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Sustainable Water Management in Tidal Lowland Agriculture: A Research Agenda

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Abstract
Water in tidal lowlands may either lack or excessive. Neither lack nor excessive of water is demanded for crop cultivation. Therefore, water management plays an important role in the development of tidal lowland agriculture through maintaining proper water conditions. Since tidal lowland with certain conditions is considered marginal, its utilization for crop cultivation should maintain its fragile characteristics such that its utilization to support crop production can be sustained. Continuing use of tidal lowlands for crop production, therefore, requires agricultural ecosystem management through the establishment and measurement of sustainability in water management. Sustainable water management in tidal lowlands for crop production should not only consider the physical resources (infrastructures), but also human resource as well as financial resource. This paper proposes three agendas for research on water management as follows: (1) identification of specific local water infrastructure developments, (2) initiation of participatory operation and maintenance of water infrastructures, (3) utilization of self-supporting financial means in water management.

Keywords: tidal lowlands, water management, sustainability, cultivation

Abstrak
Air di dataran rendah pasang surut mungkin kurang atau berlebihan. Tidak kekurangan atau berlebihan air dituntut untuk budidaya tanaman. Oleh karena itu, pengelolaan air memainkan peran penting dalam pengembangan pertanian dataran rendah pasang surut dengan menjaga kondisi air yang tepat. Karena dataran rendah pasang surut dengan kondisi tertentu dianggap marjinal, pemanfaatannya untuk budidaya tanaman harus menjaga sifat rapuh yang dapat dimanfaatkan untuk mendukung produksi tanaman pangan dapat dipertahankan. Penggunaan lahan pasang surut yang terus berlanjut untuk produksi tanaman pangan, oleh karena itu memerlukan pengelolaan ekosistem pertanian melalui pembentukan dan pengukuran keberlanjutan pengelolaan air. Pengelolaan air yang berkelanjutan di dataran rendah pasang surut untuk produksi tanaman pangan seharusnya tidak hanya mempertimbangkan sumber daya fisik (infrastruktur), tetapi juga sumber daya manusia dan sumber daya keuangan. (1) identifikasi pengembangan infrastruktur air baku, (2) inisiasi operasi partisipatif dan pemeliharaan infrastruktur air, (3) pemanfaatan sarana keuangan mandiri dalam pengelolaan air.

Katakunci:dataran rendah pasang surut, pengelolaan air, keberlanjutan, pengembangan

1. Introduction

1.1. Background

The phenomenon of lack of air and water source damage due to the presence of air by humans. Due to this error, theoretically the security of the function and the security of the results is no longer assured. The large number of water shortages to meet the diverse needs and abundance of damaged resources, both natural and human, evidence of the inappropriateness of the methods used in water resources management. Sustainable water resource management is a key issue at present. Understanding is hazy due to the lack of description of air management that can affect the extremes. One of them is a farmer who I believe luck is doing the same thing done by his ancestors, is inundating the rice field with a fairly seasonal air. [1].

Tidal swamplands are one type of wetland ecosystem. According to the Ramsar Convention the scope of wetlands includes water bodies, river waters, swamps, lakes, river embankments, beaches,

bays, fields, reservoirs, and irrigation[2]. Each of the above wetland types has properties and potentials as agricultural land resources. Tidal swamp land has long been recognized as a potential agricultural cultivation area to be developed as a support for the life of clothing producers (fiber plants, among others ramie), food (rice crops, crops, vegetables, fruits), wooden boards, and biofarmaka (medicinal plants among others, turmeric, laus, pasak bumi). For a long time, people / swamp farmers have developed a variety of cultivated crops, especially food crops such as rice and palawija[3].

Water management is one of the keys to successful swampland development for agriculture. The important principle that must be applied in order to succeed in farming in tidal land is water management, not only to avoid flooding or excessive puddles in the rainy season, but also to avoid drought in the dry season. To conduct water management in a large area should make the network of reclamation so that the existence of water can be controlled. There are three types of water system that can be applied that is macro water system, micro water system, and water system in cultivated land. All related to each other and carried out management in a large area. Because of its vast area, its development and maintenance must be carried out collectively[4].

Development or reclamation on tidal swamplands in South Sumatra Province has been carried out by the government since 1969 through transmigration program. Water network system at the beginning of reclamation is still a network system with the main function of drainage. Because the water system arrangements are still dependent on the natural conditions, the water service is still very low. In open network systems, the type of tidal flooding becomes a major consideration in the application of farming systems. With the construction of water control infrastructure, several technical issues in the development of tidal peatland agriculture began to be solved[5].

Maintaining tidal land sustainability as a natural resource is one of Sustainable Development Goals (SDGs). By 2030, the government aims to ensure sustainable food production systems and implement durable agricultural practices that can increase productivity and production, help maintain ecosystems, strengthen adaptation capacity to climate change, extreme weather, drought, floods and disasters others, and progressively improving land and land quality. Improved water quality by reducing pollution can eliminate waste disposal and minimize the disposal of hazardous chemicals and materials that can damage water quality[6].

According to the Badan Pusat Statistik of South Sumatra Province, the use of tidal land initially amounted to 271,413 Ha is now 266,674 Ha[7]. This means that tidal land use is not sustainable. Tidal land that is not utilized again also has an impact on water management that is also not sustainable, both in terms of infrastructure development, maintenance to economic support is no longer important in the utilization of water channels in tidal land in a sustainable manner. Therefore it is necessary to investigate and formulate appropriate sustainability actions in water management in tidal land.

1.2. Problems

1. What is the development of specific local water infrastructures?
2. How is the initiation of participatory operations and maintenance of water infrastructures in tidal lowland?
3. How is the utilization of self-supporting financial means in water management?

1.3. Purpose

The purpose of writing this paper is for the sustainability of tidal water management system in order to achieve Sustainable Development Goals (SDGs).

2. Experimental Section

Tidal swamplands include ecosystems that have high biodiversity and specific biodiversity. Tidal swamplands are one type of wetland ecosystem. Wetlands (wetlands) have very wide ecosystem niches. Tidal swamp land has long been recognized as a potential agricultural cultivation area to be developed as a support for the life of clothing producers (fiber plants, among others ramie), food (rice crops, crops, vegetables, fruits), wooden boards, and biofarmaka (medicinal plants among others, turmeric, laus, pasak bumi). For a long time, people / swamp farmers have developed a variety of cultivated crops, especially food crops such as rice, palawija, yam, taro, sago and others that were originally farmers and then settled farmers. The opening of tidal swamp land was initiated by the construction of canals connecting the rivers and surrounding cities.

