Model development of sustainable wetland rice farming based on rice estate community and smart farming

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Abstract. Crucial issues in rice fields production in Indonesia are narrow planting areas, small farming scale and improper cultivation techniques. The Indonesian government also faced issues and problems regarding fulfilment the need of rice-farm area due to the conversion of intensive rice fields to non-agriculture. Efforts to develop integrated and sustainable rice field agriculture are needed to overcome the threat of rice field reduction, increase the productivity of rice fields, and increase farmers' income and welfare. The intention of this study was to develop a model of rice field in an integrated and sustainable manner based on Rice Estate Community and Smart Farming (REC-SF). To get easily implemented model, participatory method was used through series of audiences and focus group discussion activities involving the main stakeholders. As a breakthrough for traditional agricultural solutions on narrow land, this model included land consolidation to reach minimum rice field area for profitable economic scale, strengthening institutional system, productivity target along with required cultivation inputs and techniques, support for information technology system, agroindustry, and marketing-selling reinforcement. Developed REC-SF model is expected to be more easily implemented and accepted by the farmers to achieve a collective farm business in a large rice-farm area.

1. Introduction

1.1. Rationale

As an agrarian country, Indonesia should give big attention towards agricultural development. Besides that, the application of inadequate cultivation technique and some of problems encountered, the most crucial problem in increasing food production, especially rice in wetland farming is too small farm area so it is not economically feasible. Based on 2013 Agricultural Cencus Report [1], the average area of rice fields owned per agricultural business household was around 0.02 ha in 2013, although the magnitude of this figure increased from 0.01 ha in 2003. In total agriculture land, the area of agricultural land authorization (rice fields and non-rice fields) was 0.3 ha per agricultural household [2]. The inheritance tradition in Indonesia, such as distributing land when their parents die, low

agricultural prospects and low landrents for rice fields are threats to the reduction of land cultivation area.

For the income and welfare aspects, farmers also face the problem of weak marketing and sales, especially during the massive harvest period, and disguised unemployment due to too small workloads if they only focused on on-farm activities in narrow rice fields. Nationally, the government is also confronted with the intensive rice field conversion to non-agriculture. Low interest of the younger generation to become farmers is increasing along with the gloomy prospects for agriculture in the future.

Efforts to develop integrated and sustainable rice field agriculture are needed to overcome the threat of rice field reduction area, to increase the productivity of rice fields for lifting rice production, to increase farmers' income and welfare as well as to increase young generation and millenial interest's back to become a farmer. Rice Estate Community (REC) implemented in the large areas is indeed required to save the production of rice in Indonesia in the future. Cultivation on a large scale will facilitate the monitoring and management of agricultural land systems so that it can be assumed that productivity and effciency can be increased, trends in land conditions are more predictable, and it is easier to make decisions. Management will be more effective if it is assisted by the concept of smart farming, which in this case is to use information technology to achieve the desired target [3]. Smart farming will display information in the form of maps and complex data that can simplify agricultural activities, accelerate the process, and increase targeting accuracy that can help farmers in implementing agricultural activities (Prasetyono, 2019 cited in [3]).

To support national rice development program, IPB University is developing a model or system as part of IPB University Rice Roadmap 2015-2030 to support IPB-University Industrial Smart Agro-system 4.0 Program. Smart Agrosistem 4.0 emphasizes on: 1) IPB core competencies with a cross-disciplinary and multidisciplinary scientific focus, 2) Application of science and technology that is solutive, transformative, and participatory, 3) Utilization of data and digital technology for decision making, and 4) Smart and precise action in every activity from land-to-table.

