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Review

Toward Water, Energy, and Food Security in Rural Indonesia: A Review

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Abstract: Indonesia is an archipelago with significant variations in natural resources, infrastructure, socioeconomic, culture, human resource capacity, accessibility, and access to financial and technical assistance. In this situation, integrated and unique efforts are needed to manage natural resources and build synergy between their protection and utilization to achieve water, energy, and food (WEF) security in accordance with the SDG targets. This paper analyzes the implementations of the WEF nexus in rural Indonesia by examining existing legal frameworks and other related policies, journals, textbooks, and publications. We explore factors influencing the success and failure of the implementation of the WEF nexus approaches from technical, socioeconomic, cultural, political, and institutional perspectives of the rural development framework.

Keywords: rural development; WEF security; integrated approach

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1. Introduction

Indonesia is dedicated to adopting a long-term development strategy to fulfill rising water, energy, and food (WEF) demands while also achieving conservation and climate goals [1]. However, it confronts a huge problem in balancing competing demands on its natural resources, which is likely to be worsened further by climate change and harsh weather. Moreover, Bellfield, Sabogal, Pareira, Gangga, and Leggett [1] state that resource consumption tradeoffs among diverse sectors could jeopardize WEF security goals. Competition for restricted land and water resources might jeopardize ambitious production goals and lead to more deforestation, affecting emissions targets and the resilience of vital ecosystem services. From 2010 to 2020, Indonesia was one of the world's greatest deforested countries, with an average rate of 0.78 million ha/year [2]. Deforestation has resulted in significant watershed degradation [3] that threatens the quality and availability of water supplies.

Water scarcity becomes a global challenge that is in line with "virtual agricultural water" demand during food production processes and embedded in national or international food trade or import [4]. Water insecurity will worsen with increasing water demand, population growth, agricultural water demand for food security, urbanization, and climate change [5]. On a global scale, the majority of freshwater extractions, roughly 80% of blue water, are used for agricultural purposes to support food production [6,7]. In fact, at the global level, the food sector accounts for nearly 30% of the total energy consumption [8]. The lack of cooperation among sectors has led to significant competition between energy and water use for food or other purposes. This is proven by conflicting strategies and policies that do not effectively support the economic or environmental sustainability, putting global food security at risk [9].

In Indonesia, WEF security is addressed in the National Medium-Term Development Plan (RPJMN) 2020–2024 [10]. However, the close interdependence among the three is not highlighted. With such diversity, the link between WEF in Indonesia will be unique, and it will need to be investigated further. The 2020–2024 RPJMN has mainstreamed the SDGs. The targets of the 17 SDGs and their indicators have become an integral part of Indonesia's development agenda going forward [11].

The village level supports a total of 74% of achieving the national SDGs; therefore, the village is the backbone of the Indonesian SDGs [12]. This contribution can be understood because 91% of Indonesia's territory is supported by 83,820 village governments [13]. On the other hand, 118 million people, or 43% of the total population of Indonesia, lives in villages [12,13]. This condition makes rural areas important in implementing the WEF nexus for achieving SDG indicators. Poverty alleviation, hunger eradication, healthy living and welfare, quality education, gender equality, decent work, and economic growth are all examples of sustainable development in rural areas [14]. The purposes of this paper are to review and analyze the implementation of the WEF nexus in Indonesian rural development.

2. Methods

The study was conducted based on the literature review and the research experience of the authors through a series of activities of finding, reviewing, and evaluating relevant materials and synthesizing information. The review materials are existing legal frameworks, rules and policies, relevant books, and scientific publications concerning water, energy, and food resources management.

The review begins with an overview of the WEF nexus theoretical perspective, which explains the intricate and close interconnections among WEF components as linked to sustainable development [15], as presented in section three. This overview is intended to equalize perceptions and understanding of the WEF nexus.

Section four analyzes rural development policy in Indonesia as a significant contributor to achieve the security of WEF. This analysis uses the literature review, mainly in the form of government laws and regulations. The discussion focused on village development overviews based on a regulatory perspective and their rules for attaining the SDGs [16]. The analysis provides an overview of the position and authority of the village in the achievement of WEF security and SDGs.

Best practices in WEF were synthesized based on the literature related to achieving WEF security in Indonesian rural areas. Some of the case studies presented will illustrate how efforts to achieve WEF security are carried out. Each case study has a different weight in the priority of achieving the WEF components, depending on the priority of community needs to be addressed. The description of each case study will provide an overview of how an area from the national level to the village tries to overcome obstacles to achieve harmony in fulfilling the WEF.

3. Theoretical Perspective of WEF Nexus

The Water, Energy, and Food Nexus is an extended concept of Integrated Water Resource Management (IWRM) and Adaptive Water Management (AWM) to overcome

and manage resource scarcity [17,18]. The WEF nexus refers to the intricate and close interconnections (synergies and tradeoffs) among the WEF sectors in order to achieve sustainable development [19]. Although the nexus approach has been developed over the years, it is still centered on theoretical discussions and investigations. This section presents theoretical perspectives from the nexus: ecosystem, socioeconomic and cultural perspectives, and policy as well as institutional perspectives.

3.1. Ecosystem Perspective

The Bonn conference "The Water, Energy, and Food Security Nexus—Solutions for the Green Economy" 2011 was known as the first international forum to consolidate the concepts of the WEF nexus [18,20]. The main reason behind the consolidation and increased visibility of this concept is insecurity in WEF supplies [20]. The emergence of the nexus is the result of the scientific community thinking about WEF resources' interrelationships and complexities and the need for multidimensional management [21].

Simpson and Jewitt [22] define the WEF nexus as the relationship among three resources in the form of synergies, conflicts, and tradeoffs generated based on how they are handled. The relationships are water for food and food for energy, energy for water and water for energy, and food for energy and energy for food. The nexus approach can support the transition to sustainability by reducing tradeoffs and generating profit margins that are greater than transaction costs in the process of integration among sectors [6]. However, although water is an economic commodity, it is not formally priced [23], so a quantitative economic analysis of exchange transactions cannot be priced.

Water, energy, and food are products of ecosystem services that are essential to support life, and all of them are interrelated in complex relationships and dynamic interactions. The complex relationship among these three ecosystem services is often called the "water–energy–food relationship" (Figure 1). In recent decades, WEF crises and ecosystem degradation have become a common problem in many countries [6,18,20]. The Department of Economic and Social Affairs [24] projects that by 2050, the population will reach 9.7 billion and close to 11 billion in 2100, and the direct use of water demand and water demand for energy will increase by 20–30% and 85% [25], while for food, it will increase by 60% [26]. This will be a large problem since, at the same time, climate change has reduced productivity by about 21% since 1961 [27].

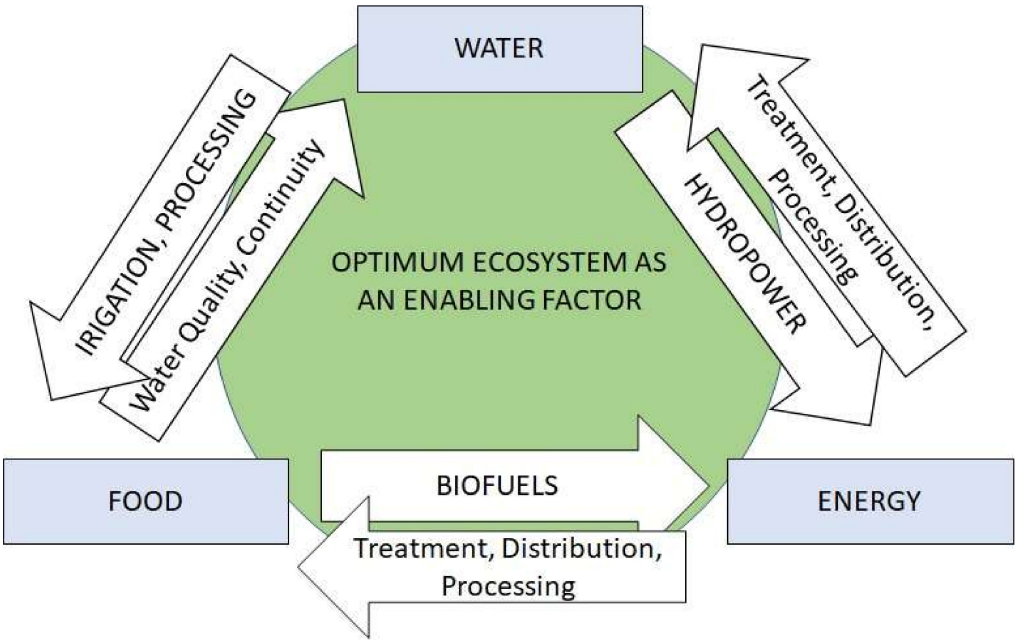

Figure 1. Interlinkages of WEF and Ecosystem (modified from [28]).

