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Status of seaweed (*Kappaphycus Alvarezii*) farming land ownership and business productivity in Sulawesi Island: quantitative study

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Abstract
The aim of this study was to analyze the income and productivity of seaweed farmers based on farmed land ownership status. This research was conducted in three provinces on the Sulawesi Island which are ranked among the 10 largest seaweed producers in Indonesia: Central Sulawesi, South Sulawesi and Southeast Sulawesi. The twelve study sites were determined based on 5 special criteria and 792 respondents fulfilled the criteria for seaweed farmers. Data were collected through field surveys and analyzed using qualitative and quantitative methods. Results showed that the seaweed farming areas are considered as private property with 4 types of marine land tenure or ownership status: own land, inherited land, leasehold land and purchased land. The productivity of seaweed farming land had a positive value greater than 1 in South Sulawesi and Southeast Sulawesi, and a positive value of less than 1 in Central Sulawesi. Seaweed cultivation in Central Sulawesi has not been managed effectively. At all sites, the maximum number of growing season cycles was 5 cycles/year. Optimal growing season conditions gave the highest marginal returns at 2–3 cycles/year with additional costs exceeding additional income for more than 3 cycles/year.

Keywords: Marine land tenure, Ownership status, Seaweed farming productivity, Sulawesi Island, Indonesia

Introduction

Indonesia has the potential to generate substantial wealth from marine resources, including fisheries and aquaculture production. Seaweeds are one such resource with great potential. There are around 782 macroalgal species found along the coasts of Indonesia, comprising 196 green algae, 134 brown algae and 452 red algae (Kepel et al., 2019). According to (Hurtado et al., 2019; Valderrama et al., 2015), the red algae rank first in terms of production volume, with cultivation spreading rapidly from the Philippines to Indonesia. Seaweeds that can grow well in marine waters include *Gelidium* sp., *Eucheuma spinosum*, *Kappaphycus*

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alvarezii (formerly *Eucheuma cottoni*), and *Caulerpa* sp., while seaweeds that can grow in brackish-water ponds include *Gracilaria* sp. (Akrim et al., 2019)

The development of seaweed farming in Indonesia has been massive in scale. The Ministry of Maritime Affairs and Fisheries (KKP) noted that Indonesia had become the second largest seaweed producer after China by 2020, with an export volume of 195,574 tons and value of USD 279.58 million (Chye et al., 2018; Luthfiana, 2022). Seaweed is much in demand as a raw material for food, medicine, fertilizer, and many other applications (Kite-Powell et al., 2022). The need for seaweed as a basic ingredient in various industries makes seaweed a valuable commodity. Therefore seaweed must be used in a sustainable manner and managed effectively (Mac Monagail et al., 2017).

Sulawesi, one of the five main islands in Indonesia, is a major Indonesian seaweed production area (BPS Provinsi Sulawesi Selatan, 2021). Sulawesi is divided into six provinces: South Sulawesi, Southeast Sulawesi, West Sulawesi, Central Sulawesi, North Sulawesi, and Gorontalo (BPS Sulawesi Selatan, 2019) Many kinds of seaweed grow naturally in the waters around the island of Sulawesi, and three of the six provinces are among the top ten provinces in Indonesia in terms of cultivated seaweed production volume: South Sulawesi, Central Sulawesi and Southeast Sulawesi.

K. alvarezii (formerly known as *E. cottoni*) is the primary commercial seaweed farmed around Sulawesi. This edible red seaweed is rich in nutrition and nutraceuticals (Sarita et al., 2021), and typically cultivated using the longline farming system or longline cultivation method (Damayanti et al., 2019; Parenrengi & Sulaeman, 2007; Soenardjo, 2011). Longline cultivation technology is relatively simple (Teniwut et al., 2017) and the investment requirements are relatively affordable (Afandi & Musadat, 2018). *K. alvarezii* farming can offer good business opportunities (Hardan et al., 2020), although innovative, efficient and cost-effective strategies are needed for sustainable management and optimal development results (Buschmann et al., 2017; Mantri et al., 2020).

The main obstacle to the development of seaweed cultivation is marine tenure, which is equivalent to land ownership by seaweed farmers. The sea area (hereafter referred to as land) where seaweed farming takes place is one factor that greatly influences the success of aquaculture (Bessie & Dawa, 2018; Hasnawi et al., 2016; Nashrullah et al., 2021). Land is a common resource (common property) which can be turned into private property with varying forms of land tenure or ownership. Various forms of land ownership by seaweed farmers have developed. Plots that have been used for seaweed farming have come to be treated as private land, which cannot be used by other seaweed farmers or other community members. This remains the case, even when the land in question has not been planted by the owner, and is, in effect, idle land. The research aimed to assess seaweed farmers' income and productivity based on land ownership status in coastal waters around Sulawesi.

Materials and Methods

The research was conducted in the 3 provinces on the island of Sulawesi which are among the 10 largest seaweed producing provinces in Indonesia. Four sites were determined in each province, giving a total of 12 study sites. These sites were selected based on the criterion that each site was a seaweed production center. The sites were: Punaga, Malloso, Tonrokassi and West Tonrokassi in Jeneponto Regency, South Sulawesi Province; Bulagi, South Bulagi, Liang and South Tinangkung in Banggai Kepulauan Regency, Central Sulawesi Province; and Kabawo, Kabangka, Lohia and Duruka, in Muna Regency, Southeast Sulawesi Province.