REC model consists of land consolidation to reach minimum rice field area for favourable economic scale, strengthening of institutional system, productivity target along with inputs and cultivation techniques required, information technology system support, agroindustry involved, and marketing-selling reinforcement. According to Surahman *et al.* [4], REC was formed by small-scale farmers in a stretch in an area by adhering to the principles of synergy, consolidation, togetherness and sustainability. One REC unit consists of 101 ha of Java Island and 303 ha outside Java Island. The development of a rice business with the REC concept has also succeeded in increasing the productivity also income and welfare of farmers in Malaysia [5]. Different research conducted by Ciaian *et al.* [6] indicates that land fragmentation is an important driver of production diversification of farm households in Albania. They find that land fragmentation stimulates significantly more diversification for subsistence farm households than for market-oriented households. Their findings have two key policy implications: (i) the consolidation policies that relocate and enlarge plots would have a significant impact on reducing agricultural production diversification; and (ii) land fragmentation contributes to the nutritional security improvement by increasing the variety of foodstuffs produced by subsistence farm households.

The objective of this study was to develop a model and/or system for developing rice production in rice fields in an integrated and sustainable manner based on smart farming and Rice Estate Community (REC).

1.2. The problems

The main problem in food crop agriculture was the low national average productivity in 2019 of 5.2 t ha^{-1} [7] and the large number of farmers having low income and welfare. Meanwhile, several rice varieties had high productivity potential, such as Inpari 1 (10 t ha^{-1}), Inpari 8 (9.9 t ha^{-1}), Inpari 28 (9.5 t ha^{-1}), HIPA 3 (11.67 t ha^{-1}), HIPA 4 (10.43 t ha^{-1}), Rokan (9.24 t ha^{-1}), Maro (8.85 t ha^{-1}) [8], IPB 3S (7 – 8 t ha^{-1}) [9], etc. The low rice productivity is dominantly caused by the low application of good,

effective and efficient cultivation management to produce optimal production at various leves of soil quality. The same cause also contributes greatly to the many farmers who were low-income and not prosperous yet. The other major problems are majority of the farmers: 1) do not know and understand about their soil, 2) low education and skill, 3) still practice subsistence farming systems, 4) low capital and financial capacity, 5) are trapped by middlemen in the bonded system and 6) cultivate in too small size or narrow rice farm area (see Figure 1).

