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# Salinity Constraints for Small-Scale Agriculture and Impact on Adaptation in North Aceh, Indonesia

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**Abstract:** We investigated the perceived effects of salinity on farming practices, income, and challenges for crop production in Blang Nibong village in North Aceh, Indonesia. We surveyed 120 smallholder farmers chosen in consultation with local leaders considering their agricultural activities and salinity susceptibility. Farmers' perceptions of major crop production constraints (e.g., salinity) and potential adaptation strategies were assessed using open and closed questions. The study revealed that farmers in the study region primarily grew rain-fed rice using traditional monoculture. Salinity was identified as the primary crop production constraint by all respondents, resulting in plant mortality, decreased soil health and water quality, limited plant growth, and low yields. Additionally, salinity has reduced the arable area (>0.5 ha), resulting in lower total production. The implications of the salinity were further corroborated by the low farmers' income. In fact, farming activities are not contributing positively to farmers' income as the results revealed off-farm activities (77%) as the main source of income. Based on the farmer's current activities to overcome salinity problems on their farms, they were clustered into adaptive and non-adaptive farmers. The non-adaptive group prefers to convert their land to pasture (81%), whereas the adaptive group prefers to improve the irrigation system (77%).

**Keywords:** lowland coastal farming; salinity risk; farmer's perception; climate change effects; adaptation strategies



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## 1. Introduction

Climate change and increased soil salinity due to natural disasters (e.g., tsunami) continue to pose challenges to agricultural production. Recent estimates indicated that around 1125 Mha worldwide are affected by salt and 1.5 Mha of land becomes unsuitable for agricultural production each year due to high soil salinity levels [1,2]. The loss of agricultural production is difficult to assess, but it is estimated that around 25% to 50% of all irrigated land is exposed to salt [3,4].

In Indonesia, salinity is mainly problematic in farmland close to the coast, covering at least 12,020 Mha of the total agricultural land (100,700 Mha) [5]. The agricultural sector plays a key role in the economy of Indonesia, contributing 13.5% of the GDP, the second-highest after the industry sector with 19.6% of the GDP [6]. Among the agricultural sector, rice is the largest contributor, with a share of about 2.7 % of the agricultural GDP in 2019 [7].

Important approaches such as the development of salt-tolerant cultivars and more traditional strategies including the deliberate management of soil, crop calendar, irrigation, and amendment of the crop environment are needed to alleviate the adverse effect of salinity in coastal farmlands [8]. In recent years, more emphasis has been placed on studies to mitigate the effects of salinity in Indonesia. Breeding programs have been able to develop salt-tolerant rice with promising adaptability to salt [9,10]. Most studies focused on rice (due to its importance to the agricultural sector in the country) with less focus on potential alternatives such as soybean [11,12] and sorghum [13].

During the 2004 tsunami, at least 70,000 ha of agricultural lands in the coastal areas of Aceh were affected by erosion, coastal deformation, and seawater intrusion. Most of the land areas were covered by a large amount of sediment containing coral fragments, sand, sea bed mud, and peat soils [14]. The tsunami devastated the local economy where most of the livelihoods came from rice farming, fish farming, and gardening [15]. At least 37,500 ha of farmland along the coast in Aceh were inundated and crops planted after the incident continue to suffer severely from increased soil salinity.

The extent to which salinity levels have changed over time after the tsunami has not been fully studied to date. Measurement of salinity levels eight months after the disaster showed mean values of electrical conductivity of saturated soil extract (ECe) varied from 1.6 to 22.6 dS $m^{-1}$ at a soil depth of 0 to 1.2 m and three years after the values had declined, ranging from 1.4 to 13.0 dS $m^{-1}$ across sites in the affected region. The first rice seedlings established in dryland rice fields in 2006 failed due to high salinity (EC of 8 to 10 dS $m^{-1}$) [16] but not in the field with sufficient irrigation [17].

A more recent study analyzed land suitability after a decade of events based on FAO salinity criteria and spatial data analysis using a remote sensing method. It was revealed that in the area near the river with freshwater input, the salt content is in the normal range (<0.1 ppt) while the area close to the coast has brackish salinity with negligible effect on plants. However, this research is limited to the Banda Aceh City area only and may not represent all zones that have been affected [18].

Yet, indirect impacts such as coastal physical transformation and continual ecosystem change are noticeable. Under a circumstance of 1 to 1.5 m sea-level rise, nearly half of the total area of existing wetlands will be lost due to the inundation of seawater that has not yet been fully recovered from the tsunami [19]. Only around 80% of the agricultural land can be recovered [17]. Aceh's economy has managed to return to its growth path before the tsunami although at a slower pace than the closest neighbor province. However, the unemployment rates remain high in the district worst hit by the tsunami wave [20].

There are several studies looking at the direct impacts of the 2004 Tsunami and recovery. Most studies have focused on the environmental impacts [21] socio-economic and urban impacts [22], and the housing dynamics and recovery in Aceh [23]. However, impact studies on agricultural soils and related farming activities are completely lacking. The existing studies to boost productivity in salinity-prone lands in Indonesia have not been fully conveyed to farmers. Limited access to currently available information on crops and technology hinders the adoption of the innovations by farmers [24].

To better manage salinity constraints in the region, the characterization of current agricultural practices and farmers' perspectives on this issue is urgent. Characterization of agricultural activities is important to identify the existing production system [25] in coastal farming that has similar agro-ecological zones. Knowing existing agricultural practices is a prerequisite to developing interventions and tools to assist farmers with proper management.

In this study, we performed a comprehensive survey to gain an understanding of the agricultural practices and farmers' perspectives on current challenges in managing salinity for the given farming activities in North Aceh, Indonesia. One basic hypothesis is that soil salinity still considerably influences farming practice, management, and farmers' income diversification in our study region. We further hypothesize that farmers' adaptation strategies concerning agricultural activities are determined by the prevalence and severity of salinity, socio-economic aspects (e.g., education, age), and availability of salt-tolerant (rice) varieties.