Data were obtained through field surveys and a library search. Data collection techniques included the use of questionnaires and interviews and a literature review. In-person interviews were conducted with eight respondents in South Sulawesi and Central Sulawesi, and telephone interviews were conducted with two respondents in Southeast Sulawesi. Data were collected from the remaining respondents using a questionnaire. The respondent sampling technique used a purposive sampling method with the following criteria: seaweed farming was the main livelihood occupation; the seaweed farming site was in marine waters; the type of seaweed cultivated was *K. alvarezii*; the longline cultivation method was used; the farmer had a minimum of five years of experience in seaweed farming with continuous cultivation activities (consecutive years). According to (Sugiyono, 2015), if the population to be sampled is less than or equal to 1,000 then all possible samples should be taken (census); meanwhile, if the sampled population is greater than 1,000, then 10% of the population should be used as a sample. The sampled population (respondents fulfilling the criteria) comprised 792 seaweed farmers (cultivators), so the census method was used. These were 313 respondents in Central Sulawesi, 209 in South Sulawesi and 270 in Southeast Sulawesi.

Qualitative and quantitative data analyses were conducted.

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Qualitative analysis refers to the process of analyzing data inductively, building partial data into themes and then providing interpretation. This type of analysis was used to determine and describe the land ownership status of the seaweed cultivators. Quantitative analysis is data processing using simple mathematical calculations such as the addition, subtraction, multiplication, and averaging of numerical data. This type of analysis was used to calculate seaweed farming productivity and income with the formulae: productivity = Y/ TC and income Y = NP – TC where Y is the income of seaweed cultivation business, NP is the net production value (NP) obtained by multiplying the price of seaweed (P) and the volume of product sold (Q) and total cost (TC) is the TC, and is the sum of all business costs consisting of fixed costs (FC) and variable costs (VC) (Nuryanto et al., 2016).

Results

Cultivated Land

The shallow-water areas used for seaweed farming can be considered as cultivated land, and are one factor that greatly influences seaweed mariculture success because the possession of cultivated land could lead to increasing land productivity and also increased seaweed production. Based on the surveys conducted at the 12 study sites, the areas used for seaweed farming can be considered as a common resource (*de jure* state property), generally managed under an open-access regime, which has come to be managed under a range of land tenure or private ownership regimes (*de facto* private property). Seaweed farmers in the study areas had cultivated seaweed with effective land tenure for years or even decades, generally since the first cultivators cleared the area used (hereafter referred to as cultivated land) to plant seaweed for the first time. Four land ownership status categories were identified at the study sites, as follows:

1) Own Land: cultivated land ownership has been obtained because the current farmer/owner was the first person to clear that land and use it for seaweed farming.
2) Inherited Land: the cultivated land has been used by several generations and has been part of the family inheritance (assets passed down from or bequeathed by parents to their children). The land management is fully the responsibility of the beneficiary without further interference from the person bequeathing the inheritance. Therefore, the harvest belongs fully to the manager or owner of the inherited cultivated land.
3) Leased Land: the cultivated land belongs to some person or legal entity other than the seaweed farmer, and management control is fully entrusted to the cultivator under an agreement (generally limited to a specific interval of time) between the two parties.
4) Purchased land: the current farmer/owner obtained cultivated land ownership through a process of buying and selling the cultivated land. Land that is sold or otherwise traded (e.g., in some form of an exchange) is generally in the form of plots that have been prepared and are ready for seaweed cultivation.

The number and percentage of cultivators by site and ownership status are shown in Fig. 1.

The proportion of seaweed farmers in each cultivated land ownership status category differed substantially between and within the three provinces. The relatively recently coupled own land category accounted for more than 25% of seaweed farmers in Central Sulawesi and Southeast Sulawesi, but only around 10% in South Sulawesi. Conversely, in South Sulawesi majority (57.9%) of seaweed farmers had inherited their cultivation land. In Southeast Sulawesi just over half (50.4%) of the farmers had inherited their cultivation land, while in Central Sulawesi the proportion was much lower (23.0%). The leased land category was most prevalent (27.5%) in Central Sulawesi, and rare in Southeast Sulawesi (8.5%) and South Sulawesi (1.9%). The proportion of seaweed farmers who had purchased their cultivation land was highest in South Sulawesi (30.1%), followed by Southeast Sulawesi (15.5%), and lowest in Central Sulawesi (11.5%). The high percentage of South Sulawesi seaweed farmers buying and selling land was influenced by several factors. One of these is that cultivated land can be used as collateral, e.g., for obtaining a mortgage or to pay for wedding expenses.

Investment

Investment is capital in the form of assets, to be used in the future (Wibowo et al., 2011). According to Adhawati & Mallawa (2019), investment is the initial fund or initial capital employed to obtain benefits in the future.

Investment categories

In seaweed farming, investment or initial outlay included ropes, floats, weights, boats, and other equipment. Typical specifications for this initial investment are shown in Table 1.