The government has planned and massively cleared swamplands since 1969 targeting an area of 5.25 million hectares for 15 years. Tidal swamp land covers an area of 20.14 million hectares spread over 17 provinces, of which about 9.53 million hectares are declared to have potential for agriculture. The estimated tidal swamp area is now estimated at 5.27 million hectares where 2.27 million hectares are cleared for transmigration by the government and 3.0 million hectares are opened by the community on a self-supporting basis. In order to achieve food sovereignty, the utilization of tidal swamp land needs to be improved[3].

Sustainable development is a development that can meet today's needs without compromising the ability of future generations to meet their needs. Sustainable development can be achieved if economic components, social inclusion, and environmental protection can be well integrated with each other[6].

Development of sustainability in tidal land can not be separated from its water management system. This is because tidal cultivation is very dependent on the water ecosystem. By developing specific water infrastructure, the participation of operations in the maintenance of water infrastructure and the utilization of good independent financial means, the sustainability goals will be achieved.

2.1. Development of Specific Local Water Infrastructures

One of the key to the development of tidal farming is the proper management of land and water system, including the condition of the network. The development of tidal farming begins with the development of a macro water system that aims to improve the effectiveness of water regulation / control in order to meet the needs of crop water and help wash toxins to improve the quality of the land.

Water management activities include macro and micro water systems. The macro water system covering primary, secondary and tertiary channels is the responsibility of the Directorate General of Watering. While the micro-water system at the farm level is the responsibility and implemented by farmers consisting of quarters channels and doors, canals and channels of kemalir. Water management is done by arranging the water system according to the typology of the land and the type of overflow water and adapted to the needs of the plant [8].

The micro-water system serves to meet the needs of plant evapotranspiration, prevent weed growth in wetland rice cultivation, prevent the formation of toxic materials for plants through flushing and washing, regulating water levels, and maintaining water quality in land and channel plots. Micro water management includes the arrangement and management of water on the quarter channel and plot of land appropriate to the needs of plants in addition to facilitate the washing of toxic materials. While the management of water in tertiary canals aims to include irrigation water, adjust the water level of the canals and plots, and regulate water quality by removing toxic materials formed on the map and preventing the ingress of saltwater into the land. Water management systems at the tertiary and micro levels depend on the type of tidal surge and poisoning rate. Water management on overflow land A and B needs to be arranged in a one-way flow system, while for overflow land C and D, waterways need to be blocked with a stoplog to keep the water level in accordance with the needs of the plants and allow rainwater to accomodate channel[9].

Agricultural development investment in tidal areas is generally still partial (separated) so the result is not optimal. In the swamp area that opened in the 1980s in Kalimantan, Sumatra, Sulawesi, Central Kalimantan, there are many water structures (water gates) that have been damaged and are not working properly and need to be repaired or rebuilt. The development of infrastructure in tidal land is very important. The success of the development of tidal areas is largely determined by infrastructure support in the form of water system, water supply, transportation, and other supporting facilities[10].

2.2. Initiation of Participatory Operation and Maintenance of Water Infrastructures

Operational plans include planting plans and water management plans, ie water regulation plans on irrigation canals and groundwater levels to create optimal conditions in land use for agriculture and community life. Water management plans are translated into water control building door operation procedures. Water management is intended to ensure adequate water availability for crops, disposal of rainwater over farmland, preventing the growth of wild plants in paddy fields, preventing toxic substances and closed conditions of soil surface by standing waterlogging, preventing water quality degradation, and Certain cases prevent the formation of sulfuric acid soils. Implementation of

maintenance on a regular basis is absolutely necessary for water management activities to be well organized and reliable. Maintenance includes regular and periodic maintenance[11].

The adoption of technology is carried out so that the operating system on water infrastructure is more efficient as well as the management of its human resources. The water management association (P3A) conducts Land and Water Management Tidal Lowlands (LWMTL) activities aimed at operations and maintenance with a participatory approach. LWMTL also contributes in supporting the planning process, budgeting and implementation of government water structure requirements. This activity is carried out to solve problems related to technology development and agricultural mechanization in order to increase the production of crops through increasing the crop index. Operation and maintenance (O & M) is conducted through the empowerment of farmers association ait (P3A) which aims to improve the responsibility and activities of P3A members and improve land and water management in tidal areas[12].

2.3. Utilization of Self-Supporting Financial Means In Water Management

Socio-economic constraints faced include the lack of capital, labor with low education levels, low agricultural prices, and weak institutional support for capital provision. The limitations of capital, either to buy production facilities or wages of labor cause farmers are not able to apply technology optimally. To meet the shortage of capital, farmers usually borrow to local traders because they are not yet available rural economic institutions such as cooperatives or not functioning properly.

Tidal agricultural development is implemented through agribusiness-oriented business systems. Implementation of development can also be done through coordination and harmonious and synergic work among institutions related to the role of farmers and institutional support in the village[13].

3. Conclusion

Tidal lowland is known as a potential agricultural cultivation area to be developed as a support for the lives of clothing, food, shelter, and biofarmaka producers. However, the current tidal lowland has been reduced in number. Tidal lowland that is not utilized again also has an impact on water management that is also not sustainable, both in terms of infrastructure development, maintenance to economic support is no longer important in the utilization of water channels in tidal land in a sustainable manner. It is therefore necessary to investigate and establish appropriate action in the management of water on tidal land in a sustainable manner.

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[12] (Pusat Data Rawa, 2010)
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Abstract
Water in tidal lowlands may either lack or excessive. Neither lack nor excessive of water is demanded for crop cultivation. Therefore, water management plays an important role in the development of tidal lowland agriculture through maintaining proper water conditions. Since tidal lowland with certain conditions is considered marginal, its utilization for crop cultivation should maintain its fragile characteristics such that its utilization to support crop production can be sustained. Continuing use of tidal lowlands for crop production, therefore, requires agricultural ecosystem management through the establishment and measurement of sustainability in water management. Sustainable water management in tidal lowlands for crop production should not only consider the physical resources (infrastructures), but also human resource as well as financial resource. This paper proposes three agendas for research on water management as follows: (1) identification of specific local water infrastructure developments, (2) initiation of participatory operation and maintenance of water infrastructures, (3) utilization of self-supporting financial means in water management.

