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Analysis of productivity levels of saline coastal land for crop cultivation activities

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Abstract. Saline land is an area zone that is widely developed for agribusiness activities with high economic value. The purpose of this study is to determine the parameters that affect the level of productivity of saline land in coastal areas for agricultural agribusiness activities. The research methods used were descriptive quantitative and descriptive qualitative methods. The indicators observed were soil and water parameters on saline land. The results showed that soil parameters that are not following the quality standards of agricultural cultivation are N 0.12-0.14%, P_2O_5 14-57 mg/L, K_2O 473-506 mg/L, Ca 0.47-1.27%, Mg 0.51-5.14%, Al 8.51-243%, and Na 0-0.37%. Water parameters that do not comply with agricultural cultivation quality standards are Ca 54.02-320.60 mg/L, Mg 78.22-424.94 mg/L, Na 582.31-3208.68 mg/L, PO_4 0.11-0.72 mg/L. $Y= 18.021+0.80_{X1}+0.262_{X2}+0.332_{X3}+0.081_{X4}+0.105_{X5}+0.177_{X6}+0.794_{X7}$ Is formula of soil regression test resulted. Meaning that parameters that do not meet soil quality standards will simultaneously affect the land productivity. The water regression model formula by $Y= 7890+0.001_{X1}+0.002_{X2}+0.003_{X3}+0.004_{X4}$, means that water quality parameters that do not comply with quality standards do not affect the level of land productivity. The results of the dynamic analysis estimate that the level of productivity and carrying capacity of land in saline coastal areas will decrease along with the increase in crop yields. Based on the study of modelling analysis, it can be concluded that there are several soil parameters such as N, P_2O_5, K_2O, Ca, Mg, Al, and Na that affect the productivity level of saline land in coastal areas.

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1 Introduction

In tropical regions, agricultural agribusiness activities are highly developed and productive. Indonesia, a tropical nation with two distinct seasons the dry and wet seasons is closely associated with agricultural pursuits [1]. According to [2], the rainy season is the one that farmers dread the most since there is a greater chance that their crops will fail and because production costs tend to rise as output declines. Contrarily, the dry season has an impact on agricultural development and output, planting schedules, and renders it hard to cultivate crops more than once a year [3]. Agricultural growth is necessary, according to [4], to boost business productivity, utilize science and technology to the fullest extent possible, enhance the caliber of human resources to boost agricultural production's comparative advantage, and expand agricultural activities. Diversification, intensification, and extensification are actions that can be taken. Indonesia has a total land area of 191.09 million ha, with 34.58 million ha of that potentially usable for agriculture in 2015, yet in 2019 there were 36.8 million ha of agricultural land in Indonesia [5, 6]. Indonesia is quite likely to become an autonomous agrarian nation given its vast potential for land.

In Indonesia, there is a good distribution of agricultural land in the high, medium, and lowlands [7]. States that upland places often have a topography of choppy to hilly ground (9>45%), an average rainfall of 2800-3300 $mm.th^{-1}$, an average air temperature of 16-22^{0}C, and a location over 700 m above sea level. Andisol soils, which have a high C-organic content, low bulk density (BD), high porosity, and high permeability, make up the majority of the soils in the uplands. In contrast, lowland soils, particularly those found near the ocean or in coastal regions, only make up 4% of the earth's surface, yet they are home to one-third of the world's population [8]. It is unable to use coastal land's water for everyday needs because of its high electrical conductivity value (4710-11,400 µs/cm) and brackish sensation, and it is also unsuitable for some plants with low tolerance levels [9]. According to [10], low organic matter, low cation exchange capacity, and high rainfall result in low soil fertility; therefore, soil analysis is one of the keys to success in figuring out the nutrients needed in particular soil conditions or determining land productivity to support crop cultivation activities. According to [11], different land areas have varying concentrations of nutrients that plants need.

The following agricultural products are grown in coastal lowlands: rice, corn, coconut, and banana [12-14]. According to [14], the top four commodities produced in coastal parts of Riau Province are coconut, sago, rubber, and coffee. A challenge for Indonesia's developing agricultural zone areas is the dearth of agricultural products in coastal lowland areas. Lowland coastal areas have historically been associated with agriculture and fisheries. Due to the challenges posed by these salty circumstances, some agricultural products grown on saline terrain, such as rice, corn, cassava, and sorghum, frequently fail.