Seaweed cultivation is carried out by the coastal communities using simple technology that has already come to be con-

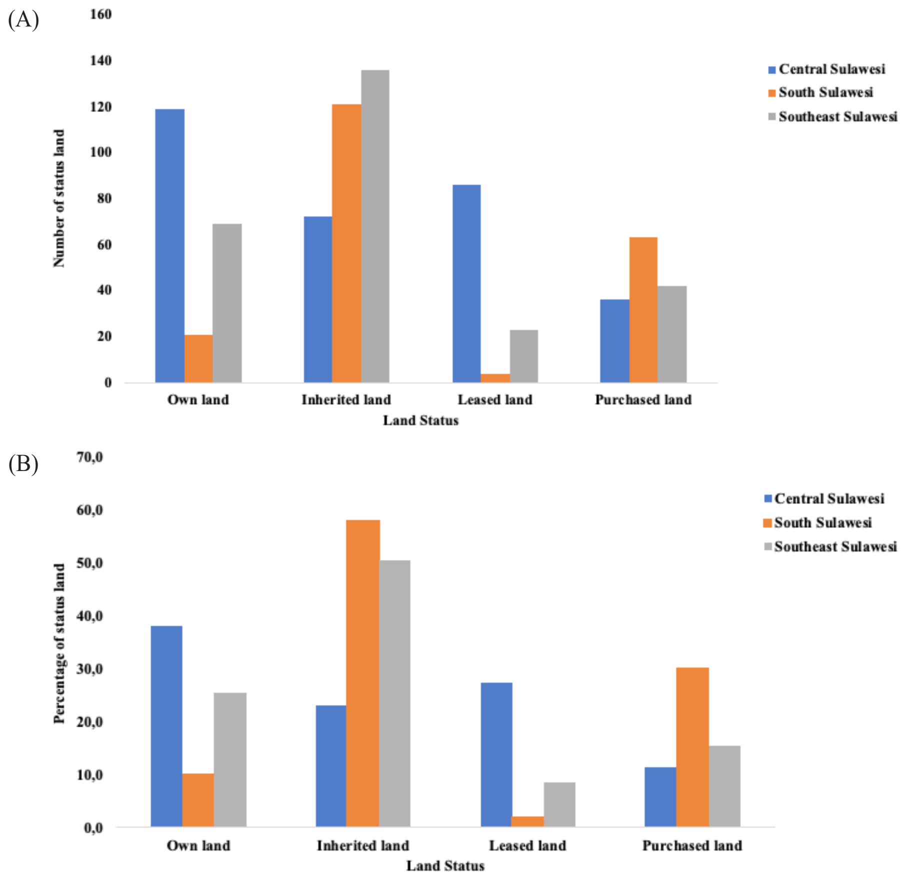

Fig. 1. Number (A) and percentage (B) of seaweed cultivators in three provinces of Sulawesi Island based on land ownership status.

Table 1. Typical categories and specifications of investment in seaweed farming around Sulawesi Island in year 2022

No	Type of investment	Specification
1	Main rope	Nylon no. 12
2	Longline rope	Nylon no. 10
3	Seaweed ties	Nylon no. 5, or Raffia
4	Floats	Jerrycans, empty mineral water bottles (1 L and 300 mL)
5	Weights	Stones
6	Motorboat	Wood or fiberglass
7	Drying area	Wood and netting
8	Working equipment	Scissors, knifes, and gloves
9	Others	Sacks, styrofoam floats/containers

sidered as traditional. The main rope is used as frame of the seaweed plot, and nylon no. 12 rope is most commonly used. The longlines to which the seaweed is attached are generally made from nylon no. 10 rope. The seaweed seeds can be tied on using fine nylon rope (most commonly no. 5) or plastic raffia. Plastic jerrycans are typically used for the main buoys, while used mineral water or soft drink bottles are typically used to keep the longlines close to the surface. While these bottles can come in a variety of shapes and sizes, the most commonly used are empty mineral water bottles in 1 L and 300 mL sizes. A kind of netting locally called *waring* is used to make frames for drying the harvested seaweed. Small motorized boats (often wooded or fiberglass canoes with long-shaft outboards) are typically used in cultivated land preparation activities, and then for transporting the seeded lines to the planting sites, seaweed plot maintenance, and seaweed harvesting.

Investment value

The investment value is obtained by multiplying the unit cost of each investment category used by the cultivator by the volume

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used. The mean estimated cost of the initial investment for seaweed farmers in each cultivated land category in each province is shown in Table 2.

Based on the data in Table 2, on average, investment by seaweed farmers was highest in South Sulawesi, except for the leased land category where Southeast Sulawesi farmers made the highest investment. Overall, seaweed farmers with inherited land made the highest investment, on average, closely followed by those who had cleared new cultivation land themselves (own land category), while seaweed farmers who leased their land tended to make the lowest investment. In Central Sulawesi, the investment value was similar, and relatively low, for all ownership categories. Despite these variations, the investments made by seaweed farmers in their seaweed cultivation business can be considered low for all categories and across all sites and provinces, in line with the results of previous research (Pereira et al., 2020) that investment in seaweed cultivation tends to be low under all scenarios.

Production Value

The production value (NP) is obtained through multiplying the seaweed production volume (Q) by the selling price of seaweed (P). NP is the result of multiplying the total amount of seaweed production produced by farmers in dry form (TQ) and the selling price of seaweed in dry form (P).

