

UNIVERSITI MALAYSIA TERENGGANU 11TH
INTERNATIONAL ANNUAL SYMPOSIUM ON
SUSTAINABILITY SCIENCE AND MANAGEMENT

UMTAS 2012

PROCEEDINGS

*Greening the Technologies and Resources
for Human Wellbeing*



9 - 11th July 2012
Ri-Yaz Heritage Marina Resort & Spa,
Kuala Terengganu, Malaysia

Hosted by
Faculty of Agrotechnology and Food Science
and
Faculty of Fisheries and Aqua-Industries

Declaration

All manuscripts printed in this proceeding had been reviewed and edited by academicians of Universiti Malaysia Terengganu. Organizing committee will not be responsible for any unintentional errors made during the publication of this proceeding. Each participant is responsible on the originality and quality of the manuscript.

PREFACE

Sustainable development has become an important trend of thought in the scientific community, especially the concern for human wellbeing which includes cleaner environment, sustained level of economic development without excessive waste and pollution, and the protection of natural resources and biodiversity. To accomplish this, a sense of citizenship in the sustainable development should be developed through the delivery of quality education and training, by reappraisal of our core values system, and the empowerment of green community that affect the personal behavior and preference towards green technologies.

Thus, the theme of this year's seminar – "Greening the Technologies and Resources for Human Wellbeing" is relevant because green technologies is believed to be the key to overcome environmental degradation of natural resources, improve health and lives, protect ecosystems, reduce costs to the government in its efforts to mitigate the impact of development, and serve as an alternative in order to boost the economy. Green technology acts as an umbrella term encompassing the investment asset class, technology and business sectors which include clean energy and environmental, sustainable green products and services.

This symposium is therefore timely and most welcome because it has brought together scientists, policy-makers, businessmen and concerned individuals to examine the challenges and opportunities to make this world a better place for all creatures. The sub-themes encompass topics of relevance in the present context of sustainability science and management. The largest contributions for this proceeding are in the field of Sustainability, Food Science and Technology as well as Science, Technology and Engineering with more than 30 papers submitted for each category. Papers from other subtopics i.e. Agriculture, Fisheries, Aquaculture and Social Sciences remain popular topics with almost equal number of papers. It is important to note that this meaningful gathering has acquired a great amount of scientific knowledge and provides an excellent platform for all resource people and individuals with experience to share their research findings and exchange information on best practice on sustainable development and resources.

The manuscripts submitted were edited and refereed by a dedicated group of academician from UMT. I would like to thank all of them for their efforts and contributions. My heartfelt thanks also dedicated to all contributors for their papers.

Finally, on behalf of our Editorial Board, my deepest gratitude to the Vice Chancellor and the Chairman of the Organizing Committee for their endless support and encouragement in ensuring the success of Universiti Malaysia Terengganu 11th International Annual Symposium on Sustainability Science and Management.