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Abstrak
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Katakunci: dataran rendah pasang surut, pengelolaan air, keberlanjutan, pengembangan

1. Introduction

Misuse of water by humans cause the phenomenon of water shortages that have an impact on damage to water resources. The consequence, security of facility functions and results are no longer guaranteed theoretically. The inaccuracy of water management methods causing water shortages to supply the various needs and the number of water resource facilities is damaged, both natural and human actions. Sustainable of water management become the main issue. The lack of understanding about sustainable water management can be an extreme impact. One of them is the farmer believing that sustainability means that inundate rice fields with certain water depths throughout the season [1]. Even though, sustainability means that utilize existing resources without giving a negative impact so that they will not run out in vain and can be used for the next generation. In the theory of sustainable development, there are three pillars that must be an important concern, that is economic, social, and environmental issues. These three pillars must be implemented in an integrated manner [2].

One of the wetland ecosystems is tidal lowland. According to the Ramsar Convention, the scope of wetlands includes water bodies, river waters, swamps, lakes, river embankments, beaches, bays, rice fields, reservoirs, and irrigation [3]. Each type of wetland above has the characteristics and potential as a resource of agricultural land. Tidal lowland is agricultural cultivation land that has the potential to be developed as a support for the life of clothing producers (fiber plants, including hemp), food (rice plants, secondary crops, vegetables, fruits), boards (wood trees), and biopharma (medicinal plants, among other, are turmeric, laus, pasak bumi). For a long time, the swamp community/farmers have also developed a variety of cultivated crops, especially food crops such as rice and secondary crops [3]. In water management, there are three types of water system, that are water system macro, micro, and on-farm water management [4]. All is related to each other and management in a large area is carried out. Because of its large area, its development and maintenance must be carried out collectively.

Reclamation in tidal lowland in South Sumatra has been carried out by the government since 1969 through transmigration program [5]. In the beginning, the water system of reclamation was still a network system with the main function of drainage. Because water management arrangements still depend on natural conditions, the water management services are still very low. In open network systems, the type of tidal overflow is a major consideration in the implementation of farming systems. With the construction of water control infrastructure, several technical issues in developing tidal lowland agriculture have begun to be solved

Maintaining the sustainability of tidal lowlands as natural resources is the one of Sustainable Development Goals (SDGs). By 2030, the purposes of the government are to ensure sustainable food production systems and to implement the durable agricultural practices that can increase the productivity and production, help the ecosystem maintenance, strengthen the adaptation capacity to climate change, extreme weather, drought, floods and other disasters, also improving land and soil quality progressively. Improved the water quality by reducing pollution can eliminate the waste and minimize the disposal of chemical and harmful materials which can damage the quality of water [5].

The characteristics of land development in tidal lowland are still experiencing many problems which include water fluctuations, diverse physical and chemical conditions, high soil acidity and organic acids on peatlands, the presence of toxic substances, saltwater intrusion and low of natural fertility. The toxic element reaches the peak of solubility in the early weeks after rain with a very low pH and will gradually decrease until approaching the dry season. Salinity in tidal lowland is caused by the presence of seawater instructors which usually occur in July to September [6]. In root areas, if the salinity is high it will inhibit the roots in absorbing water and nutrients, even at high concentrations, it can absorb the water in plant cells which can cause plants to dry out. Especially in acid sulfate fields that have high levels of soil and water acidity with and contain high Al, Fe and H_2S but the content of nutrients such as P and K are low [7].

According to the Badan Pusat Statistik of South Sumatra Province, at first, the use of tidal lowland is about to 271,413 Ha, but now it becomes 266,674 Ha [8]. It means that tidal lowland use is not sustainable. Unutilized tidal lowlands also give an impact on the unsustainability of water management. Both in terms of infrastructure development, maintenances to economic supports are no longer important in the utilization of water drain in tidal lowland sustainably. Therefore, it is necessary to investigate and measure the appropriate sustainability actions in water management of tidal lowland. Sustainability can be achieved by using three aspects, that are ecological, social, and economic.

The objectives of this paper are to examine the sustainability of water management in tidal lowlands with regards to the achievement of Sustainable Development Goals (SDGs) through a review of relevant literatures. This paper is expected to yield a measure of sustainable water management in tidal lowlands to contribute to the achievement of Sustainable Development Goals (SDGs).

2. Method

This paper was written through a review of relevant literatures in water management development in tidal lowlands from both theoretical and methodological perspectives. The literatures reviewed included journals, sustainable development goals (SDGs) documents, reports, etc.

3. Results and Discussion

3.1. Tidal Lowlands

One of the wetland ecosystems is tidal lowlands. According to the Ramsar Convention, the scope of wetlands includes water boards, river waters, swamps, lakes, river embankments, beaches, bays, fields, reservoirs, and irrigations [3]. The tidal lowlands zone reviewed by chemical properties that divided into two zones, saline and freshwater tidal lowlands zone [9]. Typology of tidal lowlands based on type and soil physicochemical divides into four, namely (1) potential land is the tidal lowlands which including the potential sulphate acid soil with pyrite layer 2% in the depth more than 50 cm from soil surface, (2) sulphate acid land is the tidal lowlands with soil pyrite layer more than 2% in the depth less than 50 cm, sulphate acid land divides into two, namely potential sulphate acid (pyrite layer not oxidized) and actual acid sulphate (pyrite layer already oxidized), (3) peat land (peat land, shallow peat, middle peat, deep peat, and extremely deep peat) is the land formed from organic matter, and (4) saline land is the tidal lowland which intruded by salt water for more than three month a year with Sodium (Na) content in soil solution more than 8%, while the land can be potential, acid sulphate, and peatland [10].