3.2. Socioeconomic and Cultural Perspective

In an archipelagic country that has very diverse geographical and socioeconomic conditions, such as Indonesia, the natural resources needed to ensure the geographical security of WEF are generally not evenly distributed, limited in number, and not easily accessible. In addition, the sustainability of efforts to meet the needs of WEF is strongly influenced by social and cultural values [29], which are also very diverse. Thus, efforts to achieve WEF resilience require a comprehensive approach by considering socioeconomic variations such as natural resources, infrastructure, culture, poverty levels, human resource capacity, and access to finance [1,30].

The next largest challenge is determining the balance between supply and demand for WEF [31]. In this context, the nexus approach can be used to ensure WEF availability by minimizing tradeoffs across sectors and optimizing benefits [32]. The WEF nexus has the potential to improve welfare while supporting efforts to achieve the SDG agenda [33]. Through the nexus approach, rural development planning in the physical aspect goes hand in hand with social protection to create a prosperous and sustainable village.

The latest trend in handling the WEF nexus focuses on effective synergy and collaboration to build interconnection and influence each other in decisions making, considering socioeconomic and environmental aspects. A comprehensive framework is needed to focus on individual security and the interaction and interdependence of all the pillars that underpin WEF's sustainability [17]. The ability to adapt to many diverse situations is a determining factor that supports the achievement of the WEF nexus approach in the future [34]. According to Fernandes Torres et al. [20], differences in data availability, technological advances, politics, economics, and sociocultural and intersector/element relations make the WEF nexus approach different from one place to another. A centralized approach that creates global imbalances can affect the social and ecological sustainability of WEF [35]. Thus, every decision-making area needs sectoral integration to minimize conflict and increase integration and consistency in achieving targets under various conditions [20,36]. An important obstacle to realizing pro-sustainability social values is the limited authority and control of the community to change unsustainable practices due to limited resources [29].

3.3. Political and Institutional Perspectives

The nexus approach involves multisectoral work on interconnected and interdependent network systems, thus requiring collaboration across ministries, different levels of government, and international cooperation [20,37]. From a global political perspective, various countries and multinational organizations have shown interest in the concept of WEF [38]. Nationally, Indonesia has included WEF security in its development priority plans. However, because the linkages among these sectors are still constrained, a comprehensive policy is needed [10]. National priority policies on WEF require roadmaps based on performance appraisals and evidence that reflect the condition of a cost-effective resource that meets the needs of the population [39].

In the sustainable management of WEF resources, formal and informal regulations are manifested in the form of management institutions. From an institutional perspective, cross-border and cross-sector water management requires an IWRM and considers ecological compensation policies allowing management agencies to enhance cross-border incentive mechanisms and encourage the involvement of various stakeholders [40]. This promises a better integration of various sectoral elements, a shift toward a better green economy, and sustainable development [40]. Cross-sectoral institutional engagement where all stakeholders can identify and prioritize common solutions from a nexus perspective will be useful in designing cost-effective policies targeting multiple cross-sectoral resources [41,42].

The integration of government policies related to the WEF nexus is highly dependent on specific case studies. The different characteristics of the resources in each country allow for different ways of managing them. This multisectoral approach can often reveal synergy weaknesses or even overturn local wisdom about the relationship among water resources,

agricultural production, and energy generation [43]. However, the WEF nexus helps avoid some of the negative implications of poor sectoral coordination, institutional fragmentation, and inadequate capacities and addresses sectoral interests and political sensitivities in a more participatory and open manner [8]. WEF nexus-oriented scenarios not only generate major co-benefits demonstrated through significant long-term increases in WEF yields but also achieve significant economic, social, and environmental outcomes [44].

Owing to large areas of villages, with 43% of the population living in these villages, Indonesian rural development policy becomes an essential factor for achieving the goals of the WEF nexus and SDGs. In the following section, the rural development policy will be explained in more detail.

4. Rural Development in Indonesia

4.1. Rural Condition

Indonesia has 83,813 villages, with 2768 (3.3%) villages located in forest areas, 18,617 (22%) villages located on the edge of forest areas [13], and 74.5% located outside forest areas. One of the problems faced by villages is the high rate of urbanization caused by: (a) the expansion of job opportunities that have not been supported by village infrastructure, (b) the uneven development of human resource capacity, (c) poor management of the village economy, and (d) the absence of initiatives from the village governments to increase village productivity [45]. In addition, rural communities face some challenges: population growth, food insecurity, land degradation, impacts of climate change, pressure on natural resources, and rapid transformation; therefore, the independence level of farmers is determined by their adaptability [46]. In addition to these limitations, rural farming communities in Indonesia have positive characteristics such as social capital, including the nature of kinship, cooperation, solidarity, and mutual trust among neighbors. Social capital can be used in empowering programs and improving community welfare with the support of transformative leadership, increasing human resources, and mentoring [47].

People in rural areas generally prioritize carbohydrate sources, especially rice, while other complementary foods are adjusted to the financial condition of each family. As an illustration, the consumption of calories and protein in the village is 2156 kcal and 60 g, while in the city, it is 2134 kcal and 64 g, respectively. This shows that the village population has a diet dominated by rice, while protein consumption (from animals and vegetables) is still lower than in urban communities. Some people in the villages obtain rice from their own fields, while protein has to be purchased depending on the availability of money [13]. Mehraban and Ickowitz [48] state that in the period 2000–2015, there was a decrease in the diversity of food consumed by rural communities in Indonesia due to the reduced diversity of agricultural land products.

Efforts to adapt to climate change in rural areas of Indonesia prioritize water management, intensification and diversification of agriculture and fisheries, education, health and food security, and human resource capacity building [49]. Not all farmers can anticipate the impact of climate change. For example, only 70% of farmers in Yogyakarta are willing to pay as a consequence of climate change adaptation [50]; therefore, efforts are needed from the government to assist farmers in dealing with the impacts of climate change.

One form of adaptation to and mitigation of climate change is by implementing an adaptive farming system through integrated agriculture. Rural communities manage their land by integrating crops and livestock; therefore, they have better food and nutrition security and protection from degradation [51]. Home yards on Java generally consist of three strata. The first stratum (bottom) consists of plant sources of carbohydrates, spices, medicines, ornamentals, and fruits; the second comprises fruit trees; and the third consists of tree species that produce wood and firewood [52].

The main source of energy for rural communities in various parts of Indonesia is firewood, obtained from the forest and from private land around the residence or in more distant locations. Firewood is used for cooking, two to four bunches per day. A bunch of firewood consists of eight pieces of wood, each 50 cm long. Village communities

around forests in Central Sulawesi use firewood from around their houses and from forest areas with a consumption rate of 447,955 kg/family or 746 m^3 [53]. The high firewood consumption in several areas in Indonesia has become a business opportunity for traders. The use of firewood is generally influenced by the price and availability of gas energy sources (LPG). People will return to using firewood if the price of LPG increases or it is not easy to obtain. Some home industries still rely on firewood because it is considered cheaper.

Several villages in Indonesia still have the problem of the availability of clean water. This problem arises due to environmental damage that results in the pollution of water sources [54], as well as an increase in population, which results in excessive water use and water pollution [55]. Inadequate water quality affects the lives of rural communities to meet household needs and agricultural needs, which are the main livelihoods of most rural communities in Indonesia.