The specific objectives of this study were (i) to characterize farmers and their farm management activities; (ii) to evaluate farmers' perception of salinity, climate variability, and change, (iii) to evaluate farmer's income diversification strategies; and (iv) to assess farmer's awareness of the impact of salinity in the long-term and their perception of adaptation options feasible in the future.

## 2. Materials and Methods

### *2.1. Study Area*

The study was conducted in Blang Nibong Village in North Aceh Regency, Indonesia located on the coast of the northern end of Sumatera Island with an area of about 225 ha (Figure 1). The rice fields cover at least 11% of the total land area (25 ha). The rest is used for other purposes such as housing, fish ponds, gardens, and others [26]. The area was destroyed during the tsunami in 2004 and rebuilt through rehabilitation programs by the central government of Indonesia in collaboration with international and local agencies. The region is characterized by 1450 mm of rainfall, a mean minimum temperature of 22 °C, and a mean maximum temperature of 30 °C (period 2000–2020) as measured at the meteorological station Malikussaleh. The rainfall regime has two seasons linked to the prevailing monsoon—the rainy season (from October to February) and the (largely) dry season (from March to September). The study area is characterized by a bimodal rainfall pattern with the main rainy season from October to early February and a very short rainy season (basically May). Maximum rainfall usually occurs from late September to early February [27,28] (Figure 2). The study area extends over a coastal lowland area with an altitude range from 2 to 11 m above sea level.

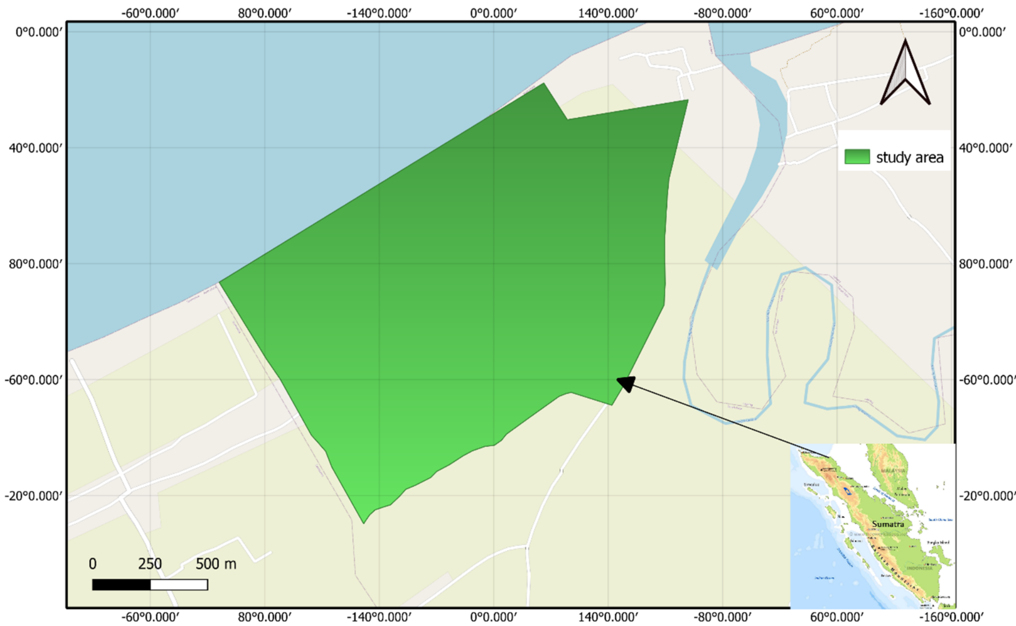



**Figure 1.** Location of the study area in Village of Blang Nibong, Regency of North Aceh, Province of Aceh Indonesia. Own illustration using QGIS.

Soils in the study area are predominantly Eutrics Regosol and Gley Regosol. Eutrics Regosol soils have a deep section, coarse texture (loamy sand, sand) gravel, and fast drainage. Gley Regosol soils have a deep section and show hydromorphic properties of gray in the lower layer, a slightly coarse texture (clay-sand), and a rather rapid drainage [29]. The agricultural land has been used for rice cultivation (as the main crop) for several decades (personal communication). No reliable record is available on land-use history for the study area.

According to the most recent census conducted in 2018 [30,31], the total population of the study area in 2018 was 1.451 of 385 households (hh) with an average of 4 members per household. A total of 251 households carry out farming as their main source of income (e.g., staple food farming, fish-farming) followed by trading (n = 38), transport (n = 11), and services and other activities (n = 85). Regarding access to education, there is a primary school in the area, and the nearest higher education facility (university) is approximately 40 km away from the study site. No public transportation is immediately available, the closest access to public transportation is within 8 km. One agricultural extension center as support for agricultural activities is located at the district level.