High nutrient availability loose soil, adequate water availability, and good soil contours are requirements for fruitful land [15, 16]. The level of productivity of the land when utilized as a cultivation medium to support agricultural production would be highly influenced by the presence of fertile land criteria [17]. The kind of plant commodity that is suitable for cultivation will eventually be determined by the amount of land productivity.

Crop cultivation models in salinity-prone areas are still only very infrequently used in agricultural agribusiness activities. Saline land is a significant element that adversely impacts agricultural yield and soil fertility [18]. According to [19], saline land is land with a high enough salt content, which makes it less suited for use as a planting medium since it can hinder plant growth and production through increased osmolarity, ion poisoning, nutritional imbalance, and oxidative stress [20, 21]. Aquatic plants like seaweed, mangroves, and some types of algae are frequently grown on saline ground [22-25]. According to [26], identifying the productivity of saline land is necessary to ascertain the structure of agricultural activities and the most appropriate commodities.Based on the aforementioned literature review, the goal of this study is to identify the factors that influence how productive saline land is in coastal regions for integrated agricultural activities. The findings of this study should reveal the soil and water characteristics that can be used as markers for crop production in coastal locations.

2 Materials and methods

This research was conducted in Gamer Village, East Pekalongan Subdistrict, Pekalongan City, Central Java, Indonesia in August-November 2022. The research method used was descriptive quantitative and qualitative with sample data collection using the concept of *ex-pose facto* causal design. The plants observed in this study were saline rice varieties cultivated in wetlands. The parameters observed in this study were soil parameters including sand, dust, and clay texture, pH, EC, salinity, C, N, C/N, P_2O_5, K_2O, CEC, KB, Ca, Mg, Fe, Al, Mn, S, Na, and water parameters including pH, DHL, NH_4, PO_4, K, Ca, Mg, Na, Fe, Al, Mn, Cl. The selection of soil and water parameters is intended to facilitate the process of analysing the level of suitability of rice cultivation land based on indicators of soil biotic factors. Sampling was conducted *in situ* in the field directly and *ex situ* at the Soil Research Centre Laboratory, Bogor, Indonesia.

The soil and water parameters studied were then subjected to quantitative and qualitative analysis using modelling. Static modelling analysis was carried out with the help of SPSS ver 19 software and dynamic modelling system analysis was carried out with the help of Stella ver 9.02 software. From the modelling results, correlation analysis was then carried out related to the parameters that affect the level of land productivity for saline rice cultivation.

3 Results and discussion

3.1 Soil parameters

Table 1 displays the findings of soil parameter observations. The results of the measurements of the soil parameters revealed that the soil parameters N 0.12–0.14%, P_2O_5 14–57 mg/L, K_2O 473-506 mg/L, Ca 0.47–1.27%, Mg 0.51–5.14%, Al 8.51–243%, and Na 0–0.37% did not match the quality standards for agricultural cultivation. For agricultural cultivation activities, soil quality standards still apply to the texture of the soil as well as a number of other physical and chemical characteristics, including pH (KCl), C, C/N, CEC, KB, Mn, and S (Table 1).

Important indicators for integrated agricultural activities include soil characteristics [27]. Comparatively speaking to other soils, soils on saline ground typically have distinctive properties. Despite having a lower rate of nutrient uptake [28, 29], soils on saline land have a greater variety of minerals [30]. The first consideration when choosing plants for saline land cultivation is this characteristic.

Agricultural commodities can tolerate saline soils in a range of ways, from sensitive to very tolerant. According to [31], wheat, sugar beet, cotton, and barley are salinity tolerant, but green beans, eggplant, shallots, and corn are salinity sensitive. Rice can handle moderate salt, while grasses can handle it quite well. The development of tolerant and adaptable varieties is one of the acceptable and adaptive agricultural approaches that must be searched out in order to make use of saltwater land [32]. This is being done as a technical trick to boost agricultural production. Crop yields on salty terrain often tend to be low and can even fail due to high salinity levels [16, 30, 32, 33].