Grouping the tidal lowlands based on the tide range (the type of water flow), are A, B, C, and D [11], [12]. Type A is the overflow area that occurs in large and small pairs, including beach until coastal and river banks. Type B is the overflow area which only pairs. Type B is an area that only overflows when high tides, including back swamps from the riverbank to more than 50 km inland. Type C is an area that does not get direct tidal overflow but has the effect of tidal recharge with a groundwater level of less than 50 cm. Type D is the same as C, but the effect of infiltration is less with a groundwater level of more than 50 cm [13].

3.2.Sustainable Development Goals (SDGs)

The sustainable development is a development that can supply today's needs without compromising the ability of future generations to supply their needs. The sustainable development can be achieved if economic components, social inclusions, and environmental protections can be well integrated with each other [14].

Sustainable development in tidal lowland cannot be separated from its water management system. This because of the tidal cultivation is very depending on the water ecosystem. By developing the specific water infrastructure, the initiation of participatory operations and maintenance of water infrastructures and the utilization of self-supporting financial means in water management, the sustainability goals will be achieved.

The objectives of Sustainable Development Goals [14] which the objectives of this study are the 6th goal, namely to guarantee and manage clean and sustainable air for all and the 13th goal, namely taking immediate action to help and encourage it. To achieve this goal, in the Sustainable Development Goals (SDGs) document contains several targets that must be achieved. The targets are:
Goal #6:

1. In 2030, achieving universal and fair access to safe and affordable drinking water for all.
2. In 2030, achieving access to proper and fair sanitation and hygiene for all and ending open defecation, by paying special attention to the needs of women and girls and those in vulnerable situations.
3. By 2030, improved water quality by reducing pollution, eliminating waste disposal and minimizing the disposal of chemicals and harmful materials, halving the proportion of untreated wastewater and substantially increasing global safe recycling and reuse.
4. By 2030, substantively increasing water use efficiency in all sectors and ensuring sustainable water supply and supply to overcome water scarcity and substantially reduce the number of people experiencing water scarcity.
5. In 2030, implementing integrated water source management at every level, including through appropriate collaboration between boundaries.
6. By 2020, protect and improve water-related ecosystems, including mountains, forests, swamps, rivers, water catchments, and lakes.

7. In 2030, increasing international cooperation and capacity building support to developing countries in activities and programs related to water and sanitation, including water harvesting, desalination, water efficiency, wastewater treatment, recycle and reuse technology.
8. Support and strengthen the participation of local communities in improving water and sanitation management.

Goal #13:
1. Strengthen resilience and adaptability to the adverse effects of climate and natural disasters in each country.
2. Integrating climate change related actions into national policies, strategies, and planning.
3. Improving education, awareness, and mitigation capabilities of climate change, adaptability, reducing impacts also early improving the warning of climate change.
4. Implement the commitments of developed countries to the PBB Convention Framework on Climate Change with the aim of jointly mobilizing funds of $ 100 billion per year starting in 2020 from all sources to help the needs of developing countries in mitigation and transparency programs in implementing the Green Climate Fund as soon as possible.
5. Promote mechanisms to effectively increase the capacity for planning and management of climate change, especially in underdeveloped countries.

Water is an important component in the management of tidal land, so the goals # 6 and # 13 of the SDGs are the right objectives to study indicators in order to achieve sustainability, especially in the tidal lowlands ecosystem. Water management in tidal lowlands can be part of efforts to mitigate and adapt to climate change. The success of these efforts can contribute to the achievement of the SDGs. The sustainable development is a development that can supply the today's needs without compromising the ability of future generations to supply their needs. The sustainable development can be achieved if economic components, social inclusions, and environmental protections can be well integrated each other [14]. Sustainable development in tidal lowland can not be separated from its water management system. This because of the tidal cultivation is very depending on the water ecosystem. By developing the specific water infrastructure, the initiation of participatory operations and maintenance of water infrastructures and the utilization of self-supporting financial means in water management, the sustainability goals will be achieved.

3.3. Threats to Sustainable Water Management in Tidal Lowlands

The threats that faced by water management in tidal lowlands are deficiency and damage due to human misuse of water. Threats due to natural impacts can also occur as in the dry season, the land will experience a shortage of water so that it can cause the pyrite contained in the soil to be oxidized. In this case, the role of infrastructure is very needed for land washing. The strongest pyrite content is at an average depth of 0-20 cm below the top layer (topsoil) with a soil pH of 25 at a temperature of 35^{o}C [15]. Pyrite formed is influenced by several factors, including the high content of organic matter, anaerobic atmosphere, the amount of sufficiency of dissolved sulfate, and dissolved iron levels (Dent, 1986). The condition of pyrite will be stable and safe if it is under the water layer. That is, the potential for oxidized pyrite will be absent if the water layer is above or inundates the pyrite layer continuously, this is another effort besides washing pyrite and other toxic compounds [16]. At the tidal lowlands area in South Sumatra, there are currently many water buildings (water gate) that have been damaged and are not functioning properly so that repairs or rebuilding are needed. This is certainly a threat in sustainable water management which directly affects agricultural (food, fishery, etc.) and non-agricultural waters such as the use of water for people's lives. Dredging conditions that should be carried out every five years are not realized and carried out every seven years. This causes the washing of land to be not optimal, irrigating water on the land is hampered and even some of the land is not watered. If the construction of water management infrastructure is not carried out in accordance with the criteria that the land will have an ecologically bad impact.

Unmanaged properly infrastructure will have an impact on unsustainability water management in tidal lowlands. In this case, the role of water user farmer association (P3A) is very important. Periodic maintenance is carried out at least once every two years depending on the condition of the building and the canal. While maintenance of the canal is carried out at least every five years dredging [17]. The existing P3A does not work as it should. Operation of the water system in the land

is not also carried out in a participatory manner. This means that the operation is only carried out when farmers only want to plant or only when they want to harvest. Whereas the arrangement of the water system in the land should also be carried out regularly as well as its maintenance for the sake of maintaining the balance or need for water in the crop.

If the role of the P3A is unsustainable, it will have an financial impact on the operation and maintenance of water management infrastructure. Less participatory farmers have no willingness to pay for maintenance. There are no costs, meaning the existing infrastructure will be abandoned. If this is not addressed, it will also have an impact on production which will cause financial losses. Therefore, the agenda of this research will be to assess the sustainability of water management by investigating and assessing ecological, social and economic aspects.