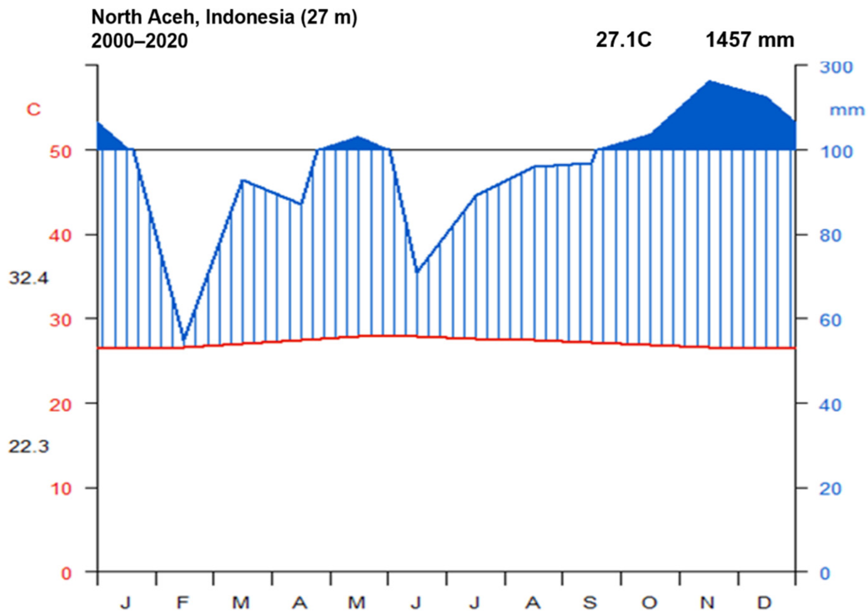



**Figure 2.** A Walter–Lieth climatic diagram exhibiting monthly averages for air temperature (left y-axis, red-colored) and average sum of monthly precipitation (right y-axis, blue colored) of the closest meteorological station to the study site. The black values on the left-hand side (y-axis) represent the maximum and minimum air temperature. The thick blue line indicates precipitation and the thin vertical blue lines above the red curve indicate humid conditions; the filled blue areas indicate wet periods. The information above the panel corresponds to station location, annual average air temperature, and an annual sum of precipitation.

### *2.2. Data Collection*

To characterize agricultural practices and farmers' perspectives on current challenges in managing salinity, we first gathered available data from national agencies, relevant NGOs, and literature on the demographics, weather, soils, and past and current farming systems in the study area. This information served as a basis for understanding the data availability situation and providing context for the design of a questionnaire, and later for conducting interviews with household heads. Data used for describing farming systems and demographic indicators in the study were obtained from the extension center for agriculture, the central agency on statistics, and the agricultural department at district and regency levels.

Interviews with household heads in the Blang Nibong village were conducted in August 2020. A total of 120 households were selected based on discussion with the local leaders considering their activity in farming and vulnerability to salinity risk, which has been an issue since the tsunami of 2004. Both open and closed questions were asked in the questionnaire: (i) respondents baseline information (name, age, gender, residence status, occupation, ethnicity, marital status, household size, and educational level); (ii) farming characteristics including land information (land holding, size of land cultivated, the period of cultivation, and information related to the main crop), and list of crop types and production in the past three years of 2018, 2019, and 2020. The respondents were asked to provide information on (iv) their farm management activities including land preparation, planting method, fertilizer application, weed control, pests, and disease management; (v) water availability and available irrigation system; (vi) information on their resource endowment (socio-economic aspects). To better understand surveyed household farming activities, farmer's perceptions were solicited on (vii) the main constraint of their cropping activities (salinity, low soil fertility, soil compaction, waterlogging) and changes in agro-climatic conditions (e.g., changes in rainfall and temperature); and (viii) income diversification. Perceptions of the impact of salinity on their crop productivity, income, and coping strategies were obtained at the end of the interview session.

Climate data was gathered from the Class III Meteorological Station, Malikussaleh. The station is located at 05°13′33″ N latitude and 096°56′55″ E longitude at an altitude of 27 m.a.s.l. Daily precipitation and air temperature data for the period from 2000 to 2020 were used to characterize climate conditions. Analysis of annual anomalies for precipitation during the main growing season (October–February), and of time series of maximum and minimum temperature were performed to identify trends during the period of record.

### *2.3. Statistical Analysis*

Information from 117 questionnaires was compiled (responses for 3 questionnaires were eliminated due to unreliable data) and analyzed using R-studio version 4.0.3 [32]. Non-parametric chi-square tests were conducted for each of the demographic and socio-economic variables to test the mean difference between two household categories (adaptive and non-adaptive) [33]. Radar charts were used to visualize the multivariate variables of farmers' perception of salinity effects and constraints. The seasonal and annual rainfall variability and trends are derived from observed daily rainfall records. Graphical methods were used to illustrate the temporal variation of rainfall during the growing season rainfall (October to February). To visualize the time-series variation of seasonal rainfall, standard rainfall anomalies were plotted against time (in years). A simple linear regression was used to identify and characterize the long-term trend of temperature variability values on an annual time scale using the equation below [34]:

$$Y = \beta x + c$$

where Y is the temperature change, β is the slope, x is the number of years observed, and c is constant regression.

## 3. Results

### *3.1. Characteristics, Current Agricultural Production, and Farm Management Practices*

The surveyed households were categorized into adaptive and non-adaptive farmers, based on their efforts to overcome salinity problems on their farms. The majority (74%) of the sampled smallholder farmers who attempted to improve their crop cultivation activities in response to salinity were classified into the adaptive group. The remaining 26% who did not report any strategies toward reducing the impact of salinity on crop performance were categorized as a non-adaptive group. In Table 1, the main characteristics of these two groups (adaptive and non-adaptive) as identified from the survey analysis are presented. The majority of the farmers, from both groups, privately own their farmlands. However, land accessibility through renting is as high as 29% in the adaptive group, and 11% in the non-adaptive group. Differences among groups are related to age, level of education, period of cultivation, and farm management. Overall, farmers of the adaptive group are younger, with a higher proportion with completed primary school and tertiary education levels, and they use higher levels of production inputs such as fertilizer and biocides.

Tractors are used by most farmers in both groups for field preparation. While waiting for the seeds to be ready for transplanting, weeds are manually removed. Manual weed control is performed at a frequency of one to two more times over the cropping period. The most common weeds reported by the farmers were considered salt-tolerant species such as tufted hair grass *(Deschampsia cespitosa)* and curly ryegrass (*Lolium multiflorum*).