It was formulated as:

$$NP = TQ \times P \text{ or}$$
$$NP = (JB \times QB) \times P$$

Where:

JB = Number of lines
QB = Production per line
P = Selling price per kg

The mean NP for each ownership category are given, by province and overall, in Table 3. The NP was far higher for seaweed farmers in Central Sulawesi than in South Sulawesi and Southeast Sulawesi.

With respect to cultivation land ownership status, NP were highest for the own land category and lowest for the leased land category. The NP was directly proportional to the number and length of lines used by the seaweed farmers. The typical length of the longline ropes used by South Sulawesi seaweed farmers was 20–30 m, while in Central Sulawesi and Southeast Sulawesi it was 50–100 m.

Costs

Costs include all expenses for business activities, both fixed ex-

Table 2. Average investment value of seaweed cultivation businesses around Sulawesi Island in 2022

Province	Investment value (IDR)				Average
	Own land	Inherited land	Leased land	Purchased land	
Central Sulawesi	31,598,432	30,998,108	30,802,002	30,487,736	30,971,570
South Sulawesi	44,931,250	45,368,218	33,455,139	44,908,396	42,165,751
Southeast Sulawesi	36,754,490	36,754,490	36,754,490	36,754,490	36,754,490
Average investment value	37,761,391	37,706,939	33,670,544	37,383,541	36,630,603

IDR, Indonesian rupiah.

Table 3. Seaweed production values by cultivation land ownership status in three provinces around Sulawesi Island in 2022

Province	Production value (IDR)				Average
	Own land	Inherited land	Leased land	Purchased land	
Central Sulawesi	38,061,413	33,001,410	32,342,344	32,690,268	34,023,859
South Sulawesi	24,994,375	26,734,903	26,277,500	17,078,570	23,771,337
Southeast Sulawesi	21,698,943	20,952,069	20,812,500	21,014,222	21,119,434
Average production value	28,251,577	26,896,127	26,477,448	23,594,353	26,304,876

IDR, Indonesian rupiah.

penses and variable expenses, where the latter vary depending on the level and type of business activity.

Fixed costs (FC)

FC are incurred regularly, irrespective of business activity. They include depreciation (PI), and other routine overheads. Depreciation is calculated based on the formula PI = NI/UE, where NI is the investment value of a given asset and UE is the expected economic life of that asset or investment component. The mean total fixed costs (TFC) for seaweed farming businesses in the three provinces, taking into account all FC incurred, are given by cultivation land ownership status in Table 4.

The average TFC value of seaweed farmers was highest in South Sulawesi, and lowest in Central Sulawesi . Based on cultivated land ownership status, TFC was similar across the four categories, but highest for leasehold seaweed farmers, and lowest for farmers who had purchased their land. The TFC incurred will remain the same regardless of the number of production cycles (seaweed planting cycles) in a year. As each cycle is approximately 2 months long, there can be one to six production cycles per year.

Variable costs (VC)

VC are outgoings that are calculated based on business activity levels or types. For seaweed farmers in the study area, VC consists of the cost of the seed, seed attachment costs, maintenance and operational costs (gasoline/diesel, cigarettes, victuals and other costs), seaweed harvesting costs, and drying costs. VC values are based on the costs incurred by seaweed farmers during one planting cycle, from seeding to harvest and sale. The mean total variable costs (TVC) for seaweed farming businesses in the three provinces are given by cultivation land ownership status in Table 5.

There was a significant difference between the TVC incurred by South Sulawesi and Southeast Sulawesi and Central Sulawesi cultivators. The average TVC of seaweed farmers in Central Sulawesi was much higher than that of farmers in the other two provinces, with TVC somewhat higher in. South Sulawesi than in Southeast Sulawesi. Based on cultivation land ownership status, TVC was highest for seaweed farmers who had cleared/prepared their own plots (own land status) and lowest for cultivators who leased (rented) their cultivation land. The TVC were strongly affected by the number of seaweed production cycles in a year, rising with each additional planting cycle.

Total cost (TC)

The TC value is the sum of fixed and VC, calculated as TC = TFC + TVC (Madani et al., 2022). TC is directly proportional to the FC and VC incurred by the seaweed farmer. The mean TC

Table 4. Average fixed costs of seaweed farming businesses by cultivation land ownership status in three provinces around Sulawesi Island in 2022

Province	Total fixed costs (TFC) in IDR				Average
	Own land	Inherited land	Leased land	Purchased land	
Central Sulawesi	6,088,993	5,888,520	5,875,602	5,813,507	5,916,656
South Sulawesi	7,065,278	6,902,524	7,675,000	6,996,242	7,159,761
Southeast Sulawesi	6,061,378	6,060,198	5,924,144	5,908,488	5,988,552
Average total fixed cost	6,405,216	6,283,747	6,491,582	6,239,412	6,354,990

TFC, total fixed costs; IDR, Indonesian rupiah.

Table 5. Average variable costs of seaweed farming businesses by cultivation land ownership status in three provinces around Sulawesi Island in 2022

Sulawesi Province	Variable costs (TVC) in IDR				Average
	Own land	Inherited land	Leased land	Purchased land	
Central Sulawesi	19,799,841	18,994,256	19,034,017	19,898,764	19,431,720
South Sulawesi	8,680,333	7,861,750	8,355,000	6,102,972	7,750,014
Southeast Sulawesi	6,894,496	6,763,940	6,358,411	6,172,056	6,547,226
Average total variable cost	11,791,557	11,206,649	11,249,143	10,724,597	11,242,986

TVC, total variable costs; IDR, Indonesian rupiah.