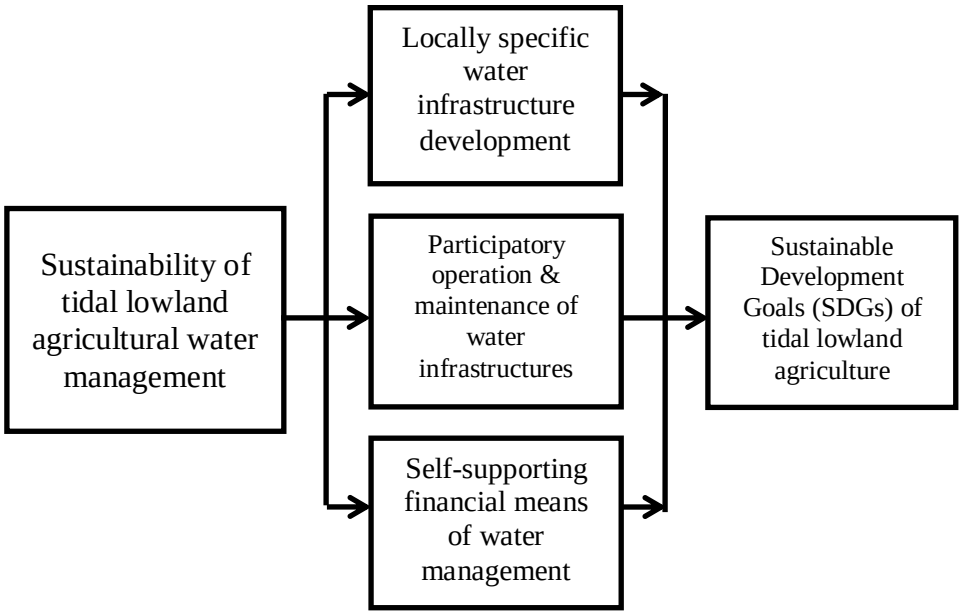

Figure I. Research Map

3.4. Development of Specific Local Water Infrastructures

One of the solutions to developing of tidal lowlands is the proper management of land and water system, including the condition of the system. The development of farming the tidal lowland begins with the development of a macro water system that aims to improve the effectiveness of water regulation/control in order to supply water needs of plants and to help the washing toxins to improve the quality of the land.

Water management activities include macro and micro water systems. The macro water system covering primary, secondary and tertiary drains is the responsibility of the Directorate General of Watering. While the micro-water system at farm level is the responsibility and implemented by farmers consisting of quarters drains and gates, drains of canals and kemalir. Water management is done by arranging the water system according to the land typology and the water overflow type also adapted to the crop needs [18].

Investment in agricultural development in tidal lowlands is generally still partial, so the results are not optimal. The success of the development of tidal lowlands is largely determined by infrastructure support in the form of water systems (canals), buildings (water gate), transportation facilities, and other supports such as markets, schools, hospitals, workshops and others [19]. The micro-water system serves to supply the plant evapotranspiration needs, prevent weed growth in rice cultivation, prevent the formation of toxic materials for plants through flushing and washing, regulating water levels, and maintaining water quality in land and drain plots. Management of micro water systems includes the arrangement and management of water on the quarter drain and land plots according to the plants needs in addition to facilitate the washing of toxic materials. While the water

management in tertiary canals aimed to entering the water irrigation, controlling the water level in canals and plots, and regulating the water quality by removing toxic materials formed on the plots and prevented the saltwater entry into the land plots [20]. Water management systems at the tertiary and micro levels depend on the type of tidal surge and poisoning rate. Water management on overflow land A and B needs to be arranged in a one-way flow system, while the overflow land C and D, the drains need to be blocked with stoplog to keep the water table sutable with the plants needs and allow the rainwater to accomodated in those drains [21].

Investment of agricultural development in tidal areas is generally still partial (separated), so the result is not optimal yet. In the swamp area which opened in the 1980s in Kalimantan, Sumatra, Sulawesi, Central Kalimantan, there were many water structures (water gates) that have been damaged and were not working properly and need to be repaired or rebuilt. Infrastructure developments in tidal lowland are very important. The successed of the development of tidal areas is determined by infrastructure support both of the water system, building (water gates), transportation, and other supporting facilities [22].

3.5. Initiation of Participatory Operation and Maintenance of Water Infrastructures

Operational plans, include planting and water management, are water regulation plans on irrigation canals and groundwater levels to create the optimal conditions in land use for agriculture and society. Water management plans are translated into procedures of water control building gates operation [17]. Water management is intended to ensure the capable of water availability for crops, throw the excess rainwater from farmland, prevent the growth of wild plants (weeds) in paddy fields, prevent the toxic substances and closed conditions of soil surface by standing waterlogging, prevent the degradation of water quality, and in specific cases, prevent the formation of sulfuric acid soils. Implementation of maintenance on a regular basis is absolutely necessary for water management activities to be well organized and reliable. Maintaining includes regular and periodic maintenance [22].

The adoption of technology is carried out so that the operating system on water infrastructure is more efficient as well as the management of its human resources. The water user farmer association (P3A) conducts Land and Water Management Tidal Lowlands (LWMTL) activities that aimed to operating and maintaining with a participatory approach. LWMTL also contributes in supporting the planning process, budgeting and implementing of the government water structure requirements. This activity is carried out to solve the problems related to development of technologies and mechanization of agricultural in order to increase the crops productions through increasing the crop index. Operation and maintenance (O & M) is conducted through the empowerment of the water user farmer association (P3A) which aims to improve the responsibility and activities of P3A members also improve land and water management in tidal areas [17].

3.6. Utilization of Self-Supporting Financial Means In Water Management

Socio-economic constraints faced include the lack of capital, labor with low education levels, low agricultural prices, and weak institutional support for capital provisions. The limitations of capital, either to buy production facilities or wages of labor cause farmers unable to apply the technologies optimally. To supply the shortage of capital, farmers usually borrow to local traders because they are not available yet the rural economic institutions such as cooperatives or not working properly.