**Table 1.** Comparison of the adaptive and non-adaptive groups identified from the surveyed households with rice as the main crop production system at research site Blang Nibong, North Aceh, Indonesia.

| Characteristics | Adaptive | | | | Non-Adaptive | | | | Chi-Square |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Min | Max | Mean | SD | Min | Max | |
| Household size (members) | 4 | 1 | 1 | 7 | 4 | 1 | 1 | 8 | 0.07 |
| Age (years) | 45 | 12 | 20 | 65 | 50 | 14 | 24 | 85 | 0.04 * |
| Period of cultivation (years) | 12 | 8 | 3 | 26 | 15 | 10 | 3 | 30 | 0.02 * |
| Land holding (ha) | 0.37 | 0.59 | 0.08 | 2.3 | 0.26 | 0.27 | 0.07 | 2.6 | 0.17 |
| Land cultivated (ha) | 0.26 | 0.39 | 0 | 1.60 | 0.18 | 0.09 | 0.04 | 0.60 | 0.13 |
| 2-years average yield (kg/ha) | 668.81 | 615.46 | 144.55 | 1995.53 | 440.44 | 355.92 | 73.12 | 1700.68 | 0.2 |
| Inorganic fertilizer (kg/ha) | 237.84 | 313.20 | 0 | 1125 | 102.20 | 38.36 | 62.5 | 375.11 | 0.005 ** |
| Organic fertilizer (kg/ha) | 658.60 | 1598.51 | 0 | 6250 | 37.90 | 260.26 | 0 | 2334.33 | 0.01 ** |
| Pest & diseases control (L/ha) | 0.14 | 0.08 | 0 | 0.34 | 0.09 | 0.06 | 0 | 0.5 | 0.0001 ** |

ns, non-significant ($p > 0.05$); *, significant ($p \leq 0.05$); **, significant ($p \leq 0.01$); n, 177 sample size.

Traditionally, planting is done in rows by hand. Non-organic fertilizer (NPK) is added to maintain soil nutrient balance by both groups at a frequency of 2 to 3 times during the cropping period. In addition, compost is also applied, with the highest quantity of 659 kg ha$^{-1}$ by the adaptive group compared to only 38 kg ha$^{-1}$ by the non-adaptive group. Respondents from both groups reported various pests found during the growth cycle such as Spodoptera, mice, golden snails, birds, and ants, which are chemically controlled.

### *3.2. Current Agricultural Production and Farm Management Practices*

Surveyed participants provided information on the main crop cultivated (rice) for the years 2018 and 2019 (Figure 3). Crop failure was reported to occur during the 2020 season, hence data for that year is not given. In the 2018 planting season, adaptive farmers harvested an average of 466 kg ha$^{-1}$, and non-adaptive farmers harvested 438 kg ha$^{-1}$, while in 2019, both groups harvested slightly higher yields with an average of 871 kg ha$^{-1}$ and 443 kg ha$^{-1}$, respectively.

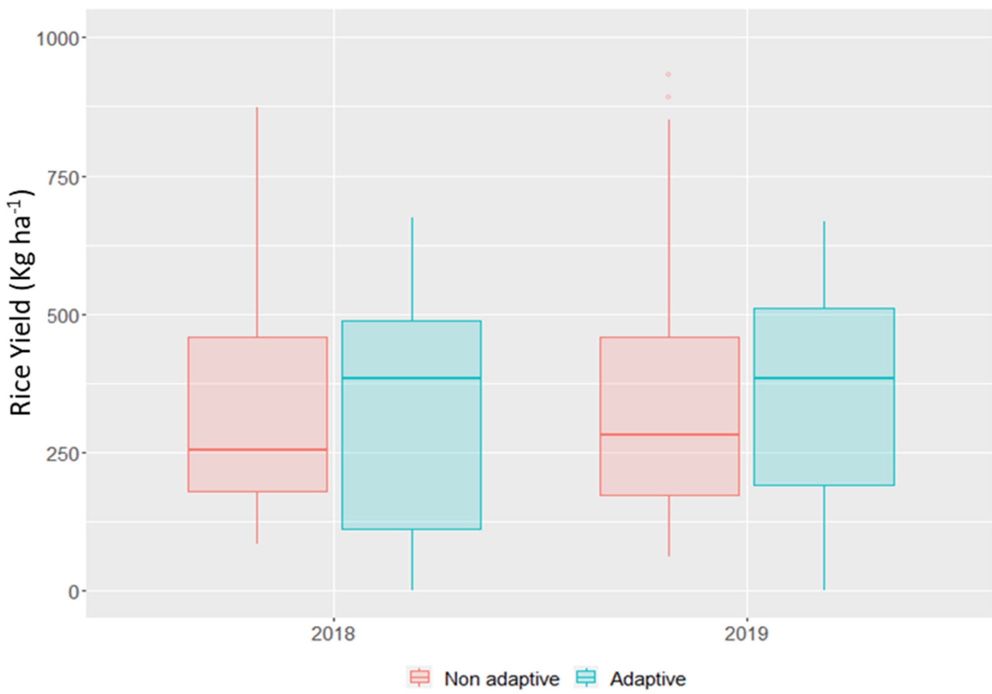



**Figure 3.** Reported rice (maincrop) yield during the 2018 and 2019 growing seasons from the adaptive and non-adaptive groups identified in the Blang Nibong village. Number of respondents = 117.

Farmers from the adaptive group are only able to cultivate approximately 79% of their land while the non-productive cultivate 82%. Other types of crops were grown as side crops, including corn, long beans, water spinach, spinach, chilies, cassava, and coconut. The harvest of these crops is usually used for meeting household food needs and the rest as some additional income.

### 3.3. Income Variability

The highest proportion of income in 2019 from both groups was from off-farm activities (Figure 4). The off-farm income sources come from fishing, trade, labor, remittance, and others. Farm profits are largely derived from non-rice agriculture. The farming incomes are mainly based on rice, maize, vegetables, tubers, coconuts, and farm fishing activities. It was also found that the share of income sources varied quite a lot in the adaptive group compared to the non-adaptive group. Furthermore, the adaptive group's sources of income from off-farm activities (80% of total household income) differ from those of the non-adaptive group (71% of household total income).