4.2. Village Overviews from a Regulatory Perspective

Based on Village Law number 6/2014, a village is defined as a legal community unit with territorial boundaries with authority to regulate and manage the government and the local community's interests based on community initiatives. The law mandates that all village governments embrace and implement good governance values such as anticorruption, transparency, participation, and accountability. The authority of the village is obligated to administer the village government and implement village development by empowering the communities based on their initiatives, origin rights, and village customs. Law number 6/2014 no longer places villages as objects but as subjects of development. Through a scheme that prioritizes the principle of recognition and subsidiarity as a foothold, a village becomes a state entity, which potentially brings the role of the state closer to building prosperity and national sovereignty. The law explicitly recognizes the position of the village as a legal subject that has the right and authority to regulate and manage its own government [56].

As a follow-up to the Village Law, the government issued Government Regulation number 60, 2014 on village funds. The village fund is allocated annually for each village, with an average amount of one billion rupiahs, used to finance government administration, infrastructure development, and community empowerment.

With authority to establish village regulations, a village becomes a pillar of the nation in ensuring the security of WEF in their surroundings. This is in line with the 'nexus' approach in ensuring the availability of water–energy–food for human needs.

4.3. Sustainable Rural Development, Adapting Sustainable Development Goals

Indonesia committed to implementing the SDGs as a global action together with 193 countries in 2015. Presidential Regulation number 59/2017 serves as the legal basis for the SDG implementation for national to regional stakeholders. The SDGs have been integrated into Indonesia's national development agenda through the RPJMN and the Regional Medium-Term Development Plan (RPJMD) at the provincial level. The SDG targets in the RPJMN have also increased from 94 targets in 2015–2019 to 124 targets in 2020–2024 [57].

Villages in Indonesia hold a strategic position in achieving the SDGs. The Government of Indonesia's long-term vision, as set out in Indonesia's National Long-Term Development Plan 2005–2025, prioritizes rural development and agricultural reform as ways to achieve food security and self-sufficiency, promote equity across the country and promote economic growth. The long-term vision is supported by four five-year plans (REPELITA), with each plan emphasizing the importance of agriculture and rural development [58].

Contributing 74 percent to the achievement of the national SDGs based on territorial and citizenship aspects, villages are the backbone of the achievement of the SDGs [12,59]. The administration area of the 74,953 villages covers 91 percent of the Indonesian government area. This means that the fulfilment of village development goals contributes very significantly to the ten regionally oriented national SDGs: clean energy, economic

growth, industry and innovation, inequality reduction, climate mitigation, ocean conservation, land conservation, institutions, justice, and development of cooperation networks. In terms of population, 118 million villagers account for 43 percent of Indonesia's population. Thus, meeting the needs of villagers contributes in a major way to the five national SDGs related to citizenship: eradicating poverty, eliminating hunger, access to health, access to education, access to clean water, and anti-gender discrimination [12].

Referring to Presidential Decree 59/2017, The Ministry of Village, Development of Disadvantaged Regions and Transmigration of the Republic of Indonesia (Kemendes PDDT) issued Regulation number 13/2020 on Priorities for the Use of Village Funds in 2021 in which the goals and targets of SDGs were used as a reference for planning, implementing, and realizing sustainable village development. Priority for the use of village funds is directed to programs and/or activities to accelerate the achievement of the Village SDGs. In this regulation, the definition of the Village SDGs is an integrated effort to realize a village without poverty and hunger, an economic village that grows evenly, a village that cares about health, cares about the environment, cares about education, is friendly to women, networked, and is culturally responsive to accelerate the achievement of the Sustainable Development Goals. The goals and targets for the Village SDGs have even been developed from the 17 goals in the SDGs to 18 goals. The 18th target in the SDGs is to achieve dynamic village institutions and adaptive village culture, accommodating local community wisdom and productive village institutions [60]. Furthermore, through Regulation number 7/2021 on Priorities for The Use of Village Funds in 2022, the Ministry of Villages PDTT set priorities for village development through village funds to be focused on four important points, namely the Achievement of Village SDGs, National Economic Recovery, National Priority Programs, and Mitigation and Handling Natural and Non-Natural Disasters [61].

5. Implementing the Rural Water, Energy, and Food Nexus: Case Analysis

5.1. Opportunity and Challenges

This subsection explains the opportunity and challenge of the WEF nexus to reinforce integrated resources management.

5.1.1. Policy and Regulation

Indonesian policies on WEF security were based on national policies, which were translated into primary ministry-level policies, such as the Ministry of Public Works and Public Housing (PUPR), the Ministry of Agriculture (MoA), and the Ministry of Energy and Mineral Resources (ESDM). In the 2015–2019 RPJMN, the Government of Indonesia, through the Ministry of PUPR, targeted a 100% increase in raw water supply in 2019, from 56 m^3 s^{-1} to 114 m^3 s^{-1}, the management of idle raw water supply capacity, and the provision of a water supply standard for the outer islands.

As the derivate and technical policy, the PUPR's strategic plan for 2015–2019 was to attain water security by constructing new dams, improving critical lakes and dams, revitalizing small natural lakes, and improving catchment areas through conservation programs such as preventing erosion and sedimentation. In line with these policies, the MoA targeted the achievement of food security by developing new irrigation and rehabilitating the existence of irrigation, increasing crop intensity by modernizing irrigation systems and expanding irrigation areas, and improving water resource management in the existing swamp areas and groundwater irrigation schemes, as well as developing ponds to support the fishery program.

The Ministry of ESDM governs energy through the National Energy General Plan (*Rencana Umum Energy Nasional*/RUEN), which is then elaborated in Regional Energy General Plan (*Rencana Umum Energi Daerah*/RUED). However, out of 34 provinces in Indonesia, only 15 provinces have enacted a RUED, and two provinces have received Regional People's Representative Assembly (DPRD) approval [62]. Local governments have the authority to determine their development priorities and to use the RPJMN as a set of options to choose a framework to follow. Scott [63] found that this situation was the

reason the implementation of the WEF nexus policy at the provincial and district levels sometimes was missing from the RPJM.

Studies related to existing WEF policies in Indonesia found tradeoffs among the three resource policies. Bellfield, Sabogal, Pareira, Gangga, and Leggett [1] proposed some policies to reduce tradeoffs and strengthen synergies, such as expanding agricultural land by prioritizing degraded land, increasing agricultural productivity, and increasing investment in forest conservation. They also stated that land use planning in Indonesia had provided a good framework as a basis for cross-sectoral and scale planning. However, the lack of data impeded reducing tradeoffs. This requires strong evidence and in-depth analysis of demand and available resource capacity across sectors.

Additionally, based on the institutional constraints reflected by the gap between national development plans and local priorities, the national mid-term development plan is seen as a menu of options rather than a comprehensive set of rules and policies. Better governance at the subnational level has been identified as an important priority in addressing the challenges of spatial planning, ecosystem planning, and land-use management [64].

In terms of regulations, there are various regulations, from laws to ministerial regulations, that are sectorally related to water, food, and energy management. In addition, for the synchronization of various sectoral regulations, there are at least seven laws and two government regulations that can be the synchronizing rules for implementing nexus. For example, law number 26/2007 regulates Spatial Planning as a space for natural resources management, implemented on the principles of integration, harmony, balance, and sustainability. At the government regulation level, two regulations harmonize the nexus, one of which is PP 37/2012 on Watershed Management. The highest source of law, namely the 1945 Constitution of the Republic of Indonesia, is the spirit of all its regulations. Article 33, paragraph 3 of the 1945 State Constitution (UUD' 45) states that the state must manage the earth, water, and other natural resources for the greatest benefit of the people.

The mandate of the constitution related to natural resources, including those related to WEF, is translated into various regulations under it, ranging from laws (UU), government regulations (PP), presidential regulations, decrees, and instructions (PERPRES/KEPRES/INPRES), ministerial regulations and decrees (PER-MEN/KEPMEN), and regional regulations (PERDA). In Figure 2, we present a hierarchy of the regulatory system in Indonesia for WEF management based on our analysis of various WEF-related rules and regulations at various levels.

