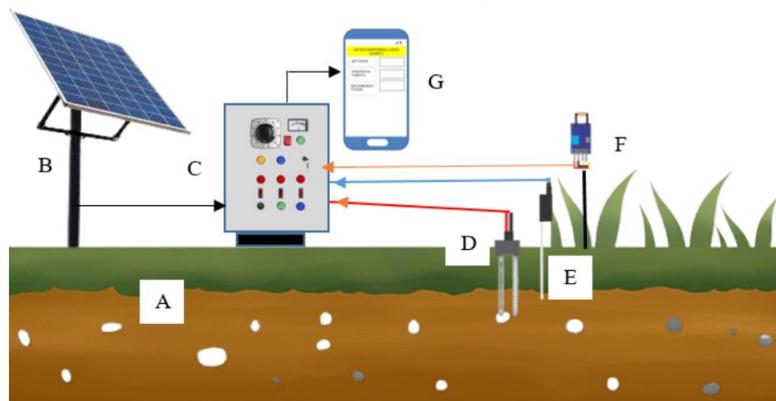
linked to the core values of sharia-based management, such as *maslahah* (common good), *tawazun* (balance), and *khalifah* (responsibility to nature). With management oriented toward sustainability and socio-ecological justice, peatlands have significant potential to support food security while maintaining their ecological function. Sharia principles such as justice, sustainability, and environmental responsibility can be applied to peatland management. This approach aligns with the concept of local wisdom-based management, where communities are actively involved in maintaining and sustainably utilizing peatlands. (Sirenden, Silvianningsih, Anggraeni, & Christy, 2023) By applying these principles, peatlands have the potential to simultaneously support food security and environmental conservation.

3.2 Peatland Monitoring Technology Integration

In the context of managing complex and degradation-prone tropical peatlands, monitoring technology plays a strategic role in providing real-time data for early detection, maintaining land quality, and preventing disasters such as fires. Technology-based monitoring not only improves technical efficiency but also expands the scope for more ecologically and ethically responsible resource management.

Researchers have developed a prototype of a sensor- and microcontroller-based peatland monitoring system (Figure 1) designed to monitor key biophysical parameters, namely:

1. Soil pH, as an indicator of the level of acidity that affects the availability of nutrients;
2. Soil moisture, which reflects water availability and the risk of drying out of the peat substrate;
3. Light intensity, which is related to the adaptive needs of plants in peat ecosystems.



Keterangan :

A = lahan gambut

B = panel surya

C = sistem monitoring

D = sensor *soil moisture*

E = sensor pH tanah

F = sensor LDR

G = android

Fig 1. Design of peatland monitoring system

The device is designed with digital sensors (pH sensor probe, soil moisture sensor, LDR) connected to an ESP8266 microcontroller and Arduino UNO. Data from the sensors is sent wirelessly to the Blynk application using a WiFi module, so it can be monitored in real-time via a smartphone. During the calibration process against standard tools, the system demonstrated a high level of accuracy with very small measurement errors, namely:

1. 0.151% for soil pH,
2. 1.11% for soil moisture, and
3. 6.15% for light intensity.

Another advantage of this system is its use of solar panels as a power source, making it environmentally friendly, energy efficient, and independent of the electricity grid. This configuration is particularly suitable for difficult-to-reach peat areas with minimal infrastructure. (Arifin, Kurniawati, Agustiani, & Elsandika, 2025). Furthermore, the system was developed for early detection of peat fires through the integration of CO (MQ-7) and CO₂ (MQ-135) gas sensors. Based on laboratory and simulation tests, the sensors were able to provide a rapid response to increases in carbon gas concentrations that commonly occur in the early stages of peat burning. The calibration model using polynomial regression produced high determination values of $R^2 = 0.9901$ for CO and $R^2 = 0.9623$ for CO₂, indicating the validity

of the system in detecting hazardous gas dynamics.(Patent No. IDS000007605, 2024; Kurniawati et al., 2025).Peatland fires are one of the most serious ecological disasters in Indonesia, with widespread impacts on the environment, economy, public health, and local and regional socio-economic activities. Every year, millions of hectares of peatland burn, releasing massive amounts of carbon emissions and polluting the air as far away as neighboring countries.