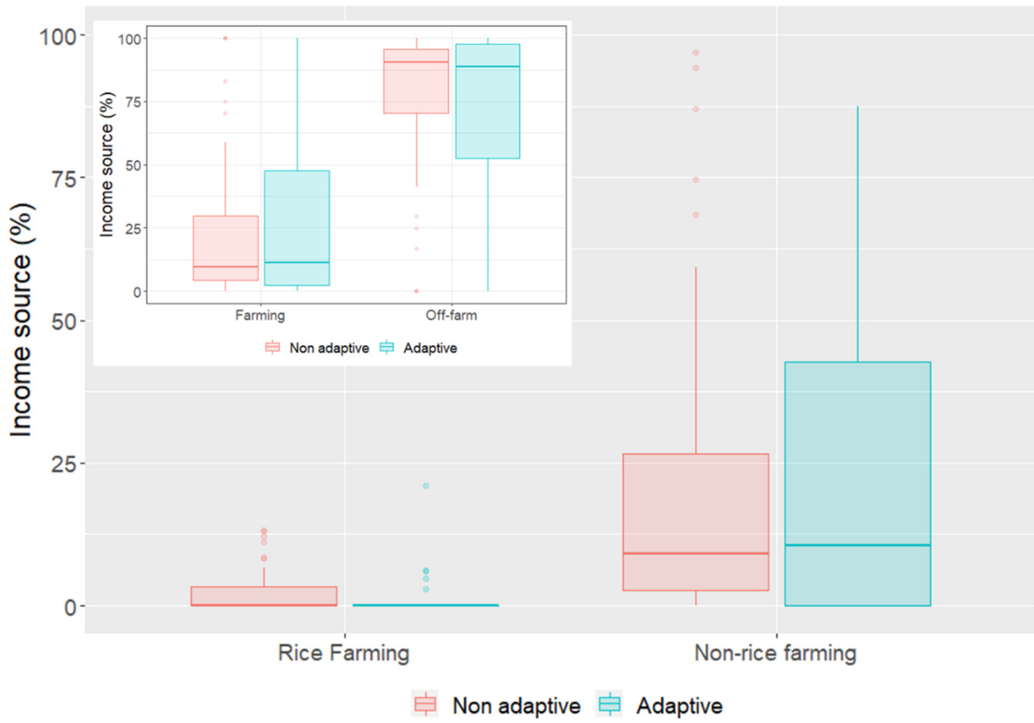



**Figure 4.** Income share distribution of household farmers in the Blang Nibong village for the adaptive and non-adaptive groups, the year 2019. Number of respondents = 117.

### 3.4. Perception of Salinity and Climate Variation

#### 3.4.1. Salinity Change

Respondents reported a significant increase in salinity after the tsunami in 2004. Since then, the salt has continued to settle on their farms although in relatively lower concentrations than immediately after tsunami occurrence. This salinity decline is evidenced by the existence of agricultural activities, even if only resulting in low yields. According to personal communication with interviewed farmers, the yield achieved in the study area is significantly lower compared to the farms located in the tsunami unaffected areas. It has been widely observed that, after extended periods of rain, the areas remained damp, and soils become waterlogged because the water is unable to drain away. Areas of bare patch on the fallow plots have been visually observed to confirm the existence of salty crystals at midday as evidence of salinity in the area. Several salinity indicators such as *Parapholis incurva*, *Puccinellia sp*, and *Paspalum distichum* were observed in the farms (Figure 5).

(**a**)

(**b**)

(**c**)

(**d**)

**Figure 5.** Salinity indicators observed at the Blang Nibong village: (**a**) *Paspalum disticum*; (**b**) *Puccinellia*; (**c**) *Isolepis cernua*; (**d**) efflorescence (This occurs where salt crystals form on the soil surface. Crystals can best be seen on a hot day when the water content of the soil has evaporated). Personal collection, 2020).

### 3.4.2. Climate Variation

Daily climate data for the period 2000–2020 collected from the nearest meteorological station to the study area reflects high interannual variability of precipitation (Figure 6). Over the period 2000–2020, the mean growing season rainfall (October to February) was 155 mm and varied between 427 mm and 1146 mm—thus considerable negative and positive anomalies. Almost all respondents stated that the traditional rainfed practice in rice farming is threatened due to the uncertainty of the rainy season. About 98% of all respondents perceived increased rainfall frequency but decreased rainy season duration.