Regulations at the level of law and government regulation contain long-term national policies, while the presidential regulations contain medium-term policies (five-year). Ministerial regulations and decrees generally regulate norms, standards, procedures, and criteria (NSPK) and technical guidelines and coordinate matters related to implementation to achieve WEF security. The objectives of the above regulations are then translated into implementing regulations in the regions, which are subsequently formalized in the form of PERDA at the regional (provincial and district) levels.

The regulations at the ministry level, lower technical levels, and regional regulations are very diverse and detailed. Even local regulations vary according to the characteristics of each region. For example, the derivative rules of Law number 17/2019 on Water Resources are regulated by 19 of PP (Government Regulations) and more than 20 of the PERPRES (Presidential Regulations).

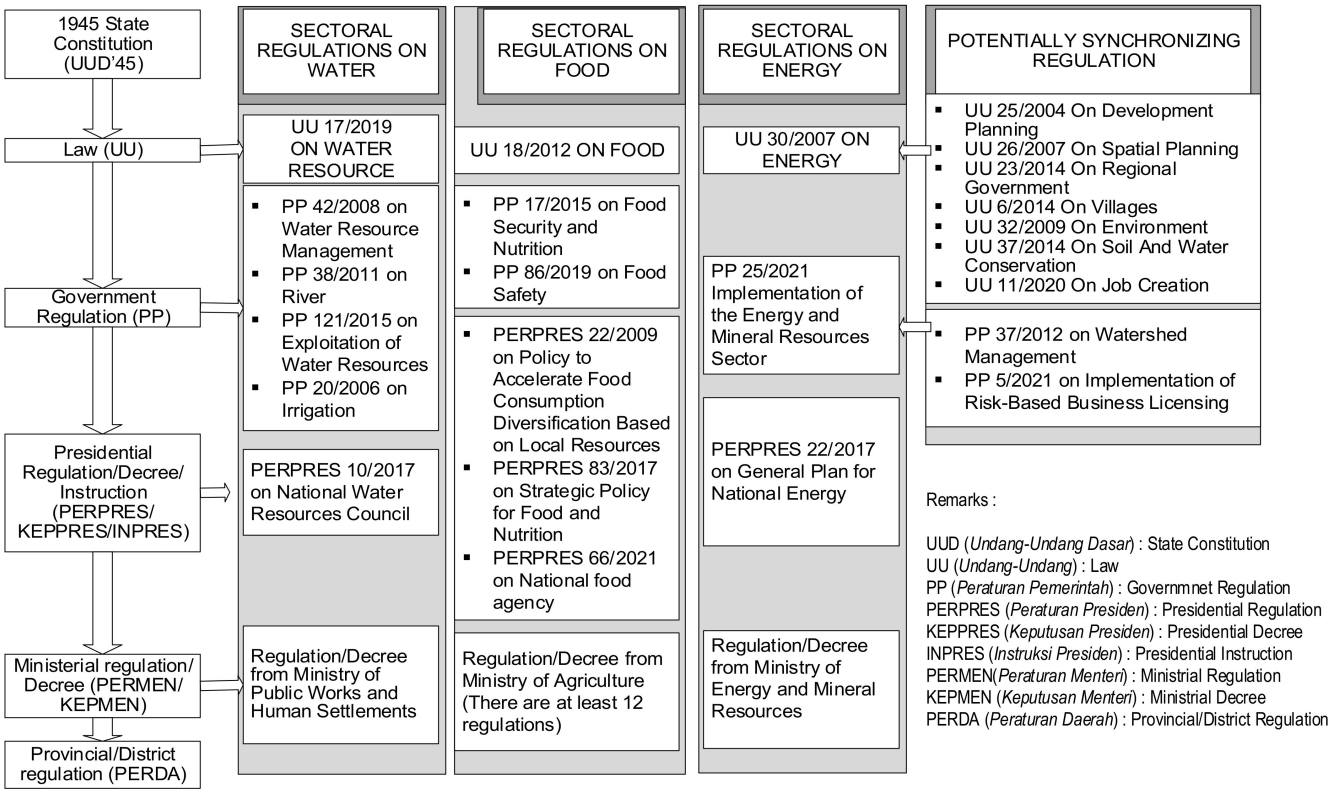

Figure 2. The Indonesian regulatory system's hierarchy for water, food, and energy management.

5.1.2. Institution

The Indonesian government is committed to meeting national targets on WEF security, as specified in the country's long- and medium-term plans. However, the WEF security targets in the 2020–2025 RPJMN are still at a macrolevel, without details on how the authority holders will implement these targets. The relationship among the WEF security programs and other natural resources (forests) and the environment has not been explicitly established [10,64]. Several major problems have hindered the achievement of these national goals, which are the mismanagement of resources, lack of coordination, and imbalance of authority across sectors, levels, and scales [1].

In the era of decentralization, the difficulties become complex when local administrations (34 provinces, 416 regencies, and 98 cities) have different ways and goals. However, a decentralized system can effectively achieve national goals if each local government has a consistent structure and implementation strategy. This has reduced the central government's power to influence provincial policies while increasing the complexity of coordination horizontally (between ministries) and vertically (among central, provincial, and district governments).

There is an institutional gap between top-down national development plans and local priorities. Addressing this problem requires various development models and policy instruments that respond to the dynamics of the Indonesian archipelago. Local governments have considerable control over natural resource management and land use planning. Decisions at this level will determine whether and how Indonesia achieves its WEF security goals. The approach commonly used in policy making on water resources for agriculture is to make it part of the economic/political/administrative policy chain from the global level to the farmer level [23].

The WEF security targets were not achieved at the rural and local government level (e.g., Karawang Regency) due to the extensive overlapping of authorities and responsibilities among institutions at the district, provincial, and national levels. Synergy and collaboration are two keywords that must be prioritized to improve the WEF sector in

a sustainable and more effective manner. This type of collaboration can be observed in the development of the WEF security nexus model, which involves all relevant players in the region [34]. Currently, joint planning and activities to accomplish WEF's security targets at the local level are still very limited. Almost all local governments, both provincial and regency/city, have established institutions to ensure the availability, accessibility, and utilization of food supply. It is in compliance with Law number 18/2012 on Food and Law number 23/2014 on Regional Government, as amended and supplemented with derivative regulations. However, no single local agency is responsible for ensuring water and energy security, resulting in discrepancies in goals, targets, and measures.

The existence of the Food Security Agency is still new in the municipal government, so it has not yet developed the capacity to serve as a coordinating entity for planning and implementation in a particular area. The unclear division of responsibilities and roles in terms of production and fulfilment of food demand among relevant agencies, such as the Agriculture Service, Fisheries Service, and Animal Husbandry Service, can result in ineffective synchronization of achieving food security targets for the region. Even within one industry, this complicated institutional structure makes achieving targets difficult [34]. Additionally, a coordinating agency for water and energy security was not established because local governments had to coordinate with regional institutions and national-level organizations.

The Regional Planning Agency (BAPPEDA) could start by involving all WEF-related stakeholders in designing and establishing realistic rules and regulations, using the processes outlined above as a guide. Further, by collaboration with other stakeholders, local policymakers can propose the establishment of a WEF Resource Security Coordinating Board to replace the Food Security Agency to the central government.

This Coordinating Board will assist in planning, executing, and synchronizing the attainment of WEF security targets between the central and local governments. Additionally, through this board, cooperation between the government of a region and other regions can help local regions to meet the demands of WEF in each region by its potential [34].

The review findings indicate that the main obstacles in implementing the WEF nexus are funding, choice of government priorities, and more urgent community needs. Inadequate institutional coordination, exacerbated by the traditional silo approach to policy formulation and landscape diversity, makes nexus strategy setting more challenging.

5.1.3. Water Potential: An Enabling Factor

Water plays an important role in Indonesia, not only in sustaining the lives of the fourth largest population in the world but also in supporting the primary needs of its people, namely food and energy. The potential of abundant water resources is an enabling factor for many other resources utilized by the Indonesian population. While electricity is needed in the Netherlands to raise water from rivers to irrigate agricultural land and while in parts of Africa water scarcity is a barrier to food production, in Indonesia, the potential energy from water flowing from the mountains naturally can be utilized to produce energy and food at a lower cost than other regions in various parts of the world.