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for seaweed farming businesses in the three provinces are given by cultivation land ownership status in Table 6.

Central Sulawesi had by far the highest average TC and Southeast Sulawesi the lowest. Based on land status, TC was highest of the own land category and lowest for farmers who leased their cultivation land.

Income

Income (Y) is the NP minus TC, calculated using the equation: Y = NP – TC. The mean income or revenue for seaweed farming businesses in the three provinces are given by cultivation land ownership status in Table 7.

On average, seaweed farmers in South Sulawesi had the largest income (Y) while those in Central Sulawesi had the lowest. Based on cultivation land ownership status, Y was highest for seaweed farmers in the own land category and lowest for those leasing their cultivation land.

Business Productivity

Productivity is a measure of the ability to produce goods or services and is based on the relative values of income (Y) and business costs (TC). Business productivity was calculated as Pdts = Y / TC, where TC is the sum of FC per year and the VC for all planting cycles during the year. This means that, based on the number of planting cycles in a given year, business productivity can be calculated using the formulae: Pdts1 = (NP1 – TC1) / (FC) + (VC1) for 1 cycle/year; Pdts2 = (NP1)(2) – (TC1)(2) / (FC) + (VC1)(2) for 2 cycles/year; Pdts3 = (NP1)(3) – (TC1)(3) / (FC) + (VC1)(3) for 3 cycles/year, and so on. If the value of Pdts > 1 the business is productive and if Pdts < 1 it is not productive. Business productivity Pdts and marginal productivity MPdts were calculated based on land status and the number of planting cycles in the three provinces, MPdts is the ratio of additional input (MTC) to the additional income (MY), and was calculated using the formula Mpdts = MTC / MY, where MTC = TC(n + 1) –TCn, and MY = Y(n + 1) – Yn, and n is the number of seaweed planting cycles/year.

Own land ownership status

Productivity (Pdts) and Marginal Productivity (MPdts) of own land cultivating businesses at the three locations are shown in Fig. 2.

The productivity of Central Sulawesi cultivators for 1–6 planting seasons/year was less than 1. This means that cultivation land management is not effective, and productivity is low. However, the value of productivity increased with the number of planting cycles up to a maximum of approximately 0.8 for 3–5 cycles/year. If the maximum of 6 cycles/year is attempted, the Pdts value drops to 0.5 with a negative yield increase of –0.3. These data explain why the maximum number of planting

Table 6. Average total costs (TC) of seaweed farming businesses by cultivation land ownership status in three provinces around Sulawesi Island in 2022

Province	Variable costs (TC) in IDR				Average
	Own land	Inherited land	Leased land	Purchased land	
Central Sulawesi	25,989,287	24,870,923	24,909,618	30,338,666	26,527,124
South Sulawesi	17,513,528	14,587,597	15,348,750	12,992,865	15,110,685
Southeast Sulawesi	13,838,990	12,864,615	11,745,174	11,375,218	12,455,999
Average TC	19,113,935	17,441,045	17,334,514	18,235,583	18,031,269

IDR, Indonesian rupiah.

Table 7. Average income (Y) of seaweed farming businesses per planting cycle by cultivation land ownership status in three provinces around Sulawesi Island in 2022

Province	Income (Y) in IDR				Average
	Own land	Inherited land	Leased land	Purchased land	
Central Sulawesi	12,072,126	8,130,487	7,432,726	2,351,602	7,496,735
South Sulawesi	7,480,847	12,147,306	10,928,750	30,487,736	15,261,160
Southeast Sulawesi	7,859,953	8,087,454	9,067,326	30,487,736	13,875,617
Average Y	10,532,811	9,455,082	9,142,934	10,162,579	12,211,171

IDR, Indonesian rupiah.

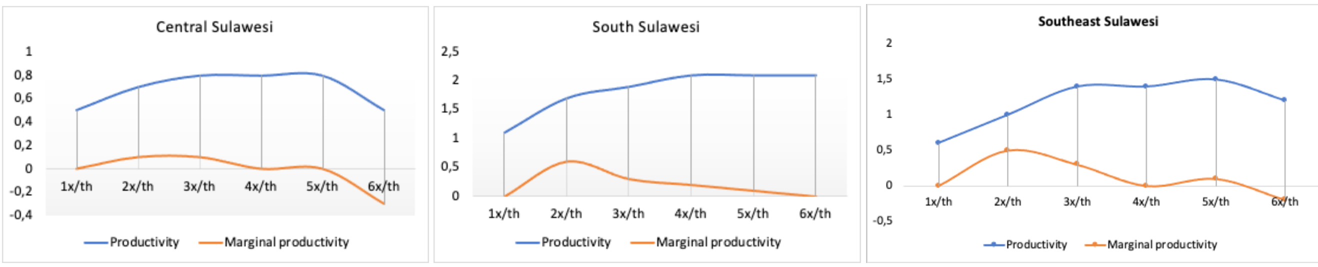

Fig. 2. Average productivity (Pdts) and marginal productivity (MPdts) of seaweed farming businesses with own land cultivation land ownership status in three Sulawesian provinces.

cycles in Central Sulawesi for seaweed farmers in the own land ownership category was 5 cycles/year. Marginal Productivity Value (MPdts) indicates that 2 cycles/year would be the ideal frequency for farmers in the own land category, as marginal income decreases with additional cycles as the additional costs incurred are greater than the additional income earned from seaweed farming (MTC > MY).