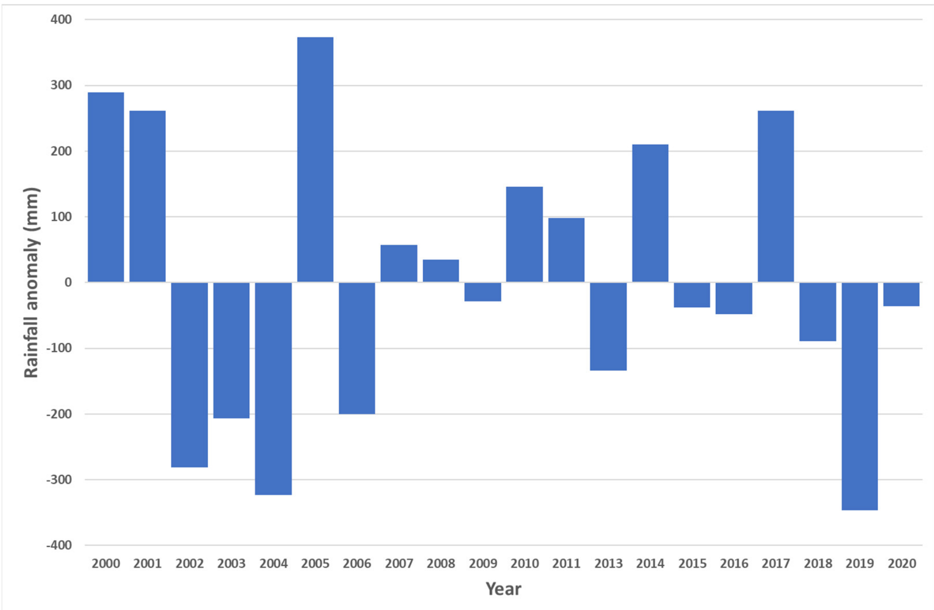
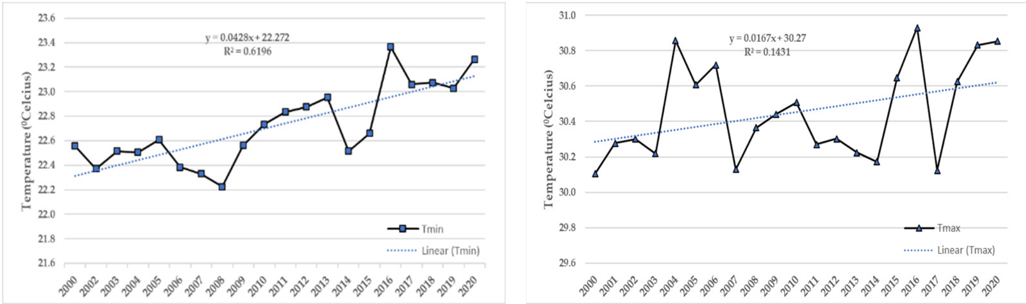



**Figure 6.** Anomalies of the growing season rainfall at Malikussaleh, Aceh Utara, North Aceh—Indonesia. Period 2000 to 2020.

A positive trend in temperature conditions was observed from 2000 to 2020 (Figure 7). The average minimum and maximum temperatures during the growing season increased by 0.16 °C and 0.43 °C per decade, respectively. These trends were also confirmed by the perceptions of at least 97% of respondents, indicating that the days during the growing season have become hotter over the years.




(**a**) (**b**)

**Figure 7.** The trend of (**a**) growing season minimum (Tmin) and (**b**) maximum (Tmax) temperatures was observed over the period 2000–2020 at Malikussaleh, Aceh Utara, North Aceh—Indonesia.

### *3.5. Perceived Effects of Salinity Risks*

All respondents from adaptive and non-adaptive groups perceived salinity as a major challenge in their farming practices (84% and 13% strongly agreed; 74% and 48% agreed, respectively) (Figure 8). Further restrictions reported were high interannual variability of rainfall, flooding, drought, low soil fertility, waterlogging, and soil compaction. However, in this study, we focused on salinity only due to the severity of its effects as perceived by most farmers.

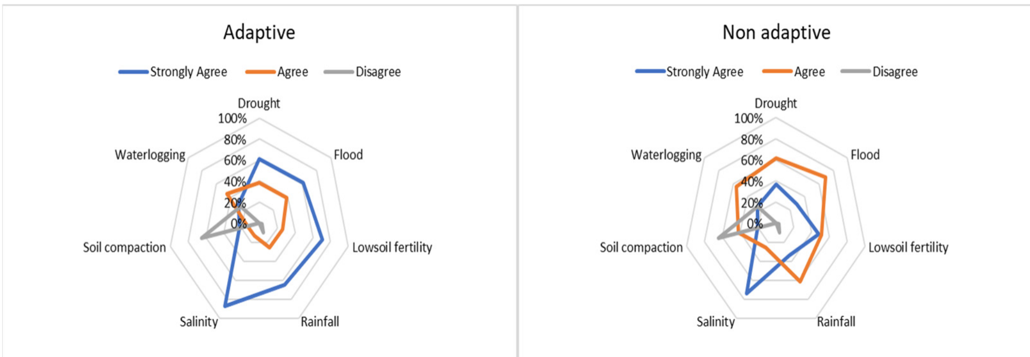



**Figure 8.** Perceived constraints in farming practices as identified by the farmers (% respondents). Rainfall = interannual variability of rainfall.

Figure 9 captures the categories of presumed effects of salinity on biophysical aspects as recognized by respondents. All adaptive farmers believed that salinity has the greatest impact on plant mortality and water quality (55% and 45% strongly agreed; 45% and 59% agreed, respectively). However, almost all non-adaptive farmers believed salinity had additional effects such as reduced soil health and plant growth (46% and 23% strongly agreed; 52% and 76% agreed, respectively). During farmers' attempts of cultivating rice in the three consecutive years 2018, 2019, and 2020, they witnessed stunted growth, reduction in height, and poor grain filling (for those who managed to bring the crops to harvest). Farmers further observed a higher mortality rate in rice nurseries, which are typically carried out in the salinity-prone rice field. In addition, respondents assumed a decline in soil health over time, as evidenced by the appearance of limited seedling emergence, a decrease in earthworm populations, and a shift in vegetation from salinity-susceptible to more tolerant vegetation. In recent years, sources of freshwater were reported by respondents to have decreased significantly based on their own experience. They explained that fresh water of good quality could be found easily at a depth of 2 m in the past but nowadays hardly at all. Even the water catchment wells to meet their daily needs are contaminated with salt.

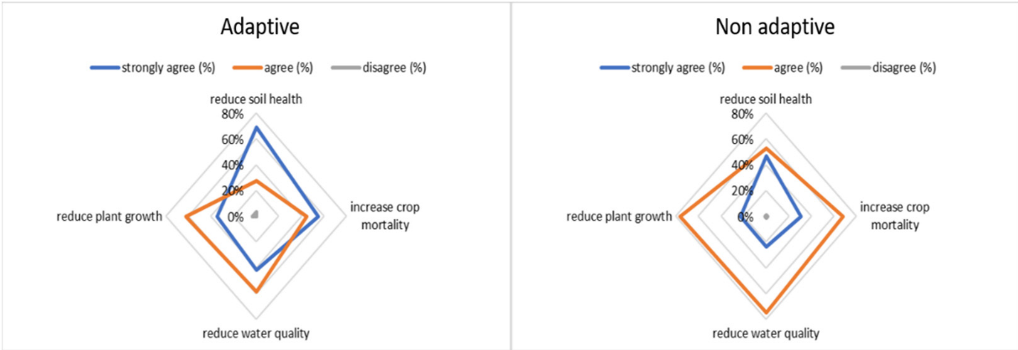



**Figure 9.** Type of perceived effects of salinity on bio-physical aspects as identified by the farmers (% respondents).