Tidal agricultural development is implemented through agribusiness-oriented business systems. Implementation of development can also be done through coordination and harmonious and synergic work among institutions related to the role of farmers and institutional support in the village [18]. The role of P3A is not only as a user and maintainer, but also must be supported by financial independence. In order for water management to be sustainable, water management costs are needed, in addition to the functional water structure and established water management guidelines. Because these costs are used to carry out the operation and maintenance of the system, it is considered a water service fee. Increasing water distribution only requires operating and maintenance costs (OM). Efficient water distribution requires higher costs to cover opportunities and costs [23].

4. Conclusion

In order to achieve sustainable water management in tidal lowlands with regard to Goals #6 and #13 the research agenda in tidal lowlands water management should include:

a. Investigation on measures of water management means of locally specific water infrastructure development.
b. Assessment of participatory operations & maintenance of water infrastructure by the P3A.
c. Establishment on measures in self-supporting financial means of water management to achieve sustainability.

5. Acknowledgement

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Sustainable Water Management in Tidal Lowland Agriculture: A Research Agenda

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Abstract: Water in tidal lowlands may either lack or excessive. Neither lack nor excessive of water is demanded for crop cultivation. Therefore, water management plays an important role in the development of tidal lowland agriculture through maintaining proper water conditions. Since tidal lowland with certain conditions is considered marginal, its utilization for crop cultivation should maintain its fragile characteristics such that its utilization to support crop production can be sustained. Continuing use of tidal lowlands for crop production, therefore, requires agricultural ecosystem management through the establishment and measurement of sustainability in water management. Sustainable water management in tidal lowlands for crop production should not only consider the physical resources (infrastructures), but also human resource as well as financial resource. This paper proposes three agendas for research on water management as follows: (1) identification of specific local water infrastructure developments, (2) initiation of participatory operation and maintenance of water infrastructures, (3) utilization of self-supporting financial means in water management.
Keywords: tidal lowlands, water management, sustainability, cultivation

Abstrak (Indonesian): Ketersediaan air pada lahan pasang surut suatu saat mengalami kekurangan tetapi di saat lain mengalami kelebihan. Kekurangan atau kelebihan air tidak diinginkan dalam budidaya tanaman. Karena itu, pengelolaan air memainkan peran penting dalam pengembangan pertanian pada lahan pasang surut dengan mengatur kondisi air yang tepat. Karena lahan pasang surut pada kondisi tertentu dianggap marjinal, maka budidaya tanaman harus memperhatikan sifat rapuh lahan sehingga pemanfaatannya untuk tanaman pangan dapat dipertahankan. Penggunaan lahan pasang surut yang terus-menerus untuk produksi pangan memerlukan pengelolaan ekosistem pertanian melalui pengukuran keberlanjutan pengelolaan air. Karena itu, pengelolaan air yang berkelanjutan di lahan pasang surut untuk produksi pangan seharusnya tidak hanya mempertimbangkan sumberdaya fisik (infrastruktur), tetapi juga sumberdaya manusia dan sumberdaya keuangan. Tulisan ini membahas tiga agenda penelitian pengelolaan air sebagai berikut: (1) pengembangan infrastruktur air spesifik lokasi, (2) inisiasi operasi dan pemeliharaan infrastruktur air partisipatif, (3) kemandirian dalam pendanaan pengelolaan air.
Katakunci: lahan pasang surut, pengelolaan air, keberlanjutan

1. Introduction

Unsustainable use of water by human beings has caused water shortage and damage to water resources. In addition, improper water management has caused water shortage to supply various needs. Therefore, sustainability of water management becomes a main issue. The lack of understanding on sustainable water management may have extreme impact. One of these is the farmers' belief that sustainability means inundating rice fields with certain water depths throughout the season [1]. In the theory of sustainable development, there are three issues that must be considered, that is economic, social, and environmental issues. These three pillars must be implemented in an integrated manner [2].

Tidal lowlands is one of the wetland ecosystems. According to the Ramsar Convention, wetlands includes water bodies, river waters, swamps, lakes, river embankments, beaches, bays, rice fields, reservoirs, and irrigation [3]. Each type of wetlands has the characteristics and potential as resource for agriculture. Tidal lowlands as resource for cultivation has the potential life support to provide food (staple food, vegetables, fruits), fiber, boards (wood trees), and bio-pharmacy (medicinal plants). For long time, swamp community have developed a variety of cultivated crops, especially food crops such as rice and maize [3].

In order to utilize tidal lowlands for above benefits, water management is a must. Water management literature proposes three levels of water management system: macro, micro, and on-farm water management [4]. All is related to each other such that water management in a large area can be carried out. Accordingly, its development and maintenance must be carried out collectively.

In South Sumatra, tidal lowlands has been utilized for crop production by the government since 1969 through transmigration program [5]. In the beginning,

the water system of reclamation was an open network system with the main function for drainage. Since water management arrangements still depend on natural conditions, water management services were considerably limited. In an open network systems, the type of tidal overflow is a major consideration in the implementation of farming systems. With the construction of water control infrastructures, several technical issues in developing tidal lowland agriculture have initially been solved.

Maintaining sustainability of tidal lowlands as natural resources is one of the Sustainable Development Goals (SDGs). The purposes to achieve in 2030 are ensuring sustainable food production systems, implementing good agricultural practices that can increase the productivity and production, maintaining ecosystem health, strengthening adaptive capacity to climate change, extreme weather, drought, floods and other disasters, and improving land and soil quality progressively. Among these, improving water quality by reducing pollution may eliminate the waste and minimize the disposal of chemical and harmful materials which can damage the quality of water [5].

Tidal lowlands development experienced many problems which include water fluctuations, diverse physical and chemical conditions, high soil acidity and organic acids on peat lands, the presence of toxic substances, saltwater intrusion and low fertility. Toxic elements solubility reach the peak in the early weeks of rainy season causing very low pH and gradually decrease until approaching the dry season. Salinity in tidal lowlands is caused by the presence of seawater which usually occurs in July to September [6]. In root areas, high salinity inhibits the roots in absorbing water and nutrients, even at high concentrations. Especially in acid sulfate soils that have high level of soil and water acidity containing high Al, Fe and H_2S, but nutrient contents such as P and K are low [7].

According to Badan Pusat Statistik of South Sumatra Province, at the beginning the utilization of tidal lowland was about to 271,413 Ha, currently slightly decreased to 266,674 Ha [8]. Unutilized tidal lowlands would negatively affect water management. Therefore, it is necessary to investigate the appropriate sustainability measures in tidal lowland water management. Sustainability may be investigated through three aspects, which are ecology, social, and economics.