Chief Editor
June 2012

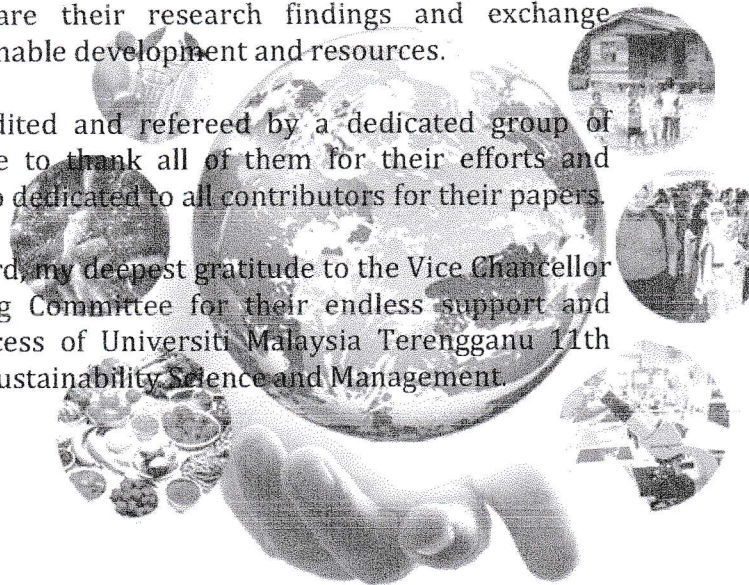


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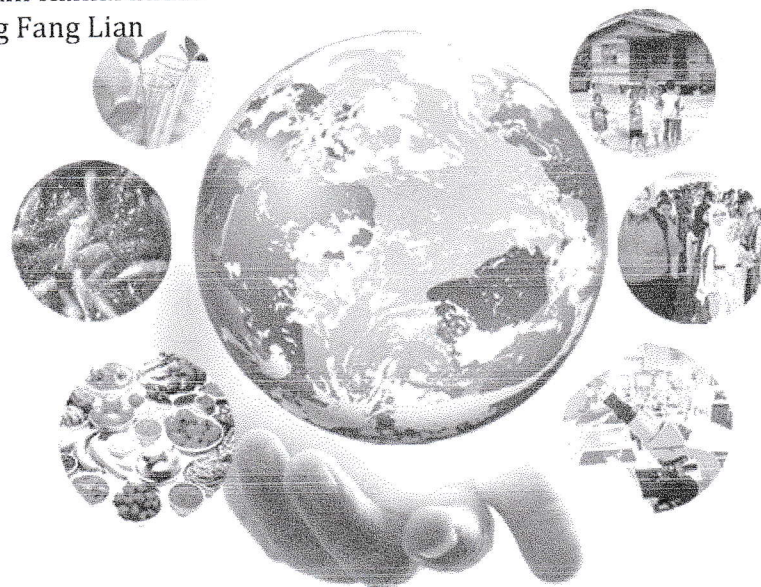


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Limiting Factors of Land Suitability and Efforts to Increase Tidal Lowland Capability for Paddy

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Abstract

The research objective is to analyze limiting factors of land suitability and efforts to increase tidal lowland capability for paddy in Delta Saleh, South Sumatra, Indonesia. Research sampling was taken intensively in typology types of A, B, C and D. The research was divided into field survey and laboratory work. The research results showed that limiting factors of land suitability for paddy are high soil acidity, very low soil fertility, depth of flood water, surface water flow and salinity. The total area of high potential land is 17,982.3 ha (67.4%), around 5,389.4 ha (20.2%) is classified as middle potential land, around 3,308.3 ha (12.4%) belongs to low potential land and less potential land is not found in the field. The soil productivity of the high potential land is 6.0 tons Milled Dry Paddy (MDP) per ha/year, 2-5 tons MDP per ha/year for middle potential land, 1-2 tons MDP per ha/year in low potential land and less than <1 ton MDP per ha/year for less potential land respectively. Efforts to improve to increase tidal lowland capability from actual to potential suitability are as follows: to make drainage channels, to apply the water barrier in order to flow water into cultivated land, to apply agricultural lime, to add and to maintain soil organic materials, to wash Na and H cations and to give N, P and K fertilizers.

Keywords: Limiting factors, land suitability, tidal lowland, paddy

Introduction

Land evaluation is purposed for land use planning. Most land evaluation is qualitative and based on expert judgment. The experts interpret their field data to make them understandable to planners, engineers, extension officers and farmers. Land use planning is expected to make a major contribution to the realization of sustainable development. It can facilitate the allocation of land to the use(s) that provide the greatest sustainable benefits. This demands that development remains within the carrying capacity of supporting ecosystems. The continuing worldwide mismanagement of soils, inadequate land use policies and ineffective implementation of soil management and conservation programs, raises questions about how the communication of natural resources information to land use planners and decision makers can be improved and how this knowledge can be put to good use [1] [2].

The main problems developed in Delta Saleh since reclaimed for transmigration program till today are follows, i.e. land suitability is not really known, changes in landuse patterns are difficult to be estimated area and its distribution in detail from year to year with conventional methods. Thus, we do not know which area is suitable for what plants? These questions till now are still questionable, thus it is causing low production [3]. The research objective is to analyze limiting factors of land suitability and efforts to increase the tidal lowland capability for paddy.