### *3.6. Farmers' Perceptions and Preferences on Adaptation Strategies to Salinity Risk*

Strategies in response to future salinity risks in farming activities are presented in Figure 10. Both groups have slightly different views on how they intend to adapt to future salinity risks. Interviewed households of the non-adaptive group prefer to convert their land to pasture (81%), while the adaptive group prefers to have a better irrigation system (77%) to allow leaching of excess salt. The strategy of integrating cropping with livestock such as cattle, goats, and chickens was seen as the most likely alternative for both groups (30% of the non-adaptive group, and 45% of the adaptive group). The current reported number of livestock per household ranges from one to two and the livestock is mainly kept as a source of additional income. Other strategies mentioned but with low interest by farmers were the use of salt-tolerant rice cultivars, crop diversification through mixed cropping and crop rotations, improvement of soil quality, and maintenance of land cover.

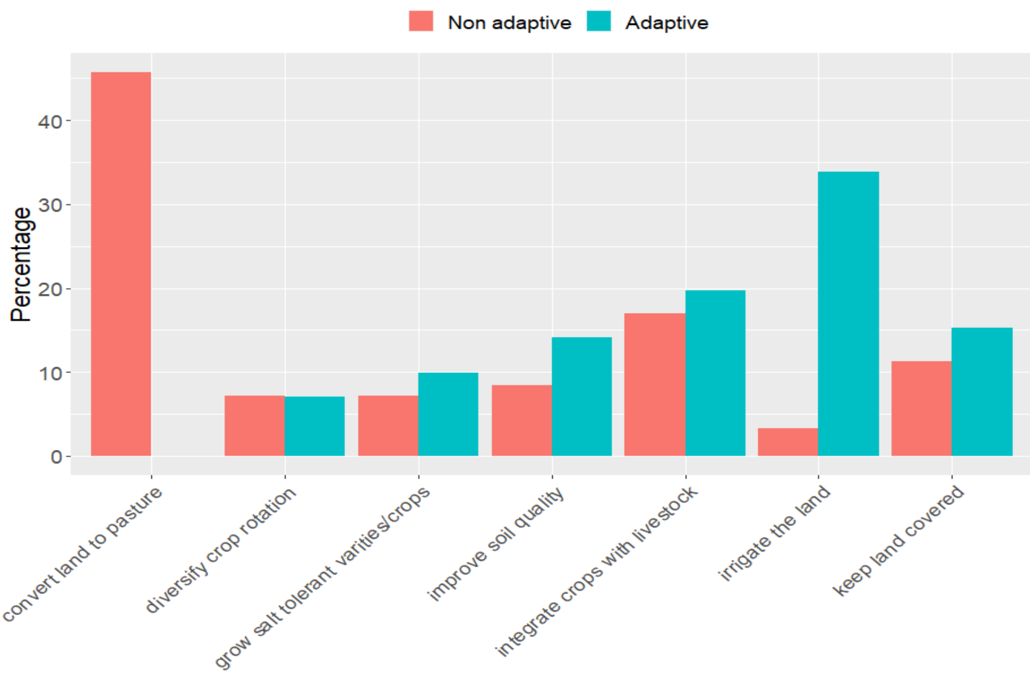



**Figure 10.** Future adaptation strategies in response to salinity risks (% Respondents).

## 4. Discussion

This study focused on the current status of farm management activities, income diversification, and adaptation strategies of farmers that have been exposed to salinity risk after the 2004 Tsunami in North Aceh, Indonesia, as indicated by the findings that relate to the initial hypothesis that soil salinity continues to have a significant impact on farming practice, management, and farmers' income diversification in the study region. In the following, we discuss implications on agricultural production, types of household income, perceptions of salinity and climate change, and adaptation and readiness of farmers to farm crops with future salinity risks. This study aimed to generate useful information for mapping the current state and challenges faced by farmers exposed to salinity. This could support future agricultural policy initiatives to be better directed to sustainable agricultural production in areas facing similar threats. Future research should expand its scope, among others, by involving policy makers, practitioners, and other stakeholders to gain a comprehensive understanding of food security in the coastal areas of Aceh, Indonesia.

### *4.1. Agricultural Production, Farm Management Practices, and Income Diversification*

According to the present study, farmers in the adaptive group are often younger, have a higher percentage of elementary and tertiary education, and use more appropriate agricultural methods than farmers in the non-adaptive group. During the 2018 and 2019 growing seasons, rice as the principal crop no longer covered most surveyed households' food and economic demands. The greatest obstacle to farming is the marked increase in salinity in agricultural land following the tsunami of 2004.

We found that farmers' management practices in the research area are fairly limited. Many agronomic management components are not up to the standards set by the local agriculture agency (Indonesian Agency for Agricultural Research and Development), such as practicing site-specific fertilizer management. Adaptive and non-adaptive farmers utilize 152 and 133 kilos of NPK fertilizer per hectare, respectively. While NPK 15-15-15 is indicated for lowland rice crops in the area at 250 kg per hectare and NPK 15-10-12 is advised at 300 kg per hectare.

The low yield could be attributed to low and unbalanced fertilizer application. The use of fertilizer at the right time and amount based on site-specific nutrient management (SSNM) fertilizers in rice farming is important to increase productivity and profitability as shown by studies in many countries in Asia [35] including the Philippines [36] and Indonesia [37].