The productivity of South Sulawesi cultivators was greater than 1 for 1–6 planting cycles/year. This means that land management is effective. The productivity value was highest, around 2.1, for 4–6 cycles/year. However, with 6 cycles/year, the added return was zero. Although in South Sulawesi farmers in the own land category could plant a maximum of 6 cycles/year, the MPdts (added value yielded) was highest for 2 cycles/year, indicating that this is the ideal frequency for own land. When seaweed is planted more than twice a year, the MPdts decreases, as the additional costs incurred by the seaweed farmers are greater than the additional income obtained (MTC > MY).

The productivity of Southeast Sulawesi cultivators was <1 for 1 annual growing cycle and > 1 for 2–6 growing cycles/year, with fluctuations by number of cycles showing no clear pattern. This means that cultivation land management can be productive with 2–6 cycles/year. The highest productivity of 2.1 was obtained with 3 cycles/year, and the added yield value was zero for 6 cycles/year. Although the maximum possible planting cycles in the Southeast Sulawesi own land category is 6 cycles/year, the MPdts value indicates that yield per cycle is highest for 2 cycles/year. This could be considered an ideal frequency for the own land category, as additional planting cycles result in lower MPdts, as marginal productivity decreases due to additional costs incurred exceeding the additional income obtained (MTC > MY).

Inherited land

Productivity (Pdts) and Marginal Productivity (MPdts) of seaweed businesses in the inherited land ownership category in the three Sulawesian provinces studies are shown in Fig. 3.

There was little difference in productivity patterns between inherited land (Fig. 3) and own land (Fig. 2). Pdts was also < 1 for seaweed farmers in Central Sulawesi, irrespective of the number of cycles/year, indicating the cultivation land management is not effective. However, Pdts did in icrease to a maximum of around 0.8 for 4–5 cycles/year. For 6 cycles/year the Pdts value dropped to 0.4 with a negative yield increase of –0.4. Therefore, for inherited land in Central Sulawesi there should be a maximum of 5 cycles/year. The MPdts values showed that the marginal value is maximised with 2 cycles/year, as the additional costs incurred are greater than the additional income earned (MTC > MY) with additional cycles.

Pdts for South Sulawesi farmers in this category was 1 at 1 planting cycle/year and > 1 for 2–6 cycles/year > 1, indicating effective cultivation land management. The Pdts was highest (2.2) for 6 cycles/year. However, the value added yield was zero for 5 cycles/year and very low for 6 cycles/year. These data explain why the maximum number of planting cycles for inherited land in South Sulawesi was 5 cycles/year. The MPdts value indicated the highest added value with 2 cycles/year. This could be considered the ideal frequency for inherited land in this province, as the additional costs incurred are greater than the additional income earned (MTC > MY) for additional cycles.

The Pdts of seaweed farmers in the inherited land ownership class in Southeast Sulawesi was < 1 for 1 planting cycle / year and > 1 for 2–6 planting cycles/year. There was fluctuation with no discernable pattern in Pdts for 3–6 cycles/year. These figures indicate that cultivated land management is effective, and productive with 2–6 cycles/year. Pdts was highest (2.1) for 3 cycles/year, while the marginal yield added for 6 cycles/year was

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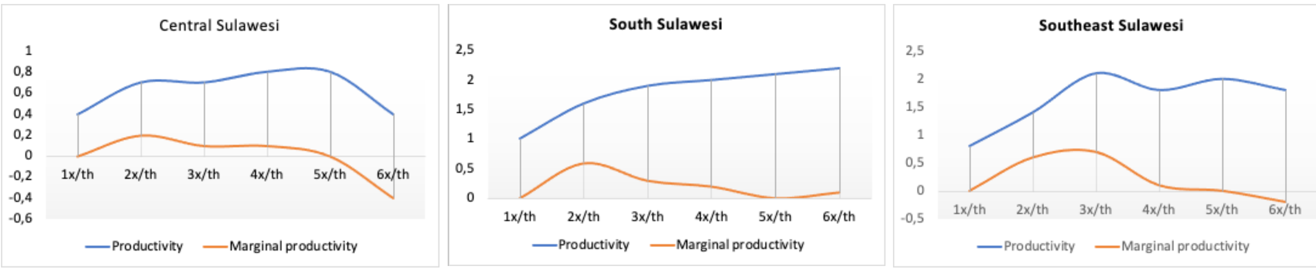

Fig. 3. Average productivity (Pdts) and marginal productivity (MPdts) of seaweed farming businesses with inherited cultivation land ownership status in three Sulawesian provinces.

negative (–0.2). These data explain that the maximum number of planting cycles for inherited land in Southeast Sulawesi was 5 cycles/year. The MPdts value was highest for 3 cycles/year, indicating that this is an ideal frequency for inherited land as additional costs incurred are greater than the additional income earned or (MTC > MY) for additional cycles.

Leased land

Productivity (Pdts) and Marginal Productivity (MPdts) of seaweed farming businesses in the leased land ownership category at the study sites in three Sulawesian provinces are shown in Fig. 4.