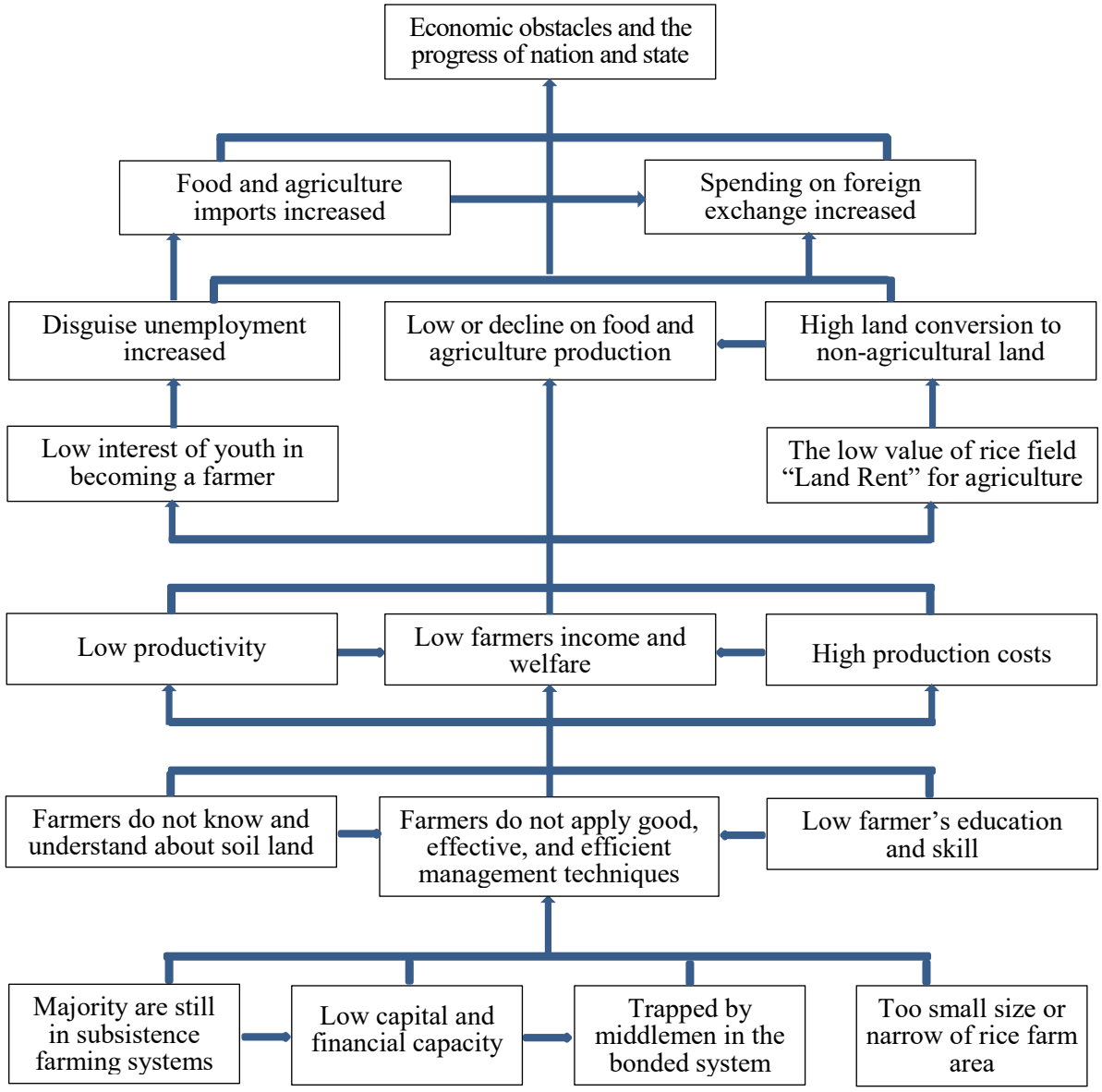

Figure 1. Problem factor tree in rice farm agriculture.

Cultivating on narrow land causes farmers face obstacles in the application of agricultural mechanization and supporting technology, encourages farmers to run individual business systems and competition between farmers, high production costs, low farmer activities (only at the on-farm level), sell the product in the form of unhulled rice (primary product) and get no added value, weak marketing, and low prices especially during the main harvest, which in the end lead to the low income and profits [10]. The low income and welfare of farmers are indicated by the low exchange rate of farmers, which nationally, in recent the average of Farmer Exchange Rates (NTP) is still around 100.

Thus, innovation is needed to develop a productive, effective and efficient agricultural system which can increase farmer income and welfare.

1.3. Aim

The objective of this study was to develop a model and/or system for developing an integrated and sustainable wetland rice production based on smart farming and Rice Estate Community (REC) which cultivate rice in a wide or extensive area.

1.4. Theoretical framework

One of the main problem in increasing rice productivity and farmers' income and welfare is the small area of cultivation of rice fields. The low level of farmer welfare can be measured by using the level of food subsistence (TSP) and the farmer exchange rate (NTP) parameters. Based on the result of Putri and Noor [11], the NTP value of farmers who cultivate land with relatively narrow areas has the smallest TSP value compared to farmers who have large land areas. The TSP value correlates with the ability of farmers to provide food for comsumptions, so that the greater the TSP value means the more household food stocks will be. The farmer exchange rate is a comparison of the price index received by the price index paid by farmers. This value indicates the level of purchasing power of farmers and shows the exchange power of goods and service consumed as well as for production costs. The NTP value of food crop farmers from January to July 2020 was only 101.76 [12], which indicates the low farmers' income and welfare. Under traditional agriculture system with small scale area and without any support for seed, fertilizer, mechanization and other technologies, the productivity and farmers income will be low. Regarding the market system, mostly is middlemen class by producing unprocessed product such as unhulled rice and this caused farmers have low bargaining position.