In addition, knowledge on local agroecosystem conditions should be updated to address the current challenges (e.g., salinization), which farmers in the study area most often neglected. For example, despite being aware of salt exposure on their land, farmers lack almost complete knowledge about selecting suitable and salt-tolerant rice varieties. In 2014, at least three improved salt-tolerant rice varieties (Inpari 34 Salin Agritan, Inpari 35 Salin Agritan, and Inpari Unsoed 79 Agritan) with an average yield ranging from 4 to 5 ton per hectare were released by the Indonesian Center for Rice Research [38]. However, none of the farmers interviewed was aware of this.

The current approach to farming and coping with associated challenges in the study region have resulted in significant losses in rice production. Our findings showed that rainfed rice farming as the main activity has not been able to support the farmer's primary food needs. The yield currently obtained in a single growing season is considered very low (Figure 3). According to data from 2018 [30], productivity in the region was about 5 t $ha^{-1}$ at the sub-district level (Kecamatan Samudera), while the maximum average reported by the interviewed farmers in the study site was only half a ton or less per hectare.

Low yields and a high potential for failure, such as observed in the 2020 crop year, have shifted agricultural activities from rice farming to other more productive activities such as fishing, other non-rice farming, or off-farm activities. Our results showed that 77% of the farmers reported the largest income share from off-farm activities, whereas most of the farming income was from non-rice activities such as on-farm fishponds and horticulture. The statistical data from 2017 to 2019 show, however, that the main source of income from food crop (rice) agriculture has remained stable (Table S1) [30,39,40].

### 4.2. Perception of Salinity and Climate Variation

Like most of the agricultural land on the coast affected by the 2004 tsunami, farming in this area has changed due to an increase in the NaCl content in the soil [16]. In lowland coastal agriculture, high salts are still present to date as one of the long-term effects of the disaster [19]. Although production data between the farms flooded by seawater and unaffected agricultural land are not recorded for the study area, clear differences can be seen based on visual observations, which the target farmers confirmed. The increase of soil salinity as perceived by the farmers in the study region has been justified by some salinity indicators. At least three species and surface symptoms as salt indicators have been observed in areas such as those found in saline soils in NSW [41].

There are similarities between farmers' opinions and climate data on decreasing rainfall during the growing season in the last 20 years. Observed rainfall data show a high variation in precipitation over 2000 to 2020, while it was slightly reduced during the growing season. Contrary to rainfall, farmers perceived an increase in temperature. A study conducted in one district in Aceh Province, Indonesia, showed a decrease in rainfall in the 90s. After the tsunami, the trend of rainfall increased due to changes in land use, and during La Niña, precipitation was even higher than usual [41,42]. Farmers' opinions are often not supported by observable data instruments [43,44].

### 4.3. Perceived Effects, Preference Adaptation Strategies, and Preparedness for Salinity Risk

Farmers in our study area believe that salinity threatens their agricultural activities. Combined with other limiting factors such as low soil fertility, rainfall, drought, flooding, waterlogging, and soil compaction, agriculture requires full support and innovative interventions for rehabilitation [45,46]. The presence of salt has changed the soil's composition and properties, affecting plant performance [47,48]. The respondents perceived a reduction in their plant growth and increased crop mortality rate throughout the whole growth cycle [49,50]. Freshwater sources with good water are difficult to find, unlike in the past [16,51]. They also stated that soil fertility had decreased considerably. According to them, in the past, they applied a considerably less amount of fertilizer [14,52].

In response to salinization risks in the future, our surveyed households intended to implement various coping and adaptation strategies. Adaptive farmers mainly prefer to have an adequate irrigation system for their land. Applied proper irrigation [33] and good water management allow the leaching of excess salt accumulated in the root zones and beyond which may save further soil degradation [3,53]. Farmers grouped as non-adaptive mainly choose to convert the land to pasture. The perception of converting the land to pasture might not be suitable for this type of soil, considering salinity and waterlogging might inhibit the growth and production of fodder plants [54]. Other strategies mentioned but with little interest by the farmers were integrating crops and livestock, keeping land covered, improving soil quality, growing salt-tolerant rice or other crops, and diverse crop rotations. Integrating crops and livestock might bring benefits both economically and for the environment by nutrient recycling. However, further studies need to be done by considering the region's farm characteristics [47]. Although the option to use salt-tolerant rice cultivars or other crops and rotation has not been prioritized as salinity adaptation strategies by the farmers, some studies prove that these could be effective [33]. Selecting suitable varieties [50] and diversifying cropping by taking advantage of the off-season planting time may reduce the production risk under the anticipated future climatic conditions [55,56].

## 5. Conclusions

Restricted by considerable socio-economic constraints and non-favorable physical and chemical soil properties, the development of agriculture in the coastal saline belt does not appear to be an easy task. The study revealed that farm practices in the study region are severely affected by the presence of salinity. Our respondents are experiencing an increase in salinity which affects the growth and yield of the major crop (rice). The high potential for failure in farming is causing a shift from agrarian to other sources as seen from the main income share, which is dominated by non-agricultural activities. In response to salinity and climatic variability, farmers are perceiving dynamic changes in salinity, rainfall, and temperature. In response to salinity threats in the future, most adaptive farmers in the study area favor having a proper irrigation system while most of the non-adaptive indicated conversion of the land to pasture. Raising awareness about potential future adaptation strategies is essential to choose and implement responses to salinity by the smallholder rice farmers in the study region and other similar areas in Indonesia. Further studies on context-specific agricultural innovations and technologies with input from government, intellectuals, and successful practitioners will be required.

**Supplementary Materials:** The following are available online at https://www.mdpi.com/article/10.3390/agronomy12020341/s1, Table S1: Planted area, harvested area, production, and crop productivity in District of Samudera, North Aceh, Indonesia.

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