Pdts was < 1 (unproductive) for seaweed farmers in this category in Central Sulawesi, irrespective of the number of cycles/year, indicating poor cultivation land management. However, Pdts did increase from 1 to 5 cycles/year, reaching 0.9 for 5 cycles/year, and then dropping to 0.5 for 6 cycles/year with a negative yield increase (–0.4). These data explain why the maximum number of seaweed planting cycles in Central Sulawesi is 5 cycles/year. The MPdts values indicate that 2 cycles/year could be the ideal frequency for leased land in this province, as additional costs incurred are greater than the additional income earned (MTC > MY) for additional cycles.

Pdts values were > 1 for South Sulawesi seaweed farmers in the leased land category, irrespective of the number of cycles/year, indicating effective (productive) land management. The highest Pdts value (2.8) was for 6 cycles/year. With 5 cycles/year, the added yield value was 0.1 and for 6 cycles/year it was 0.2 These data show that maximum planting seasons for leased in this province can vary between 5–6 cycles/year. The MPdts values show a maximum increase in yield for 2 cycles/year, as additional costs incurred are greater than the additional income earned (MTC > MY) for additional cycles.

For leasehold seaweed farmers in Southeast Sulawesi. Pdts was < 1 for 1 planting season and > 1 for 2–6 cycles/year, indicating mostly effective land management with 2–6 cycles/year. The Pdts was highest (2.0) for 5 cycles/year, with a negative added yield (–0.26) at 6 cycles/year. These data explain that the maximum planting season for leased cultivated land in Southeast Sulawesi is 5 cycles/year. The MPdts value was highest for 2 cycles/year, as with further cycles the marginal income decreases due to additional costs incurred exceeding the additional income earned (MTC > MY).

Purchased land

The Productivity (Pdts) and Marginal Productivity (MPdts) of seaweed farming businesses in the purchased land ownership category at the study sites in three Sulawesian provinces are shown at Fig. 5.

The Pdts values for seaweed farmers with purchased land ownership status in Central Sulawesi were < 1 (unproductive) irrespective of the number of planting cycles/year. However, Pdts increased to a peak of 0.9 with 5 cycles/year, decreasing to 0.5 for 6 cycles/year with a negative yield increase (–0.4). These data explain that the maximum number of planting seasons for leased cultivated land in Central Sulawesi is 5 cycles/year. The MPdts value was highest at 2 cycles/year, indicating this could be an ideal frequency for leased land, as the additional costs incurred are greater than the additional income earned (MTC > MY) with additional cycles.

In South Sulawesi, the Pdts of seaweed farmers in this class were >1 irrespective of the number of planting cycles from 1–6, indicating effective cultivated land management. Pdts was highest (2.8) for 6 cycles/year. The MPdts values indicate that the additional yield dropped to 0.1 for 5 cycles/year, but was slightly higher (0.2) for 6 cycles/year. These data indicate that the max-

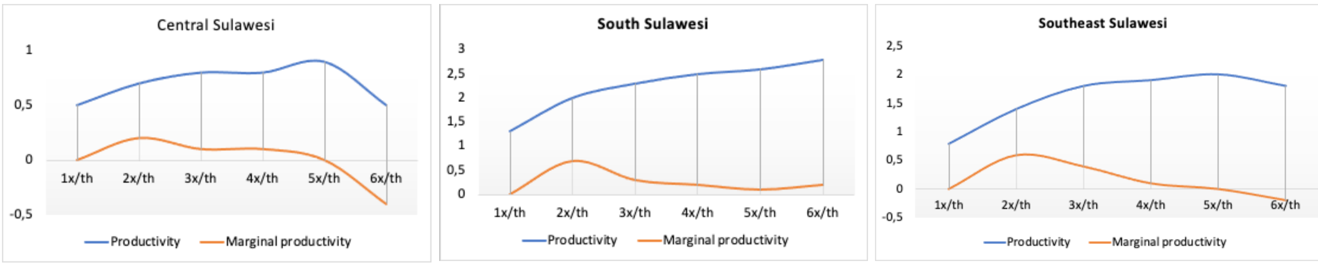

Fig. 4. Average productivity (Pdts) and marginal productivity (MPdts) of seaweed farming businesses with leased cultivation land ownership status in three Sulawesian provinces.

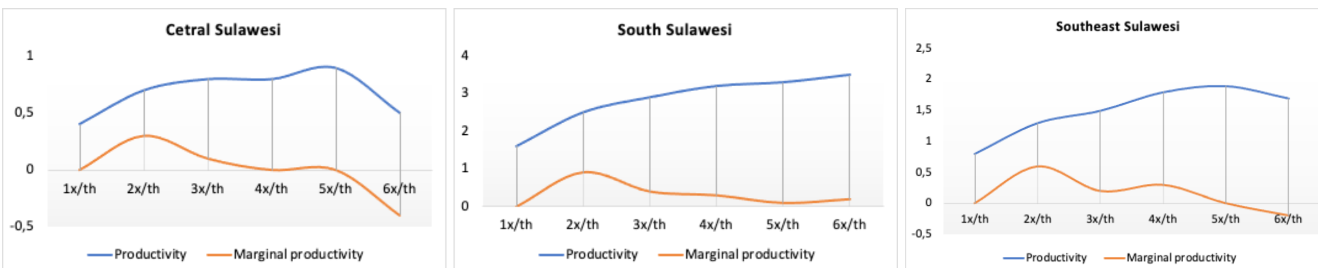

Fig. 5. Average productivity (Pdts) and marginal productivity (MPdts) of seaweed farming businesses with purchased cultivation land ownership status in three Sulawesian provinces.

imum growing season for leased land in this province can vary from 5–6 cycles/year. The MPdts value was highest for 2 cycles/year, which could be an optimal planting frequency as the additional costs incurred exceeding the additional income earned (MTC > MY) with additional planting cycles.