Indonesia has a large and abundant water resource potential [65,66]. Vallee et al. [67] stated that Indonesia ranked fifth in terms of total water/capita/year, which was 13,381 m^3/capita/year and also ranked fourth in terms of actual total renewable water resources after Brazil, Canada, and Russia. The status of water resource availability in Indonesia can be seen from the availability of primary water from major islands in Indonesia. The total available water is 2110 mm $year^{-1}$ or 127,775 m^3 s^{-1}, which is equivalent to 4 billion m^3 $year^{-1}$ [68]. In detail, Table 1 presents the data on the availability of water resources for the major islands in Indonesia based on 1996 data [69] and average surface water availability between 2003–2015 [70].

Table 1. Surface Water Availability on Major Islands in Indonesia in 1996 and 2003–2015.

Island	Area (km^2)	Population		Water Availability (m^3/s)	
		1995 [1]	2015 [2]	1996 *	2003–2015 **
Java	132,698.13	114,733.5	146,675.4	7360	5567
Sumatra	472,849.20	40,830.3	56,119.3	32,198	23,026
Kalimantan	534,912.09	10,470.8	16,301.3	28,369	25,126
Sulawesi	185,150.03	13,732.4	18,973.3	9458	6470
Bali and Nusa Tenggara	71,718.55	10,118.8	14,299.8	3251	1141
Maluku	78,373.79	2,086,516	2901.4	4385	2575
Papua	412,738.35	1,942,627	4100.8	32,754	24.350

Sources: [1] [71]; [2] [72]; * [69]; and ** [70].

Based on Table 1, there is a decrease in the average availability of surface water on all the big islands in Indonesia. On Java, the total water availability decreased from 7360 m^3 s^{-1} to 5567 m^3 s^{-1}. The largest decrease in surface water availability occurred on the island of Sumatra, which was 9.172 m^3 s^{-1}. The island of Java, with 60% of the total population of Indonesia, only has 10% of the water reserves. In contrast, Kalimantan, with 30% of Indonesia's water reserves, is only occupied by 6% of Indonesia's population. In addition, Papua, with 70% of the water reserves, is only inhabited by 13% of Indonesia's population [73,74]. Due to population density, Java is predicted to experience a water crisis because of an imbalance of water availability and population. In 2015, the water demand on Java reached 164.672 million m^3 year^{-1}, while the availability of water was only 30.569 million m^3 year^{-1} or a deficit of 134.103 million m^3 year^{-1} [73].

The increase in population caused an increase in the need for water for various purposes. Meanwhile, water resources remained constant and even experienced a decline in quality due to pollution [66,75–78].

The Ministry of PUPR estimates that water availability on Java will decline to 476 m^3 per person per year by 2040. This is categorized as "total scarcity" and is below the current annual rate of 1169 m^3 per capita, while the ideal amount of water per capita is 1600 m^3 year^{-1}. Almost 10% of Indonesia's territory is predicted to experience a water crisis in 2045 [11]. The problem is that Indonesia, as an archipelagic country, will face difficulties in distributing water from abundant to water-scarce areas [11,74].

5.1.4. Constraints and Strategy of Implementing Nexus Approach in WEF Management

From the various literature sources, we tried to formulate supporting conditions, constraints, and strategies in implementing the nexus approach to realizing water, energy, and food security in Indonesia. Supporting conditions in the form of regulations are for instance (1) the availability of regulations on soil and water conservation, watershed management, environmental management, and community empowerment [79–81]; and (2) the availability of local regulations on waste management and sustainable land protection of food agriculture [79]. In WEF management, the existence of specific institutions is an important asset. These institutions are those related to the rivers and watershed management [79–81] and regional agencies related to WEF and environmental resources [82]. At the implementation level, there are several programs that have been carried out by government with financial support from central and local governments [79,80], namely the construction of reservoirs/dams [66,80], soil and water conservation technologies for rural and urban communities [79,80], and forest and land rehabilitation programs [79,80,83]. These efforts are not only carried out by the government (central and regional), but also by the community, individually and through community groups such as farmer groups, water resource conservation groups, and associations of farmer water users. [80,84,85]. In addition, Indonesia also has useful natural resources, such as plenty of rivers, tributaries, and springs [66,86]. Those become capital and opportunities for improving WEF management in the future. On the other hand, WEF management in Indonesia also faces

many constraints at the institutional and implementation levels. The existence of some institutions related to the management of WEF faces many constraints in coordination due to conflicts of interest among sectors. [79,81,82]. The weak coordination between central and local agencies, as well as between regional and cross-regional governments [66,79,80] hinders the integrated WEF management.

At the implementation level, there are interrelated constraints influenced by people. Firstly, higher population growth will increase the need for land for settlements and industries. This will lead to a conversion of land use from agricultural land to other uses [87,88]. As a result, agricultural land will be exploited beyond its carrying capacity, and agricultural practices are not environmentally friendly [66,79,89], causing land degradation, erosion, sedimentation, and reducing water resources [46,79,87]. In the end, it will reduce water availability significantly, especially during the dry season [66]. Secondly, the higher population growth results in an increased demand for WEF [46,80,85,90]. In turn, this leads to WEF scarcity. Unfortunately, this condition is exacerbated by the improper use of water [80,85], decline of local wisdom in water management [91], and improperly managed waste polluting groundwater and rivers [84]. Considering the importance of human influence in WEF management, community participation is needed, but it is still not optimal [79,83].

In the WEF nexus, water is at the heart of the bond because the availability of water is critical to food and energy security [1]. Therefore, efforts to preserve water resources, both in quality and quantity, are the focus of the management strategy to fulfill the need of the three components of WEF. On the other hand, the sustainability of water resources is influenced by land cover and use [1], so efforts to manage land in a sustainable manner are very important in preserving water resources. Increasing the success of forest and land rehabilitation (RHL), improving soil and water conservation practices, controlling land-use change aimed at controlling and reducing erosion and sedimentation, and increasing catchment areas will ultimately preserve water resources, thus ensuring energy source and land productivity for food.

Many sectors are involved in WEF management, such as forestry, agriculture, water resources, and energy. WEF management also involves cross-regional government. Therefore, integrated management is the primary strategy that must be taken [66,79,81]. However, coordination among stakeholders and across regions is still a challenge. To overcome it, the WEF management strategy at the government level is to build coordination among stakeholders and across regions and integrate each sector's policies. The strategies used are (1) improving effective coordination among cross-sectoral institutions at both the central and regional levels; (2) improving cross-regional coordination; and (3) integrating water management policies for various sectors related to food (such as agriculture, fisheries, and animal husbandry), households, industry, etc. The program is expected to be implemented in an integrated manner through this strategy, making it easier to monitor and evaluate its success. However, integrating policies requires a strong commitment from each stakeholder, so the strategy of informing law enforcement about national and regional laws and regulations for waste management and WEF sustainability must also be carried out.

In WEF management, the community is not only the beneficiary of water, food, and energy, but the community as the landowner will determine the management pattern. Therefore, community participation (individual or group) is necessary [86]. The strategies chosen are (1) enhancing community awareness in water and waste management; (2) transferring soil and water conservation technology through farmer groups, water resource conservation groups, associations of farmer water users, etc.; (3) empowering community groups in managing water and land properly and paying attention to conservation principles; and (4) empowering community groups in waste management. In addition, considering that there is a lot of local wisdom in water management in Indonesia, which is currently starting to disappear [91], maintaining this local wisdom is also important. Through these strategies, the activities carried out are more bottom-up and in accordance with community conditions. This community empowerment strategy will maintain the sustainability of conservation efforts [83], so it is expected to maintain the

quantity and continuity of water resources. Moreover, the strategy of waste management is also important because when the waste is managed properly, the soil and water quality will be maintained.