Materials and Methods

This research was conducted in Delta Saleh, Banyuasin, South Sumatra, Indonesia. The study was carried out from January to April 2011. Materials used in this study are: 1) Maps of study sites reclamation network and hydro topography, 2) Landsat TM image Path/Row 124/62 in June 1992, June 2001 and August 2010 that packaged in a CD-media ROM, and 3) Questioner for reclamation network conditions, cropping patterns, and tracking network data. Tools used are Global Position System (GPS), Drill the ground, Peroxide (H₂O₂), Label, Elastic Band, Plastic sample, program of image interpretation tool of Arc View GIS (Geographical Information System) and its stationery.

Data processing and analyses were carried out in stages. The stages can be explained in the flow diagram of Figure 1. Data analyses included as follows [4], i.e. Pre processing, Processing, Field Survey and Analysis. This activity involves the analysis of availability and landuse pattern. Landuse pattern analysis is done by combining spatial information with land coverage of spatial information of land characteristics, analysis of changes carried out only in 1992, 2001 and 2010. This was done according to the availability of satellite images.

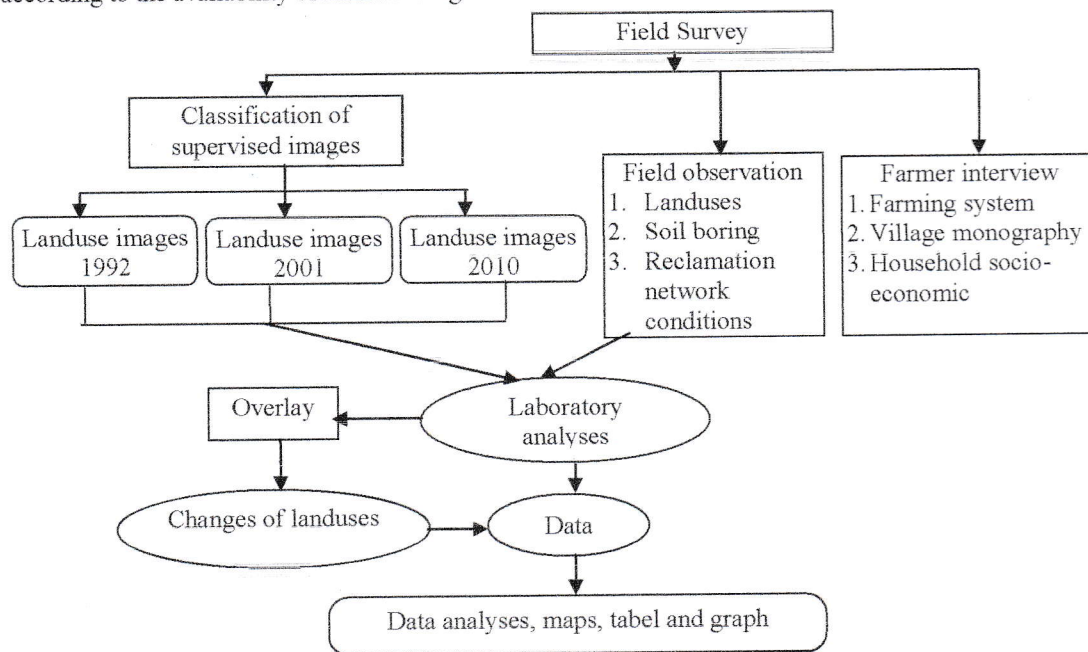


Figure 1. Flowchart of field activities and data analysis

Composite soil samples were taken after completing soil profile descriptions and then analyzed in the laboratory. Soil color was determined using Munsel Soil Color Chart while bulk density was determined using ring sampling. Particle-size analysis was performed using hydrometer method. Chemical analysis (organic carbon, soil pH, total nitrogen, CEC and exchangeable cations were determined according to Sparks [5].

Results and Discussion

Delta Saleh is geographically located 105° 02'31" to 105° 33'66" Longitude Lines and 2° 20'10" up to 3° 07'43" Equator Lines. Delta Saleh in northern part is bordered limits by Bangka Strait, southern of the river Musi and Cinta Manis Transmigration area, bordering the eastern with River Saleh, while the western bordering with Upang River (Figure 2).