In Southeast Sulawesi, the Pdts for seaweed farmers in the purchased land ownership category was < 1 for 1 planting season and > 1 for 2–6 cycles/year. with increasing values, indicating effective (productive) land management with 2–6 cycles/year. The Pdts was highest (2.0) with 5 cycles/year with a negative added value (–0.2) at 6 cycles/year. These data explain why the maximum planting season for purchased cultivated land in Southeast Sulawesi is 5 cycles/year. The MPdts value was maximized at 2 cycles/year, indicating this may be an ideal frequency, as the additional costs incurred are greater than the additional income earned (MTC > MY) from additional cycles.

Discussion

Cultivation sites (land) pose a major obstacle to the development of seaweed cultivation in the waters around the island of Sulawesi. According to (Bessie & Dawa, 2018), data and information on seaweed cultivation land are incomplete; in particular the land used has not been completely inventoried, which has implications for overlap and competing uses of marine territory. The possibility of control over coastal and marine waters by local communities arises from the concept of control of natural resources as stated in article 33 paragraph (3) of the 1945 Constitution, which reads: "Earth, water and the wealth contained therein is controlled by the state and used for the greatest prosperity of the people" (Astiti et al., 2015). In the elaboration of this article, it is stated that the state becomes the sole owner of natural resources (Arizona, 2016). The *de facto* control exerted over seaweed cultivation sites by seaweed farmers has effected a change in empirical status from state property to private property (Bessie & Dawa, 2018). The sale and purchase of seaweed cultivation land carried out by community members cannot be legalized because *de jure* the seaweed cultivation land is not privately owned but belongs to the state (State Property). Private ownership gives the right to the owner to prevent other parties from benefiting from the resources they own. At the research sites, perceived land ownership rights over seaweed cultivation plots are marked by the existence of socially recognized tenure rights over land clearing, inheritance, leasehold cultivation,

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and transfer (trading and purchasing). The community makes boundaries in coastal areas to demarcate the plots for seaweed cultivation. The presence of seaweed cultivation plots means other people involved in mariculture or fishing can no longer utilize the cultivated land.

Seaweed cultivation has played an important role in efforts to increase the income and welfare of people in coastal communities. Seaweed farming contributes to global food security, supports the livelihoods of rural communities and alleviates poverty (Alemañ et al., 2019). At the study sites, seaweed farming can provide income to cultivators from up to 6 planting seasons or cycles per year. This is in line with findings that seaweed cultivation is a relatively new employment field with a high growth rate and short turnover time so that seaweed farmers can obtain income up to six times a year (Zainol, 2016). Meanwhile, according to Muslimah et al. (2019), seaweed production can be carried out for five harvest cycles in a year, and another study (van den Burg et al., 2016) shows that several harvests (planting seasons) can reduce production costs and seaweed cultivation businesses can provide benefits to seaweed farmers if cultivation activities are carried out with 4 cycles/year.

The results of this study conducted at 12 sites in three provinces around the island of Sulawesi show that, in general, seaweed farming was productive (productivity > 1) for 1 or 2 up to 5 planting cycles/year, indicating that at most sites there should be a maximum number of 5 planting cycles/year. Based on the marginal increase in yields received by seaweed farmers for each additional cultivation cycle, an optimal increase in income would be obtained with 2–3 cycles/year, as additional cycles appear to result in a case of the law of diminishing returns. According to (Jannata & Ma'rif, 2017; Setiawan & Prajanti, 2011), at some point the addition of the number of input variables will cause a decrease in the value of the product (Yasin, 2016). The law of diminishing returns states that the output received from the production process would decrease if the variable input used increases continuously beyond some optimum point. In other words, this law states that an increase in the variable production factors will initially provide an additional increase in yield, but after reaching a certain point, an increase in the input factors of production will reduce the profit obtained from production output.

Conclusion

Seaweed cultivation sites in the three Sulawesian provinces within the study area are, in practice, treated as land that can be privately owned, inherited, rented out, and transferred or traded, although there is no legal basis for these marine tenure or land status categories under Indonesian law, because the seaweed cultivation areas are below the high tide line, and are therefore state property. Of these four *de facto* land status categories, privately-owned land provided the highest proportion (26.8%) of seaweed farmer income in the study area. Of the three provinces, South Sulawesi contributed the highest proportion (41.7%) of revenue from seaweed farming. In Central Sulawesi, the overall productivity of seaweed cultivation businesses was not effective, with a positive value less than one. South Sulawesi and Southeast Sulawesi had effective seaweed cultivation businesses, with positive productivity values greater than one. The maximum number of seaweed planting cycles was five cycles per year. The maximum accrual of income occurred with two planting cycles each year. If seaweed was planted three or more times, the additional business revenue was generally less than the additional costs incurred.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate

Not applicable.

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