5.2. WEF Nexus Implementation: Lesson Learned

Indonesia faces complex challenges in meeting the food and clean water needs of its 270.2 million people, with a growth rate of 1.25 percent per year [92], while the area of agricultural land has decreased by 12.9% yearly [93]. The disruption of the habitat of food commodities due to the increase in population and livelihood pressures threatens the food production sustainability [94–96], which in turn reduces carrying capacity [9]. The decline in the carrying capacity of agricultural land is the reason for realizing national food security in Indonesia [97] and also for the relation between agriculture and food security for rural farming households facing land degradation, water availability, and climate variety [94]. Based on the Prevalence of Undernourishment (PoU) calculation results in 2017, the number of Indonesians experiencing insufficient food was 8.26 percent or around 21.63 million people and increased to 8.60% or 23.24 million in 2020 [98].

Environmentally friendly agriculture is needed to ensure safe food access by implementing reciprocal relationships among the water, energy, food, land, and ecosystem (WEFLE) sectors [9]. The ability to access food must be accompanied by ensuring the sustainable use and stability of food stock. Indonesia has demonstrated a commitment to a more diverse, sustainable, and healthier diet to achieve the SDGs (end hunger, achieve food security, and improve nutrition) with sustainable agriculture [93]. The concept of outsourcing staple food in tropical forest margins [99] has pointed to rural income security as a basis of food security.

5.2.1. Agroforestry as an Option for Promoting Rural Water and Food Security

The Nexus concept (Ecosystem–Water–Food–Energy) represents a challenge toward achieving sustainability goals, especially within the agri-food sector [9]. Optimization of agroforestry in the WEF nexus is very important to determine the availability of land and water and to support the search for alternative resources effectively [100]. Site-specific forms of agroforestry management can reduce problems in forest–water–human relations by balancing upstream and downstream interests [101]. Agroforestry is the potential to meet the challenges of food security and climate change in dry areas [102–104]. Agroforestry also improves crop security and agricultural livelihoods, especially among the most vulnerable food producers (poor rural farmers) [105]. The high interdependence, synergies, and tradeoffs among components (forest, water, food, and energy) make the use of the nexus approach in the era of climate change a priority. A comprehensive policy is required to support the development and sustainable management of forests, water, food, and energy [106]. The challenges in developing forest–water–human linkages are (1) unclear extrapolations in each case, (2) cultural limitations to applying linkages among factors, and (3) difficulty in integrating these three factors into a policy, so further research is required [101].

Agroforestry is a form of landscape management that allows for close linkages among water, energy, food, and land as well as climate change and human well-being. [94,105,107–109]. Smart agroforestry as a food and energy production nexus can produce energy (fuel wood, oil seeds, lignocellulosic, biomass, and biogas), agriculture, food, and water (water table and water quality) [107]. A case in Africa describes that agroforestry can produce fire wood, food, soil, and water conservation in a WEFL (water, energy, food, and land) nexus [100]. Agroforestry as an efficient agroecological practice can be a tool to change unsustainable agriculture into sustainable agriculture (efficiency of water and energy) [107]. The agroecological system can impact climatic change adaptation, biodiversity, and soil and water conservation (water and energy efficiency) [104]. In rural planning, agroforestry is a beneficial land use that can produce local food, timber, ecosystem services, and biodiversity [110]. Multifunction agroforestry can enhance water infiltration and storage, reduce runoff, produce fuelwood and food, and adapt to climate change in the WEF nexus [105].

Trees in agroforestry can manage natural water, produce bioenergy and food diversity, and provide ecosystem services in the WEF nexus [109]. A sustainable agroforestry landscape can be a tool to manage forest–water and people–food rules [109]. Agroforestry in micro, meso, and macroscales is multifunctional, i.e., it can be a tool for the sustainable use of hydropower (reducing silting of reservoirs and river sediment load), fire wood, food, climate change, and water nexus [111].

5.2.2. Microhydropower and Productive Use of Energy (PUE) Development: Relating Water to Energy Security

Water, one of the "forest products," has great potential as a source of electrical energy through microhydropower. A microhydropower (MHP) plant employs a rotor placed in a water line or pipe to generate power ranging from 5 kW to 100 kW [112]. MHP is the most attractive alternative renewable energy source compared to other renewable energies, partly because it is efficient, has little impact on the environment, and is localized [113–115]. This energy access will significantly impact rural growth and livelihood improvement positively [116].

Since 2003, Balai Penelitian dan Pengembangan Lingkungan Hidup dan Kehutanan (BP2LHK) Makassar (Research and Development and Innovation Agency of the Ministry of Environment and Forestry of Makassar) has been designing the use of MHP incentives as an instrument of Community-Based Forest Management (CBFM) in the upstream watershed. Based on the observations, apart from the problem of forest destruction in most of the observed villages, there are many inefficiencies in water use. The available water throughout the year is not used properly. Unmaintained waterways drain water into the land below and trigger sheet erosion, channel erosion, and landslides due to a load of wet soil on top of the impermeable layer [117]. Technically, the opportunity to build microhydropower plants around forest areas is very high [118] as long as there is running water and different heading heights [117]. In general, the water potential around forest areas in the upstream watershed is abundant throughout the year, and the mountainous topography allows for differences in altitude [119,120].

Replication of MHP activities began in 2009. The MHP activities have been implemented by several institutions, including regional governments, the Technical Implementation Unit (UPT) of the Ministry of Environment and Forestry (MoEF), and local community groups, in collaboration with BP2LHK Makassar to meet the needs of dozens of villages around conservation forests and protected forests in various regions of Indonesia.

At the implementation stage, the use of MHP extends from lighting to economic improvement through processing agricultural products and carpentry (almost in all locations), rural development of education and skills course institutions (The District North Buton, Southeast Sulawesi Province), and development of community character through religious activities (The District of Bulukumba, South Sulawesi Province).

In 2016, BP2LHK Makassar began to conduct research on and develop electricity from MHP to improve the community's economy by developing integrative PUE in the districts of Bantaeng and Bulukumba. The development of this PUE is also part of efforts to develop "green products", which is in line with one of the corrective steps taken by the MoEF to promote a green economy policy. This policy is part of efforts to balance the economic added value of forestry businesses and utilization of environmental services while maintaining forest sustainability, environmental quality, and ecosystem balance to achieve sustainable development. Through the development of this PUE, the electricity generated from the MHP is not only for lighting but also for driving the rural microeconomy. The development of energy use for productive activities will trigger an increase in the rural economy, which can create a healthy and prosperous community. In the long term, this activity increases income and reduces the potential for migration of the poor from rural to urban areas [116].

Based on the research activities carried out for more than 6 years above, the authors who are also the research team of these activities formulate the relationship between inputs

and outputs in the management of participatory MHP in the Bantaeng and Bulukumba districts in a flow chart as presented in Figure 3.