The objective of this paper is to examine the sustainability of water management in tidal lowlands with regards to the achievement of Sustainable Development Goals (SDGs) through a review of relevant literature. This paper is expected to yield a measure of sustainable water management in tidal lowlands to contribute to the achievement of Sustainable Development Goals (SDGs).

2. Method

This paper was written through a review of relevant literature in water management development in tidal lowlands from both theoretical and methodological perspectives. The literature reviewed included journals, Sustainable Development Goals (SDGs) documents, reports, etc.

3. Results and Discussion

3.1. Sustainable Development Goals (SDGs)

Sustainable development is defined as development that can supply today's needs without compromising the ability of future generations to supply their needs. The sustainable development can be achieved if economic components, social inclusions, and environmental protections can be well integrated with each other [14]. Sustainable development in tidal lowlands cannot be separated from its water management system. By developing local specific water infrastructures, initiating participatory operations and maintenance of water infrastructures and the utilization of self-supporting financial means in water management, the sustainability goals will be achieved.

The objectives of Sustainable Development Goals [14] discussed in this paper are the 6th goal, namely to guarantee and manage clean and sustainable water for all and the 13th goal, namely taking immediate action to help and encourage climate actions. To achieve these goals, the SDGs document contains several targets that must be achieved by 2030, which are:

Goal #6:

1. Achieving universal and fair access to safe and affordable drinking water for all.
2. Achieving access to proper and fair sanitation and hygiene for all and ending open defecation by paying special attention to the needs of women and girls and those in vulnerable situations.
3. Improving water quality by reducing pollution, eliminating waste disposal and minimizing the disposal of chemicals and harmful materials, halving the proportion of untreated waste water and substantially increasing global safe recycling and reuse.
4. Substantively increasing water use efficiency in all sectors and ensuring sustainable water supply to overcome water scarcity and substantially reduce the number of people experiencing water scarcity.
5. Implementing integrated water source management at every level, including through appropriate collaboration between boundaries.
6. Protecting and improving water-related ecosystems, including mountains, forests, swamps, rivers, water catchments, and lakes.
7. Increasing international cooperation and capacity building support to developing countries in activities and programs related to water and sanitation, including water harvesting, desalination,

water efficiency, waste water treatment, recycle and reuse technology.
8. Supporting and strengthening the participation of local communities in improving water and sanitation management.

Goal #13:
1. Strengthening resilience and adaptability to the adverse effects of climate and natural disasters in each country.
2. Integrating climate change related actions into national policies, strategies, and planning.
3. Improving education, awareness, and mitigation capabilities of climate change, adaptability, reducing impacts also early improving the warning of climate change.
4. Implementing the commitments of developed countries to the UN Convention Framework on Climate Change with the aim of jointly mobilizing funds of $ 100 billion per year starting in 2020 from all sources to help the needs of developing countries in mitigation and transparency programs in implementing the Green Climate Fund as soon as possible.
5. Promoting mechanisms to effectively increase the capacity for planning and management of climate change, especially in underdeveloped countries.

Water is an important component in the management of tidal lowlands, so the goals # 6 and # 13 of the SDGs are the proper indicators in order to achieve sustainability in tidal lowlands ecosystem. Water management in tidal lowlands can be part of efforts to mitigate and adapt to climate change. The success of these efforts can contribute to the achievement of the SDGs. The sustainable development can be achieved if economic components, social inclusions, and environmental protections can be well integrated each other [14].

3.2. Threats to Sustainable Water Management in Tidal Lowlands

Threats to water management in tidal lowlands include deficiency and damage due to human misuse of water. Threats due to natural impacts can also occur in the dry season. In the dry season, tidal lowlands would experience shortage of water so that it can cause the pyrite contained in the soil to oxidize. In this case, the role of infrastructure is very important for soil washing. The strongest pyrite content is at an average depth of 0-20 cm below the top layer (topsoil) with soil pH of 2.5 at a temperature of 35^{o}C [15]. Pyrite formed is influenced by several factors, including the high content of organic matter, anaerobic atmosphere, the amount of sufficiency of dissolved sulfate, and dissolved iron levels. The condition of pyrite will be stable and safe if it is under the water layer. That is, the potential for oxidized pyrite will be absent if the water layer is above or inundates the pyrite layer continuously, this is another effort besides washing pyrite and other toxic compounds [16]. At the tidal lowlands area in South Sumatra, there are currently many water infrastructures that have been damaged and are not functioning properly so that repairs or rebuilding are needed. This is certainly a threat to sustainable water management which directly affects agriculture, fishery, and non-agricultural waters uses such as the use of water for households. Dredging that should be carried out every five years is done after seven years. This causes the washing of soil is not optimal, irrigating water on the land is hampered and even some of the land is not watered. If the construction of water management infrastructure is not carried out in accordance with the criteria, the land will have an ecologically bad impact.

Infrastructures that are not managed properly will have a negative impact on sustainability of water management in tidal lowlands. In this case, the role of water user association (WUA) is very important. Periodic maintenance can be carried out by WUA at least once every two years depending on the condition of the building and the canal. While maintenance of the canal is carried out at least every five years [17]. However, the existing WUA does not work as it should. In addition, operation of the water infrastructures is not carried out in a participatory manner. This means that the operation is only carried out when farmers want to start cultivation and when they want to harvest.

If WUA is not functioning properly, it will have a financial impact on the operation and maintenance of water management infrastructure. Farmers who participate less will have less willingness to pay for maintenance. Without WUA payment, the existing infrastructure will be abandoned. If this problem is not addressed, it will also affect the production and cause financial losses. Therefore, the assessment of the sustainability of water management by investigating and assessing ecological, social and economic aspects should be performed (see Figure 1).

3.3. Development of Specific Local Water Infrastructures

One of the solutions to developing tidal lowland agriculture is the proper management of land and water system. The development of farming in tidal lowland begins with the development of a macro water system that aims to improve the effectiveness of water regulation/control in order to supply crop water needs and to help washing toxic substances to improve soil quality.