Table 1. Soil Physical and Chemical Parameters

COMPONENTS	LOCATION			Quality Standard
	GAMER 1	GAMER 2	GAMER 3	
Texture (%)				
Sand	13	14	12	
Dust	33	40	39	
Clay	54	46	49	
pH				
- H_2O	5.8	6.4	6.4	6.6-7.5
- KCl	5.3	5.7	5.9	
(EC) (dS/m) (soil paste extract 1:5)	1.833	2,120	2,200	> 4
(ECe) (dS/m) *	12.79	17.00	16.79	> 4
Salinity (mg/l)	916	1061	1100	200-500
C (%)	1.45	1.57	1.69	0.6-3.5
N (%)	0.12	0.14	0.14	0.2-0.75
C/N	12	11	12	8.0-25.0
P_2O_5 (ppm)	57	48	14	20.0-40.0
K_2O (ppm)	473	506	496	10.0-20.0
CECKTK (cmol/kg)	25.94	22.1	27.62	25 – 40
KB (%)	0.65	0	0	< 20
Ca (%)	0.47	1.27	1.24	0.04-0.4
Mg (%)	5.14	0.53	0.51	0.006-0.096
Fe (%)	9.48	8.54	8.72	1.0-10.0
AI (%)	243	8.51	8.62	0.05-0.025
Mn (ppm)	143	244	203	50-200
S (ppm)	0	10	11	40
Na (%)	0	0.34	0.37	0.4-0.7

Remarks: *The EC 1:5 was converted to ECe using the equation: Ece= (14.0-0.13) x clay%) x EC 1:5 [34]

3.2 Water parameters

The results of the measurement of water quality parameters showed that only the parameters Ca 54.02-320.60 mg/L, Mg 78.22-424.94 mg/L, Na 582.31-3208.68 mg/L, PO_4 0.11-0.72 mg/L were not by the water quality standards for agricultural cultivation activities. While for other parameters such as pH, EC, NH_4, K, Fe, Al, Mn, and Cl are still suitable (Table 2). In general, the water parameter profile at the research site is still very favorable for agricultural activities.

The primary element needed for plant existence is water [35-38]. Water has the ability to dissolve a wide variety of nutrients. For agricultural cultivation activities, enough water is defined as having a suitable nutritional content and the right amount of flow [39, 40]. Water in saline environments has a tendency to be more dynamic than water in fresh environments.

High degrees of hardness are typical of water in saline environments [28]. The solubility of nutrients will be challenging due to the high degree of hardness. High hardness water does, however, typically have a larger mineral ion profile [41]. It takes some suitable cultivation strategies to use saline water for agricultural cultivation activities. Haloculture is a viable paradigm that might be created in saline-affected locations, according to [42]. Haloculture is an engineering technique for the environmentally friendly production of various industrial and agricultural goods in salty settings. The management practices for salinity control include the selection of tolerant crops or varieties that will yield satisfactory yields, the investigation of land preparation and planting techniques that are helpful in controlling salinity, the development of irrigation that maintains relatively high soil moisture, the periodic leaching of salts from the soil, the maintenance of water conveyance and drainage systems, and the use of manure, green manure, and amendments [43]. By creating agricultural conservation methods such minimal tillage, crop residue management, fertilization/composting, and wise crop selection, increased attempts have been made to lessen the effects of saline soils [44].

Table 2. Physical and chemical parameters of water

COMPONENT	LOCATION			Quality Standard
	GAMER 1	GAMER 2	GAMER 3	
pH	8.01	7.89	7.93	6.5-7
EC (dS/m)	2,700	19,080	14,390	1.0-2.5
NH_4 (mg/L)	1.24	2.30	0.13	5
K (mg/L)	22.34	82.26	91.37	380
Ca (mg/L)	54.02	320.60	0	15
Mg (mg/L)	78.22	424.94	0	50
Na (mg/L)	582.31	3208.68	2658	40-400
Fe (mg/L)	0.03	0.03	0.03	2.0-10.0
Al (mg/L)	1.25	2.50	0	5.0-10.0
Mn (mg/L)	0.01	5.36	0.02	0.1-0.2
PO_4 (mg/L)	0.15	0.72	0.11	0.1
Cl (mg/L)	0	0	3941	140

3.3 Linear regression analysis

A straight forward linear regression analysis was then performed using the measurements of soil and water parameter levels at three sites inside the research site. The level of influence of soil and water characteristics on the level of land production was examined using a linear regression analysis. The following formula represents the regression model's findings for soil parameters:

$$Y= 18.021+0.80X_1+0.262X_2+0.332X_3+0.081X_4+0.105X_5+0.177X_6+0.794X_7 \quad (1)$$

According to the regression model, soil parameters that fall short of quality requirements will also have an impact on the level of land production. The coefficient of regression value

>0.05 is what determines how much simultaneous influence there is. In large quantities, saline fluids contain certain mineral components as N, P_2O_5, Ca, Mg, Al, and Na. Saline land's mineral composition will have an impact on how many dissolved nutrients are present [45]. Through the sedimentation process, soil is a medium that readily absorbs nutrients.