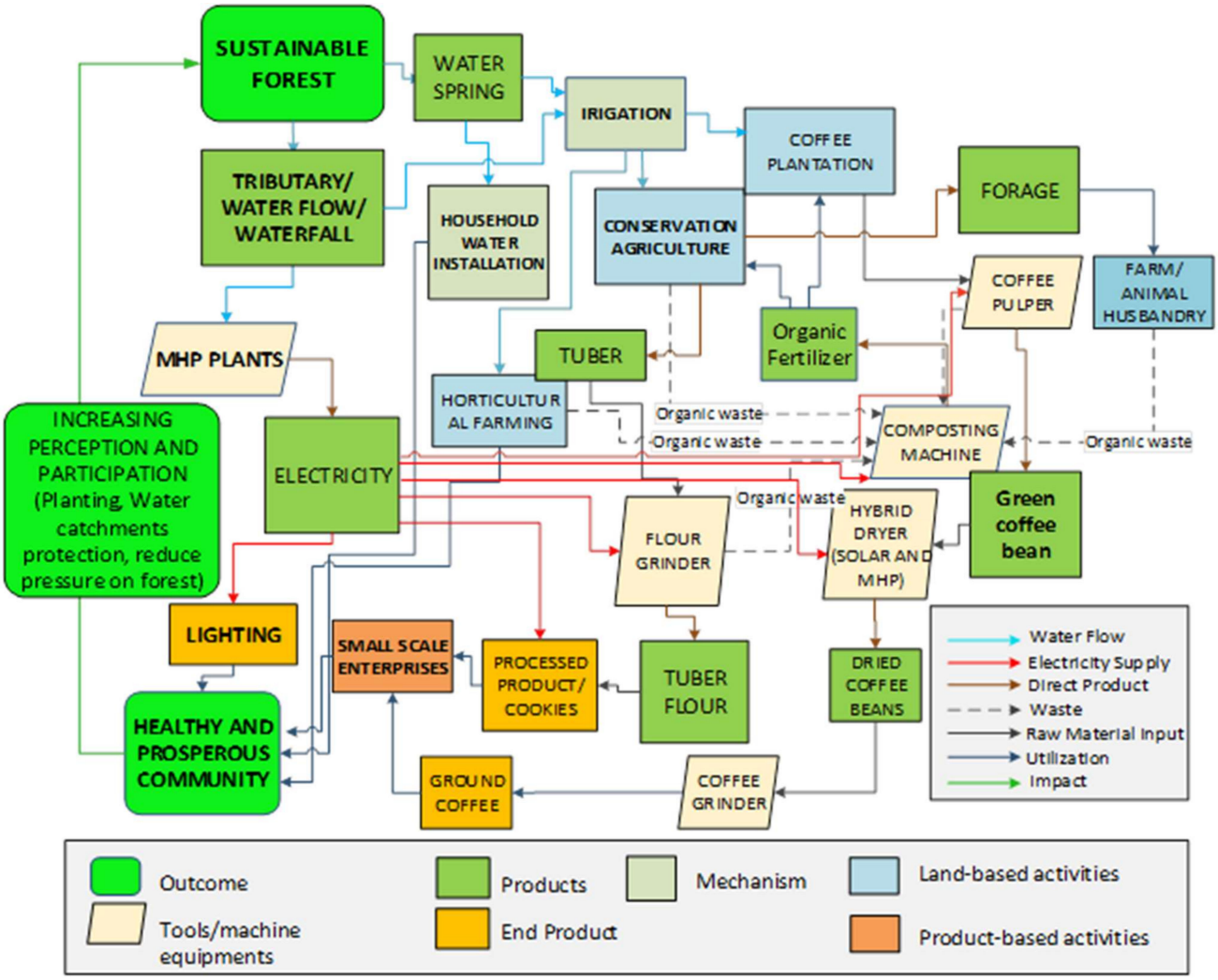

Figure 3. Extensive and integrated development of MHP utilization in Bantaeng and Bulukumba.

The collective awareness of the community in participating in the protection of water sources and surrounding forests has increased. The community manages the resources in groups, repairs the damage, and develops their use to drive a productive rural economy. This is positively correlated with the level of disturbance to the forest. In the beginning, there was a lot of unproductive free time, so the community entered the forest to carry out activities damaging the forest and land. With the MHP-based PUE activities, productive time increases, and more time at home to carry out productive business activities provides economic benefits. Socioreligious activities are also improving. The presence of electricity maximizes the function of places of worship such as mosques and churches.

5.2.3. Social Forestry to Support Water, Energy, and Food Security of Forest-Dependent People

Social forestry (SF) is the policy that is closely related to the achievement of WEF since this policy focuses on the socioeconomics and culture of the communities. Social Forestry embarked on a new phase when the Ministerial Regulation No. P.83/2016 was enacted. In the RPJMN 2015–2019, the Government of Indonesia targeted 12.7 million hectares of forest managed by communities through SF schemes, including hutan kemasyarakatan (community forestry), hutan desa (village forests), hutan tanaman rakyat (community

plantation forests), and hutan adat (customary forests), as well as forming partnerships for collaborative forest management. This scheme has not yet covered private forests, which are the main component of forested areas in several districts of Indonesia. For instance, in Bulukumba Regency, South Sulawesi, 72% of its forested area is private forest [121].

The social forestry scheme gives the community the flexibility to manage and maintain forest cover while at the same time resisting attacks from other parties who want to encroach on their forest areas [122]. Regarding food security, the social forestry scheme is expected to produce around 11 million tons of rice in an area of about 2.7 million hectares. This amount is equivalent to 30–33 percent of national rice production [123].

Bantaeng Regency is one of the pioneers in the development of Village Forests, which aims to provide access for the community through village institutions to use forests in a sustainable manner. Village Forests provide tangible benefits to the community through the use of Non-Timber Forest Products (NTFPs) in the form of honey bee (Honey bee), passion fruit (*Passiflora edulis*), coffee (*Coffea canephora*), candlenut (*Aleurites moluccana*), rattan (*Calamus* Spp.), and keluak (*Pangium edule*) [124]. In addition, there are benefits as a source of irrigation water for irrigating rice fields that support food security programs, a supply of 15.4% of raw water for PDAM Bantaeng Regency, and a source of energy for microhydropower plants with a capacity of 10,000 kWh managed by a community group of Biringere Sub Village, Pattaneteang Village [125].

Another successful example is forest management as a water catchment area and community power source in the Aek Rau Lestari Community Forest in North Tapanuli. Water resources from the forest area are capable of driving a microhydro turbine of 10,000 watts, generating power of up to 30,000 watts to meet the electricity needs of the community [126]. However, although SF in Indonesia was started before 2016, there is no effective evaluation framework for SF programs in achieving the desired goals such as (1) resolution of tenure conflicts, (2) improvement of welfare, and (3) forest protection. Therefore, a more substantial commitment from all stakeholders is required to further advance the SF program's achievement in Indonesia [127]. Community-managed areas require support and innovation to improve the economy and overcome poverty around forests [122]. One of these areas is the legal certainty of social forestry licensing to forest farmers, in addition to facilitating social governance, production, institutions, and capital and marketing [123].

Unfortunately, the budget for social forestry is still very small. According to the Indonesia Budget Center, the budget required for social forestry should ideally be Rp. 327,000/ha. In fact, the available budget is only Rp. 100,000/ha [122].

5.2.4. Paludiculture as an Alternative Sustainable Peatland Utilization for Food

Paludiculture is an alternative to the revegetation of degraded Indonesian peatlands. It is an act of revegetation and local livelihood revitalization [128]. Paludiculture is cultivation in wetlands to conserve peat (or even establish new peat), stop subsidence, and minimize GHG emissions [129]. Basically, paludiculture is a sustainable alternative to peatland utilization involving growing crops with no drainage [130]. The key point of paludiculture is, first, "no drainage" and rewetted or wet peatland. Therefore, dryland species that require drainage will not survive on rewetted or wet peatland. Secondly, the paludiculture species only use local native and nonnative species that adapt to the wet peatland [131–133]. Budiman, Bastoni, Sari, Hadi, Asmaliyah, Siahaan, Januar, and Hapsari [133] concluded that paludiculture projects in Indonesia could be categorized as "compromised" paludiculture because they do not follow paludiculture principles such as rewetting and the utilization of local peatland species. Giesen [134] emphasized that the implementation of real paludiculture is lacking in Indonesia for two reasons: very few examples for farmers to follow and a lack of information about paludiculture species. Giesen [134] stated that there were 1376 lowland peat swamp forest species, and only 38.8% of those species (534) are useful species, and 514 exist in Indonesia. Not only for food, but trials have also been conducted using plant species for bioenergy production in the peatland of Central Kalimantan [135]. Moreover, Maimunah et al. [135] showed two bioenergy-producing species were

able to survive and grow well in the peatland, namely *Calophyllum inophyllum* (Nyamplung) and *Reutealis trisperma* (Kemiri sunan). These findings have confirmed that paludiculture can be an alternative to peatland utilization to provide food and energy; by conserving the water (peatland rewetting), we can obtain sustainable food and energy production. The paludiculture species found in Indonesian tropical peatland are presented in Table 2.

Table 2. The paludiculture species found in Indonesian tropical peatland.