The tradition and culture to inherit rice field in smaller part to their descendent is one of the factors on the narrowing land scale [13]. The increasing interest in investment and development in the non-agricultural sector has resulted in high conversion of rice fields. The low income of farmers and the land rent of rice fields have triggered land conversion from agricultural to non-agricultural. This is supported by the large gap in the comparison of the land rent value of agricultural land with industrial areas of 1:500 and 1:622 for the comparison of agricultural land rents with residential areas [14]. Another aspect that causes the program to increase lowland rice productivity stagnating is the low introduction and contribution of cultivation technology that supports the achievement of a productive, effective and efficient farming system through the use of superior seeds, fertilizers, irrigation, controlling pests and diseases that support through application of agricultural mechanization, information technology and other modern equipment and technologies, such as drones, etc. cultivation of lowland rice on small fragmented land greatly impedes the realization of these things.

Thus, innovation is needed for agricultural development models which is more productive, effective, efficient and sustainable based on Rice Estate Community and Smart Farming (REC-SF) in a relatively large area. The government through the Ministry of Agriculture has encouraged the growth and development of farmer cooporations [15]. However, studied from the released guidelines, the idea is too optimistic if the government wants to objectify rice farming areas with an area of 1,000 or even 5,000-10,000 ha nationally throughout Indonesia, especially if it will be implemented in Java and other provinces where rice fields are already fragmented into small lands. The idea about farmers corporation will fave fewer obstacle and challenges if it is implemented to provinces or districts with rice fields area which relatively large average. It would be great if farmers in a unified stretch, not working on their own rice fields, apply a communal farming system with a minimum area of 300 ha [16].

In the disruption era that the challenges are getting strong, it is necessary to have research that can accelerate development in all fields, especially agriculture. IPB Univerity designed the Agro-Maritime 4.0 is a concept as a form of contribution to national development. The concept of Agro-Maritime 4.0 is a concept that regards land, sead air as a unified system involving complex social, economic and ecological systems with a transdisciplinary, integrated, and participatory approach directed at the

characteristics of agro-industrialism [17]. Some problems related to rice commodities, both in terms of cultivation, economy, and the welfare of farmers, often still occur. IPB University has produced innovations for the development of lowland rice farming and cultivation. So that in 2018, IPB University has tried to compile the concept of a Rice Estate Community (REC) and implemented it in 2019, but has not achieved success. In 2020, along with the Agro-Maritime 4.0 concept and the existence of the IPB University Rice Research Roadmap, the preparation, improvement and development of the REC model is still carried out based on the concept of Corporate Agriculture of the Ministry of Agriculture and REC IPB which has been compiled and tried to be implemented in 2019 but with necessarily improvement.

However, the integrated agricultural development process really requires an active and participatory role from farmers (Suhardjo, 2008 cited in [18]). According to Cohen and Uphoff [19], the participation stage is divided into four stages, which consists: 1) Planning and decision making, 2) Implementation phase, 3) Result utilization stage, 4) Evaluation stage. These four stages need to be applied to the preparation of a concept or model, including the model of SWRF based on REC-SF.

Therefore, this study has sought the participation and major stakeholder participation to develop an integrated and sustainable wetland rice production model based on smart farming and Rice Estate Community (REC) which cultivate rice in a wide or extensive area. This model is expected to be a concrete solution to overcome the problems and challenges above so it ready to be implemented to achieve a better implementation.

2. Methodology

2.1. Methods

The methods used to achieve the goals and targets along with participants and major stakeholders who are expected to provide suggestions and input fot participatory preparation of the REC-SF model can be seen in Table 1.

2.2. Study period and research site

Activities that have been carried out and their methods, periods and locations are presented in Table 2.

3. Results and discussion

3.1. Description of REC-SF model for sustainable wetland rice farming

There are several main requirements for a model to meet the criteria as a REC-SF-based sustainable wetland rice farming model.