(Marlier et al., 2013; Murdiyarso et al., 2010)One of the main causes is undetected early peatland drought, coupled with the low capacity of local communities to monitor and respond to early signs of changes in the microclimate and peat substrate.(Tacconi, 2016)This situation is exacerbated by a governance system that is still reactive and not fully based on data and community participation. Therefore, the existence of an early warning system (EWS) is crucial for strengthening community resilience to this disaster. In this context, researchers' findings in the form of a prototype sensor-based monitoring system for measuring critical parameters such as soil moisture, temperature, and CO/CO₂ gas concentrations demonstrate significant potential for further development. This system can serve as the foundation for a more integrated EWS, which not only functions as a technical detection tool but can also be connected to online notifications based on mobile applications, historical data visualization, and spatial vulnerability mapping.By strengthening digital infrastructure, community engagement, and a values-based approach, this system has the potential to become part of a fair and sustainable disaster risk reduction scheme, in accordance with the principles of ecological justice and trust-based governance.

3.3 Peatland Adaptive Plant Culture

3.1.1 Recommended Plant Types

Peatlands have significant ecological and economic potential because they support the growth of various local plant species that are adaptable to extreme environmental conditions, such as high acidity and water saturation. Some recommended plant species for cultivation in peatlands include kelakai (*Stenochlaena palustris*), galam wood (*Melaleuca cajuputi*), and Dayak onion (*Eleutherine palmifolia*). Kelakai is a type of fern commonly found in swampy areas and has traditionally been used by local communities as a food and medicine. Studies have shown that kelakai is effective in increasing hemoglobin levels in people with anemia.(Amilia, Andaruni, Amini, Makmun, & Harahap, 2024; Negara, Murjani, & Basyid, 2017)Meanwhile, galam is known as a producer of essential oils, often referred to as eucalyptus oil, which has high economic value and plays a role in soil conservation.(Rosmainar, Nugroho, Sudyana, & Ayuchecaria, 2023)On the other hand, Dayak onion is a tuber plant native to Kalimantan that has been clinically proven to have medicinal properties. Its active ingredients include alkaloids, glycosides, flavonoids, phenolics, quinones, steroids, tannins, and essential oils, making it a potential raw material in the pharmaceutical, functional food, and nutraceutical industries. (Atikah, 2021; Atikah, Syahid, & Widiarti, 2023).

3.1.2 Soil Cultivation without Damaging Peat Structure

Peatland management must be carried out with strict conservation principles to avoid damage to the soil structure that can trigger subsidence and accelerate peat decomposition. Some recommended soil management strategies include the use of dolomite lime before planting, which neutralizes soil pH and increases the availability of essential nutrients such as phosphorus (P) and magnesium (Mg), without disrupting the soil's biological balance. Furthermore, the use of organic compost and biofertilizers is also an effective alternative for sustainably increasing soil fertility. A study showed that the use of Dayak onion waste and active microorganism (AMF) fermentation successfully increased the growth of bok choy plants in peat media. (Atikah, Syahid, et al., 2023). The combination of organic and inorganic fertilizers has also been proven to increase crop yields such as shallots on marginal soils such as spodosols, while simultaneously reducing dependence on chemical fertilizers.(Atikah, Muliansyah, Rohmad, Haruna, & Syahrudin, 2023). For planting systems, the surjan method is recommended, especially in shallow peatlands. Surjan is a technique for creating ridges and valleys, where vegetable crops requiring aerobic root conditions are planted in the ridges, while anaerobic-tolerant crops are planted in the valleys. This is important because peatlands are naturally saturated with water, and most horticultural crops require oxygen in their root zones. (Resdati, Hidir, & Syafrizal, 2021).