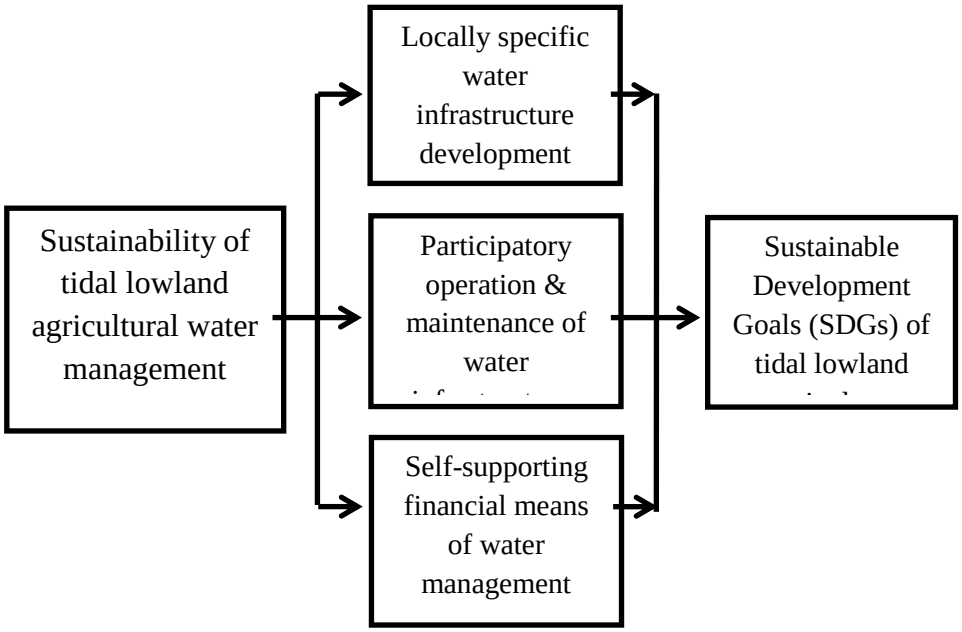

Figure 1. Proposed Research Map

Water management activities include macro and micro water systems. The macro water system covering primary, secondary and tertiary canals is the responsibility of the Directorate General of Water Resource. While the micro-water system at farm level is the responsibility and implemented by farmers, consisting of quarter canals and gates. Water management is done by arranging the water system according to the land hydrotopographic characteristics. In addition, water flow is adapted according to the crop needs [18].

Investment in agricultural development in tidal lowlands is generally partial, so the results are not optimal. The success of the development of tidal lowlands is largely determined by infrastructure support in the form of water systems (canals), buildings (water gate), transportation facilities, and other supports such as markets, schools, hospitals, workshops and others [19]. The micro-water system serves to supply the plant evapotranspiration needs, prevent weed growth in rice cultivation, prevent the formation of toxic materials for plants through flushing and washing, regulating water levels, and maintaining water quality in land and drain plots. Management of micro water systems includes the arrangement and management of water on the quarter canals and land plots according to the plants needs in addition to facilitate the washing of toxic materials. While the water management in tertiary canals aimed to entering the water irrigation, controlling the water level in canals and plots, and regulating the water quality by removing toxic materials formed on the plots and prevent saltwater entry into the land plots [20]. Water management systems at the tertiary and micro levels depend on the type of tidal surge and poisoning rate. Water management on hydrotopographic A and B needs to be arranged in a one-way flow system, while the hydrotopographic C and D, the drains need to be blocked with stoplog to keep the water table suitable with the plants needs and allow the rainwater to accommodate in the canals [21].

In Kalimantan, Sumatra, Sulawesi, and Central Kalimantan, there were many water structures (water gates) constructed in the 1980s have been damaged and were not working properly and need to be repaired or rebuilt. Infrastructure developments in tidal lowland are very important. The success of the development of tidal areas is determined by infrastructure support for water management system, building (water gates), transportation, and other supporting facilities [22].

3.4. Initiation of Participatory Operation and Maintenance of Water Infrastructures

Operational plans, including planting and water management, are necessary to create the optimal conditions in land use for agriculture and society. Water management plans are translated into procedures of water infrastructures operation [17]. Water management is intended to ensure water availability for crops, drain excess rainwater from farmland, prevent the growth of wild plants (weeds), prevent the toxic substances, prevent the degradation of water quality, and in specific cases prevent the formation of sulfuric acid soils. Implementation of maintenance on a regular basis is absolutely necessary for water management activities to be well organized and reliable. Maintaining includes regular and periodic maintenance [22].

The adoption of technology is carried out so that the operating system on water infrastructure is more

efficient as well as the management of its human resources. Water user association (WUA) conducts land and water management activities that aimed of operating and maintaining through a participatory approach. WUA also contributes in supporting the planning process, budgeting and implementing of the government water structure requirements. This activity is carried out to solve the problems related to development of technologies and mechanization of agricultural in order to increase crop production through increasing the crop index. Operation and maintenance (O & M) is conducted through the empowerment of WUA which aims to improve the responsibility and activities of WUA members [17].

3.5. Utilization of Self-Supporting Financial Means In Water Management

Water management in tidal lowlands faces several constraints including lack of capital, labor with less education, low agricultural prices, and weak institutional support for capital provisions. The lack of capital, either to buy farm inputs or to pay wages for farm labor prevent farmers from applying the technologies optimally. To overcome the shortage of capital, farmers usually borrow money from local traders since formal financial institutions such banks and cooperatives are not available in most tidal lowland areas.

Tidal agricultural development should be implemented through agribusiness-oriented business systems. Implementation of development can also be done through coordination and synergistic work among institutions related to the role of farmers and institutional support in the village [18]. The role of WUA should not only be as financial user, but must be directed towards financial independence. In order for water management to be sustainable, water management costs are needed, in addition to the functional water structure and established water management guidelines. These costs are used to carry out operation and maintenance of the system. With financial independence, water management can be carried out properly by WUA to achieve efficient water distribution and to support higher farm productivity [23].

4. Conclusion

In order to achieve sustainable water management in tidal lowlands with regard to Goals #6 and #13 the research agenda in tidal lowlands water management should include:

1. Investigation on measures of water management means of locally specific water infrastructure development.
2. Assessment of participatory operations & maintenance of water infrastructure by the WUA.
3. Establishment of measures of self-supporting financial means of water management to achieve sustainability.

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