3.2. Crucial points and requirements for implementing the REC-SF model

From the results of the FGD activities, panel discussions, and online seminars, crucial matters and requirements that were considered very basic were to be able to invite farmers to participate in implementing REC-SF successfully in large areas of rice fields jointly through a REC are:

1). Guarantee of increased income for cultivators and farm laborers. Thus, an accurate survey is needed to determine the level of income of cultivators and form laborers as well as land owners who will become members of a REC. The income level survey becomes the baseline for benchmarking in terms of initia data to determine the amount of income of farmers and land owners in establishing a REC
2). Guarantee of certainly in the security of land ownership. Farmers must be able to be convinced that there is no change in status and ownership boundaries and a reduction in land area

Table 1. Methods used with their objectives and targets and participated participant.

Methods	Objective and Target	Actor / Participant
Desk Study	1. Concept Preparation of the REC-SF Model 2. Preparation of presentation materials for the socialization and FGD	Research Team
Panel Discussion and Online Seminar	1. Explain the concept and research plan of SWRF action based on REC-SM to the Department of Agriclture in each district 2. Discuss alternative REC-SM area candidates in each district 3. Discuss plans for the implementation of SWRF action research based on REC-SM with regional agencies in each district	✓ Regional Head ✓ Department of Agriculture ✓ Related Agencies ✓ Related Agricultural Extension ✓ Farmer Representatives
Focus Group Discussion	1. Explain the concept and plan of the SWRF action study based on REC-SM area candidates in each district 2. Discuss alternative REC-SM are candidates in each district 3. Discuss plan for the implementation of SWRF action research based on REC-SM with regional head and related agencies in each district 4. Get suggestions and input from stakeholders, so the REC-SM Model can be applied and implemented successfully	✓ Department of Agriculture Apparatus ✓ Subdistrict Head ✓ Village Head ✓ Related Agricultural Extension ✓ Farmer Representatives

Table 2. Location and timing of activities for each method.

Methods	Period	Location
Desk Study	June 1- July 27, 2020	IPB University, Bogor City
Panel Discussion	July 28, 2020: 08.00 - 09.30	Purbalingga Regency Agriculture Office, Central Java Province
	July 28, 2020:10.00 - 11.30	Purbalingga Regency Verandah Meeting Room, Central Java Province
	July 29, 2020: 08.00 - 10.00	Regional Secretariat Hall, Malang Regency, East Java Province
	August 9, 2020: 08.00 - 11.00	Universitas Sumatera Selatan Hall
Focus Group Discussion	July 28, 2020: 13.00 - 15.30	Bukateja Village Meeting Hall, Sub-district. Purbalingga Regency, Central Java Province
	July 29, 2020: 12.30 - 16.30	Bengkel Mimpi, Pagelaran Village, RECanjen District, Malang Regency, East Java Province
	July 30, 2020: 15.00 - 17.30	Penolih Village Meeting Hall, Kaligondang District, Purbalingga Regency, Central Java Province
	August 9, 2020: 11.00 - 13.00	Sungai Dua Village Meeting Hall, Rambutan District, Banyuasin Regency, South Sumatera Province
	August 10, 2020:08.00 - 11.00	Karang Agung Ilir Village Meeting Hall, Lalan District, Musi Banyuasin Regency, South Sumatera Province

Table 3. Components and its requirements as necessities of REC-SF model for sustainable wetland rice farming.