3.1.3 *Agroforestry Systems and Cover Crops to Maintain Humidity*

The implementation of agroforestry systems on peatlands is an effective adaptive approach to maintaining the land's ecological function. Agroforestry allows for the integration of perennial and annual crops in intercropping systems, thereby increasing ecosystem diversification, productivity, and stability. (Ardiansyah, Masnang, & Jannah, 2023) One agroforestry strategy that is relevant for peatlands is paludiculture, which is a system of cultivating plants without permanent drainage, by selecting local plant species that are tolerant of flooding, such as sago and jelutung. (Triadi, 2020) This plant is not only able to grow in water-saturated conditions, but also functions to maintain soil moisture and prevent fires. In addition, the application of a multi-strata system with shade plants such as jelutung, coconut, and rubber is very important to create natural shade, reduce soil temperature, and produce litter that helps maintain soil moisture and improve the physical structure of peat (Gunawan et al., 2019). (Gunawan & Afriyanti, 2019) This combination supports the stability of peatland microclimates and enhances the sustainability of agricultural systems.

3.4 *Islamic Ecological Justice: An Islamic Systems-Based Framework for Peatland Sustainability*

The development paradigm that positions peatlands as objects of economic exploitation has proven to be a failure in achieving sustainability. One glaring example is the One Million Hectares Peatland Development Mega Project (PLG) in Central Kalimantan, launched in 1996 by the New Order government. (Haryanti & Alexander, 2020; Sigit, 2016; Wikipedia, 2023) This project aimed to turn peatlands into a national rice barn, but its technocratic approach, which ignored the ecological and socio-cultural aspects of local communities, led to an ecological disaster. A total of 1.45 million hectares of peatland were cleared with the construction of approximately 4,600 km of canals. (Omar et al., 2022) As a result, there is degradation of the peat ecosystem, a decrease in groundwater levels, and an increase in forest and land fires. BRGM reports that more than 60% of the PLG area is currently classified as damaged and in need of restoration. (PPID: BRGM, 2023). In addition to ecological damage, the project failed to improve the well-being of the community, the majority of whom continue to live in poverty and marginalization. A similar project was repeated during President Joko Widodo's administration through the Food Estate program, which began in 2020 in Central Kalimantan with a target of clearing 165,000 hectares of land. However, by 2022, planting had only reached 30,000 hectares, and many crops failed due to the incompatibility of peatland with rice and corn.

(Ministry of Agriculture of the Republic of Indonesia, 2022) A study by WALHI Central Kalimantan stated that around 50% of the program area is abandoned, while some have been converted into oil palm plantations, exacerbating peat degradation. (Suhadi, 2024) According to Global Forest Watch records via Atlati, from 2001 to 2023, Central Kalimantan lost around 3,741.6 thousand hectares of tree cover, with most of it converted to agricultural land or plantations. (Goldman, Carter, & Weisse, 2023) This shows that a large-scale land conversion-based approach without proper ecological understanding only perpetuates failure. Furthermore, peatlands serve vital ecological functions that are often overlooked in conventional development approaches. As the world's largest carbon store, peatlands store more than 600 gigatons of carbon globally, or twice as much as the world's entire forests. (Page et al., 2011) In Indonesia alone, peatlands cover 13.43 million hectares and store more than 57 Gt of carbon (KLHK, 2020). When peatlands are drained or burned, this carbon is released as greenhouse gas emissions, accelerating climate change. Peatlands also serve as hydrological regulators and habitats for rare species such as the Bornean orangutan (*Pongo pygmaeus*), which is now threatened with extinction due to habitat destruction (UNEP, 2022). This situation is further exacerbated by the expansion of oil palm plantations on peatlands, which are converting natural landscapes into monocultures that are poor in biodiversity and have significant ecological impacts.

Approximately 3.1 million hectares of oil palm plantations in Southeast Asia are planted on peatlands, increasing to 4.3 million hectares in 2015—representing a 37% increase in the past five years. (Davis, 2016; Hashim, Subramaniam, Harun, & Kamarudin, 2018; Numata et al., 2022) This conversion resulted in very high greenhouse gas emissions—averaging between 53 and 86 tonnes of CO₂ equivalent per hectare per year over the 30-year post-conversion period. (Cooper et al., 2020) The failure of

various exploitation-based projects such as the PLG (Reforestation Project) and the Food Estate underscores the need for an alternative framework for peatland management that considers not only economic and technocratic aspects but also integrates spiritual, legal, social, and ecological values. Within the Islamic system, this solution can be realized through a sharia-compliant bioeconomic approach consolidated within an Islamic governmental structure (the Caliphate), with the state acting as a regulator and servant of the people's interests and guardian of the natural balance.