Species	Reference
Ipomoea aquatica (water spinach)	[128,133]
Momordia charantia (bitter groud)	[128,133]
Stenochlaena pallustris (kelakai)	[128,130,133]
Metroxylon sagoo (sagoo)	[128,133]
Garcinia mangostana (mangosteen)	[128,133]
Syzigium aqueum (water apple)	[133,136]
Aleurites moluccana (candlenut)	[130,133]
Ananas comosus (pineapple)	[128,130,136]
Cucumis melo (sweet melon)	[130]
Shorea app. (Illipe nut/Tengkawang)	[130]
Salacca sp. (snake fruit)	[130]
Nephelium lappaceum (rambootan)	[130,136]
Local fish in *beje* (natural fish pond in Central Kalimantan)	[128]
Baccaurea spp. (rambai/fruit)	[132]
Mangifera spp (mango)	[132,136]
Dimocarpus longan (longan)	[132,136]
Sandoricum koetjape (*Santol*/fruit)	[132,134,137]
Oncosperma tigillarium (*nibung*/spice)	[132,134]
Cyperus rotundus (teki bulbs/spice)	[132,134]
Garcinia morella (edible oil/fat)	[132,134]
Canarium littorale (edible nut)	[132,134]
Calophyllum inophyllum (nyamplung/bioenergy)	[135]
Reutealis trisperma (Kemiri sunan/bioenergy)	[135]

Regardless of its application in Indonesia, whether pure paludiculture or not, we agree that paludiculture is a win-win solution to restore degraded peatlands, reduce GHG emissions, and avoid fire risks while increasing food and energy security [133]. The challenges for paludiculture development are (1) lack of information about local peatland species (cultivation techniques, postharvest, and marketing aspects), (2) lack of seed sources for local peatland species, and (3) limited knowledge of migrant farmers about the cultivation of wetland species and how to conduct rewetting without causing flooding.

5.2.5. Participatory Water Resource Management (WRM)

One of the regulations that supports/requires participation in WRM in Indonesia is the law on soil and water conservation (Regulation No 37/2014). The regulation mandates that everyone who has land rights, both in cultivation areas and in protected areas, is obliged to carry out soil and water conservation for each type of use. Similarly, everyone who uses land and water is also obliged to carry out soil and water conservation. Indonesia's land use planning tools provide a good framework that can be used to improve the consistency of development plans across sectors and across scales [1]. Indonesia's Spatial Planning Law (Law number 26/2007) stipulates the spatial distribution of land use within the country, provinces, and regions and guides the formulation of Indonesia's mid-and long-term development plan. This regulation directs landowners/land users to use their land in such a way that does not provoke conflict.

WRM cannot be separated from the management of the watershed. A watershed can be a unit of management because, in the watershed, there is an interaction of human activities, namely land use, which directly affects water. Water quality, quantity, and continuity are directly affected by human activities (land use) [138–142]. Stakeholder involvement is

very important in realizing integrated watershed management, while sectoral development methods must be discontinued. The legal aspect of involving stakeholders, government institutions/agencies, the private sector, non-governmental organizations (NGOs), and local communities is written in Regulation No.37/2012. Each stakeholder has roles and functions according to their main duties and responsibilities. At the local level, the role of the community becomes critical; it should be encouraged to reduce the rate of forest and land degradation in watershed units. The regulation also mandates (Article 57) the community to share information, suggestions, and considerations in watershed management.

The government, through the Directorate General of Watershed and Protected Forest Management (PDASHL) and the MoEF, established a program for increasing the carrying capacity of watersheds by improving environmental quality, increasing the economic and social benefits of watersheds in protecting forests, and saving water resources (lakes, rivers, springs, and groundwater) along with artificial infrastructure resources (dams, reservoirs, etc.) as well as strengthening the management of watershed control and protecting forests [143]. The government has established village and community nurseries that are distributed free of charge to attract community participation in forest and land rehabilitation. Local communities, both individuals and groups, are involved in the nursery management and use the seeds to rehabilitate their land. In addition, to improve land cover, this vegetative land rehabilitation also supports the lake restoration program [143].

The state government ensures the people's right to have water for daily needs in sufficient amounts, of good quality, safe, sustainable, and accessible. In this regard, water assets cannot be possessed and/or controlled by people, communities, or business entities. The central government stipulates arrangements for meeting water needs in watersheds in accordance with their respective authorities. Law No 17/2019 on Water Resource regulates the involvement of village-level government in WRM policy formulation.

Indonesia has applied multisector collaboration among parties in WRM; the parties involved are the Ministry of Public Work and Housing, the Ministry of Agriculture, the Ministry of Trade, and subnational governments. All parties share responsibilities in terms of infrastructures, such as dams and irrigation, markets, and transportation. However, in its review, the World Bank provides several recommendations to improve the WRM aspects, such as improving operations and maintenance, scaling up and institutionalizing participatory irrigation at the subnational level, and improving convergence in planning, budgeting, targeting, and monitoring [144].

The WEF nexus influences and is influenced by other sectors, such as economic, social, political, and environmental, which adds to the nexus complexity. By law, Indonesia has integrated many related parties to play roles in WRM. In practice, although this law is complemented by more practical regulations, it is difficult to implement for several reasons, such as confusion between government regulations and the interests of relevant institutions [145].

6. Conclusions

With the resources owned and supported by the authority to set village regulations and manage the village budget independently, the village becomes a pillar of the nation in ensuring the security of WEF in their surroundings. This is in line with the 'nexus' approach in ensuring the availability of water–energy–food for human needs, which strategically needs to start from management at the source. The emergence of the nexus is the result of the scientific community thinking about WEF resource interrelationships and the need for multidimensional management due to its complexity.

The Indonesian government is committed to meeting national targets on WEF security, as specified in the country's long- and medium-term plans. The largest challenge in optimizing the WEF nexus is balancing human needs and environmental sustainability as mandated in the Indonesian State Constitution. However, from a regulatory perspective, the integrated management through the nexus approach is still in its early development. This is reflected in the partial planning of WEF security in the RPJMN, in which the linkages between them are still weak. The WEF security targets in the 2020–2025 RPJMN are still

at a macrolevel, without details on how the authority holders will implement the targets. Additionally, the review's findings indicate that the main obstacles to implementing the WEF nexus are funding, choice of government priorities, and more pressing community needs. Inadequate institutional coordination, exacerbated by the traditional silo approach to policy formulation and landscape diversity, makes nexus strategy setting more challenging.

At the implementation level, despite land degradation and food insecurity due to climate change, rural areas with existing landscapes and human and natural resources become strategic areas in realizing water, energy, and food security. Rural farming communities in Indonesia have positive characteristics such as social capital, including the nature of kinship, mutual cooperation, solidarity, and mutual trust among neighbors. Social capital can be used in empowerment programs and improving community welfare with the support of transformative leadership, increasing human resources, and mentoring.

The main strategies of WEF management in rural Indonesia are adopting an integrated and coordinated cross-sectoral and cross-border approach to reconcile the potential conflict of interests, empowering the community, and informing law enforcement about laws and regulations for WEF sustainability. In upstream watershed areas, villages and existing forests can forge mutually beneficial relationships. The social forestry program developed by the government is managed at the site level by the local village government, and farmers can be an entry point for farmers and communities to participate in managing the potential water, energy, and food chains. The ability to access food must be accompanied by ensuring the sustainable use and stability of food. Indonesia has demonstrated a commitment to a more diverse, sustainable, and healthier diet to achieve the SDGs (end hunger, achieve food security, and improve nutrition) with sustainable agriculture. Indonesia has demonstrated a commitment to promoting sustainable agriculture to achieve food security through more diverse local food products. Forest and tree crop products can be a basis of income and food security. Through agroforestry, land productivity can be achieved sustainably because of its ability to control water use and erosion, maintain soil fertility, and restore degraded land.

In addition to the agroforestry system, best practices that can support the success of WEF nexus implementations are microhydropower plants (MHP) and social forestry. In rural areas surrounding forests and in the upper watershed, energy access through MHP has significant positive impacts on rural growth, livelihood, and environmental conditions. Synergized with MHP-based incentives, the social forestry scheme gives the community the flexibility to manage and maintain forest cover while at the same time resisting attacks from other parties who want to encroach on their forest areas.

However, despite holding a strategic position, the village is not the sole actor. The WEF nexus influences and is influenced by other sectors, such as economic, social, political, and environmental situations, which adds to the nexus complexity that requires the ability to adapt to many situations through a multisectoral approach. Adopting an integrated and coordinated cross-sectoral approach to WEF management can reconcile potentially conflicting interests.

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