Component	Description
Concession area	Ideally, at least 100 ha through land consolidation work plus 1 ha of land for seed production. Inventory and mapping of land ownership are carried out together with the Badan Pertanahan Nasional (National Land Agency) or Subdistrict Head as the Maker of Land Deeds.
Institutions	The Farming Institution is managed by an institution which is a group of cultivating farmers and/or land owners in the joint cultivation area. Cultivators and/or land owners are appointed as shareholders. The minimum management organizational structure consists of a Supervisory Board, Manager (Chair), Assistant Production/Post-Harvest Manager, Assistant Manager for Sales/Marketing and Assistant for Human Resources and Institutional Capacity. Election of management is based on the agreement of all members of the institution at the General Meeting and also involving and witnessed by local government officials. Managers should be drawn from professionals.
Financial and Economic	Economically viable, independent and sustainable. In this concept, farmers who are members of the institution can create side businesses that are closely related to agricultural activities (on-farm and off-farm). To increase the farmer's economy, the final product is no longer unhulled but packaged rice. Not only rice, but there are other by-products that can be sold. Investment financing and business capital are supported and guarded by local governments.
Technology application	Ideally uses modern agricultural principles, supported by the use of modern technology, agricultural mechanization (tractors, combine harvesters, drones, etc.), information technology, field-verified state-of-the-art research results, management management as well as infrastructure and saprotan as needed to support SWRF and REC-SF.
Scope of works	Activities are managed by institutions, ranging from upstream to downstream activities, applying involving integrated farming and on-farm and off-farm.
Environmental aspect	Sustainable for the long run cultivation and applying zero waste concept.
Crop productivity	At least reach a high productivity, minimum of 10 t ha^{-1} for good soil quality and 7 t ha^{-1} for marginal soil or low soil quality.
Input application	Optimal use of input to get optimum crop productivity based on minimum production cost at each
Human resource capacity (farmer)	There is a continuous learning process for rice farmers in the fields of agriculture, farming and institutional management. Learning activities are carried out in the form of assistance to farmers in carrying out every activity, both on-farm and off-farm. Learning and mentoring activities will take place effectively and efficiently if there is an active and participatory role from farmers and shareholders.
Net-working and business promotion development	REC needs to develop and expand business networking and promotion to sell all products and commodities produced at good and profitable prices.
Supervising, monitoring, and evaluation	To supervise the implementation and operations in accordance with the mutual agreement and plan, supervision, monitoring and evaluation activities are required.

3). Land mapping is carried out using drones along with ownership information for the lands that will be consolidated in a REC management. The income level survey and land mapping become the baseline for benchmarking the establishment of a REC. Rice fields turned into coordinate points that can be stored digitally and documented at the Regency/City/Provincial/Central BPN office. Removing rice fields on plots of narrow fragmented agricultural land with an area of 1,000-2,000 m^2 to be converted into a large agricultural area (minimum 100 ha) can increase the total effective area by 10 percent
4). Mutual agreement is needed to form long-term cooperation through a solid REC institution that is fully trusted by all its members. This is very crucial because during REC management, members' land cannot be reclaimed and/or traded freely at any time
5). Good management: transparency, accountability, etc
6). Government support, from the village to the central level (financing, agriculture facilities assistance, regulations, certification, research and development, counseling, and training)
7). Partnerships with Regionally-Owned Enterprise, private sector, related government agencies, research institutions and universities
8). The existence of an institution/cooperative must be able to facilitate the fulfillment of the needs of members, especially in the first year as well as for the needs of members who are classified as pressed
9). There is a program of continuous guidance and learning for farmers until they are independent
10). The application of technology, both for cultivation and post harvest
11). There is an active and participatory role from farmers and shareholders

3.3. Strategy and stages in forming Rice Estate Community (REC)

3.3.1. Strategy. REC formation is the most fundamental thing and must be done at the earliest period. Surahman *et al.* [4] suggested that REC is represented by the Farmers' Owners and Tenants Representative Forum (FP4L). Four fundamental strategies should be applied in the formation of FP4L in order to achieve the objectives, they are: 1) implementing programs to achieve the vision of a joint or collective business, 2) building and developing collective businesses in one management for rice commodities and side businesses, 3) optimizing the use of agricultural by-products and non-agriculture to be engineered into products of economic value and renewable energy sources, 4) following the directions of doing collective business according to the direction of the experts. FP4L is an institution that is decisive in making policies and strategic plans in REC.

It is well known that the process of forming FP4L is not easy and requires serious effort considering that land issues for someone are very fundamental and crucial. The preferred approach technique is persuasive and participatory, not compulsion, pressure, intimidation or threats. After the socialization process, if necessary, a mentoring process can be carried out by someone who can influence (convince) and change the thinking and culture of the community so that they can be invited to farm collectively and collegally in a large area which not fragmented as before. In its implementation, FP4L needs to be backed up by a professional manager. The hierarchy and their respective duties and authorities are presented in Figure 2.