Formula 2 shows the outcomes of a linear regression study on water parameters. The regression coefficient level from the water parameters that don't meet quality criteria is modest (<0.05). The following formula shows the outcomes of a linear regression study of water parameters:

$$Y= 7890+0.001X_1+0.002X_2+0.003X_3+0.004X_4 \quad (2)$$

According to the findings of the regression analysis, it can be said that the levels of soil production in saline land are unaffected by the water quality indicators that do not fulfill quality criteria. A solute that is plentiful in nutrients is water [46]. Due to the high concentrations of dissolved salt, many mineral elements, including Ca, Mg, Na, and PO4, are particularly soluble in saline fluids [47]. The lengthy process by which water nutrients are absorbed by solid media (soil) accounts for the lack of influence of water characteristics on land productivity [48]. The degree of nutrient mixing in nature is also impacted by variations in media structure [49].

3.4 Dynamic modelling analysis results

A dynamic modeling system study was conducted in addition to a linear regression analysis to ascertain the extent to which parameters that fall short of quality criteria have an impact on land productivity. Determine the amount of land productivity and crop support in saline land areas using this dynamic modeling system study. The multi-indicator relationship was first established using a causal loop model pattern in the dynamic modeling system analysis. Additionally, the analysis is conducted using the required indicators. Figure 1 displays the outcomes of the examination of the dynamic modeling and causal loop modelling.

It is predicted that the level of land productivity and planting carrying capacity in saline land areas will decline along with the increase in harvest quantity based on the dynamic modeling analysis of the indicators of harvest quantity, land productivity, and planting carrying capacity in Figure 1. The productivity of the land will gradually decrease as a result of overuse [50]. In general, excessive land use would negatively impact the performance of the carrying capacity of the land for agricultural cultivation activities because decreased land productivity will reduce the level of carrying capacity of a commodity [51].

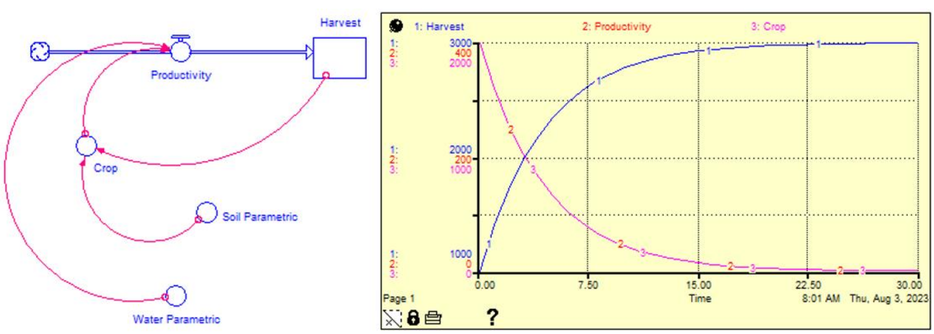

Figure 1. Results of causal loop modeling and dynamic modeling analysis

On saline land, it can be expected based on the findings of this dynamic modeling research that the increase in agriculture intensification, which influences the increase in harvest intensity, will have an impact on the decline in land carrying capacity. The level of land productivity rate for agricultural cultivation operations is significantly impacted by saline land because of its distinctive characteristics [16]. Saline terrain will be challenging to employ as excellent agricultural land due to the high mineral and salt concentration [52].

Overall, high mineral and nutrient concentrations have a significant impact on the nature of saline land. In saline environments, soil characteristics play a significant role in determining the amount of land production. As a result of the modeling, it is also evident that salty lands' carrying capacity for agricultural cultivation will decline as land use intensity rises. With greater intensity of resource usage, the carrying capacity of the land will decline [53]. Along with changes in environmental factors, the level of land production will also be dynamic [54].

4 Conclusion

Based on the results of modelling analysis, it can be concluded that there are several soil parameters such as N, P_2O_5, K_2O, Ca, Mg, Al, and Na that affect the productivity level of saline land in coastal areas.

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