3.4.1 *Sharia Basis for Ecosystem Management*

Islam views the earth and all its contents as a trust that must be safeguarded, not exploited. The principle of *tawhīd* (the oneness of God) positions humans as *khalīfah fī al-arḍ* (Quran, Al-Baqarah: 30), that is, guardians of God's creation, not absolute rulers. In this context, all development policies, including the use of peatlands, must comply with sharia regulations that prioritize the principles of *maṣlahah 'āmmah* (public benefit), *mīzān* (balance), and *ḥifẓ al-bi'ah* (environmental protection).

3.4.2 *Baitul Mal as a Supporter of Economic and Ecological Justice*

In the *Khilafah* system, the state's fiscal functions are carried out through the *Baitul Mal* institution, which manages various Islamic revenue items such as *zakat*, *fai'*, *kharāj*, *'usyūr*, and *jizyah*. These funds are allocated not only for social needs but also for:

1. Development of conservation infrastructure and ecological agriculture on peatlands;
2. Research and technology that supports peat ecosystem monitoring;
3. Education and training of farmers, particularly in adaptive cultivation techniques, without reliance on chemical fertilizers and destructive land clearing;
4. Incentives for indigenous communities who maintain their territories sustainably.

By not relying on foreign loans, foreign private investment, or carbon trading schemes that reduce the value of the environment to a market commodity, this system maintains the sovereignty of natural resource management and prevents economic inequality and ecological injustice.

3.4.3 *Adaptive Cultivation as a Pillar of Sharia Bioeconomy*

The Islamic system encourages the exploration of peat-adaptive plants that do not damage the soil substrate, such as:

1. Kelakai (*Stenochlaena palustris*) as a source of food and natural medicine;
2. Dayak onion (*Eleutherine palmifolia*) as a herbal plant with high economic value;
3. Galam wood (*Melaleuca cajuputi*) is a conservation tree that also has commercial value.

This cultivation is carried out using methods such as *paludiculture*, *surjan* planting, and *multi-strata agroforestry*, in accordance with the characteristics of peat ecosystems. The resulting products are processed and marketed within a sharia-compliant bioeconomic scheme, a production and distribution system that meets *halal* (permissible), *thayyib* (good), and *maṣlahah* (beneficial) criteria and is aimed at creating local added value and community empowerment.

3.4.4 *Monitoring Technology for Prevention (Dar' al-Mafāsīd)*

One form of actualizing Islamic principles in land management is the development of monitoring technology as an early detection tool for pre-fire conditions. This system, developed by researchers, includes sensors for temperature, soil moisture, water level, and carbon dioxide, connected in real time via IoT. This technology reflects the principle of *dar' al-mafāsīd muqaddam 'ala jalb al-maṣāliḥ*—preventing damage is preferable to taking immediate advantage. (Auda, 2008). The state under an Islamic system is obligated to facilitate the equitable development and dissemination of this technology, ensuring that communities in peatland areas have access to environmental data and early mitigation measures. This aligns with the spirit of *shūrā* (deliberation), *'adālah* (just distribution), and *ta'āwun* (cooperation) as Islamic social principles.

3.4.5 *Fair and Participatory Distribution of Benefits*

In the Islamic system, the benefits of peatlands, whether raw materials or processed products, are not concentrated in the hands of a small elite or institution, but are distributed through a just distribution mechanism that reaches all levels of society, especially those living near the land. The state manages this distribution through *al-'iṭā'āt* (gifts), subsidies, and support based on the people's real needs, without discrimination. Thus, the Islamic solution forms a comprehensive framework that encompasses resource

management, institutional support, technology, and the direction of production, distribution, and consumption within a cohesive, long-term oriented value system.

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