In addition, FP4L needs support from several parties, especially: 1) government agencies and/or agencies, particularly the district and province level, agricultural extension agents, the central government (particularly the ministry of agriculture, Directorate of Food and Agriculture, Bappenas), regional leaders (head of village/urban village, subdistrict head, regent/mayor, governer), related instances (particularly BPN); 2) financial institutions (banks, credit, institutions, etc); 3) universities and agricultural research institutions (BPTP, LIPI, etc.); 4) private institutions, state-owned enterprises, and regionally-owned enterprises related to agriculture, food and agroindustry association, particularly Logistics Affairs Agency (Bulog), associations in the agriculture and food sector, RMU (Rice Milling Unit), CRPC (Centralized Rice Process Complex), supermarkets, grosiers of food and agricultural products, traditional markets, etc.

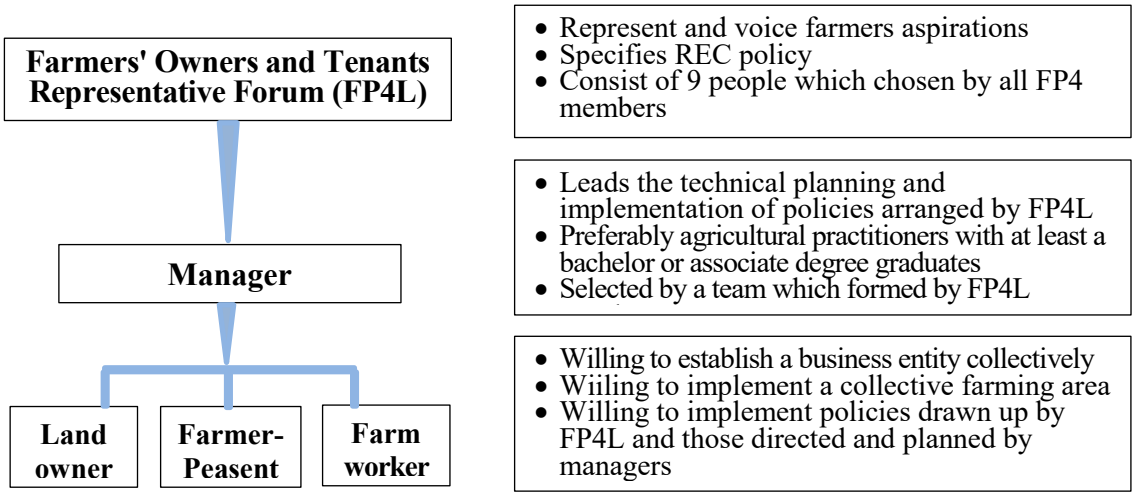

Figure 2. REC's organization structure accompanied by a description of its authorities and duties (Modified from Surahman *et al.* [4]).

3.3.2. Institutional formation stages. Proposed steps should be accomplished to develop a collective business institution in rice farm based on the REC-SF are the following:

1. Planning study and alternative determination of REC candidate areas
2. Coordinate at the provincial, district/city level to determine REC candidate areas
3. Sosialization (village consultation, focus group discussion) in the REC candidate areas
4. Approaches to formulate and institutionalize REC to the prepation of organizational structures and statutes also the selection of managers/diretors
5. Demonstration plots for searching and testing optimum cultivation technology
6. Business plan preparation (upstream-downstream)
7. Preparation of Standard Operation Procedures in some aspects needed
8. Implementation Guidence: a) transtition period, b) full operation
9. Monitoring, supervising, and evaluation
10. Planning and development

4. Conclusions

The REC-SF Model for SWRF has been compiled in a comprehensive manner which has received suggestions and input from key stakeholders, particularly through panel discussion and focus group discussion. This model is a breakthrough for traditional agricultural solutions on narrow land. It is an integrated and sustainable wetland rice production based on smart farming and Rice Estate Community (REC) which cultivate rice in a wide or extensive area through land cosolidation. REC is represented by the Farmers' Owners and Tenants Representative Forum (FP4L).

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