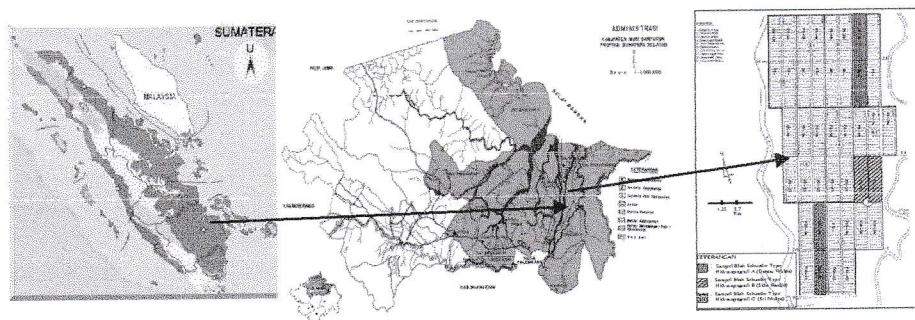


Figure 2. Research site of Delta Saleh in Eastern Parts of Sumatra

Delta Saleh is a tidal land that is reclaimed and occupied migration began in 1981. According to Agricultural Research (1999), based on the type of land reclamation in its Delta Saleh

hydrotopography, the flood type B has 1,856 ha area, type C is 5,630 ha and type D is covering 2,944 ha (Figure 2). The dominant land is a potential land area of 9,438 ha, and acid sulfate soil is around 992 ha.

Morphology and Descriptions of Soil Profiles

Descriptions of soil profiles can be obtained through field observations and analysis of soil and water samples in the laboratory and explained as follows:

Soil pedons in the study site consists of several horizons based on soil depth. Horizon of Apg (0-20 cm) is upper soil horizon which are strongly cultivated. The horizons showed also strong process of gleization as indicated by the low chroma (2) and a rusty that almost spread to the entire horizons. Bg horizon (20-41 cm) is a horizon that has undergone further development as indicated by changes in color with a lower value. This horizon showed gleization process with a low chroma (1). Cg1 horizon (41-63 cm) and Cg2 horizon (63-100 cm) are the parent material horizon which is slightly influenced by the process of pedogenesis. The process of pedogenesis which can be observed in the field is the result gleization process as indicated by the low chroma (0) and rusty spread on the entire horizon.

Soil texture is dominated by sand (25.10-50.61 %), followed by silt (32.13-40.90 %), and clay fractions (17.26-35.84 %). Therefore, the soil has a large pore spaces, so that the soil is very porous and less able to hold water. As a result, relatively higher water loss. While the texture analysis method in pedons showed an increase in clay fractions from the horizon above it, except in the Cg1 horizon (depth of 41-63 cm) to the Cg2 horizon (63-100 cm). This is caused by different sediment, but it has not been able to form under argillic horizon. This is because the total clay content of more than 40 %, so as to meet the requirements of argillic horizon, must have a clay increase of more than 8 % over the horizon clay content on it. It turned out that these requirements are not met.

The soil color from top to bottom on each horizon indicates a color change that leads to more black color. By striking the top layer of soil is brown-grey (10YR5/2 - 10YR4/1), while the horizon beneath is blackish grey to dark grey (2.5 Y4/0 to 2.5 Y3/0). This happens due to the reduction process permanently inundated (water logged), so that the color grey (gley), which grew stronger. Even though the color of the topsoil has a value lower than 3.5 (moist), but it cannot enter into other epipedons, thus it included in the category ochric epipedon. Rusty soil was found to spread almost in all horizons except the Bg horizon (20-41 cm depth). Rusty reddish brown (7.5 YR5/8) found in the Apg and deeper horizons, leading to rusty color of grey dark (10YR4/1) in Cg2 horizon. Rusty like this is often found in the soil with moisture regime as a result of groundwater fluctuations.

Soil Fertility Status

Fertile soil when the soil is able to provide sufficient and balanced nutrients for plants, free of Al toxicity or excess salts and should be sufficient to provide water and air. Plant will grow well when soil fertility and other environmental factors can support its growth. The level of soil fertility is determined by several factors, i.e. contents of primary mineral and organic matter, the level of climate destruction, sorption complex, the intensity of leaching and soil reaction. In general, soil fertility status at the study site is low, it is characterized by the low levels of Nitrogen (N), potassium (K) and organic C and soil acidity is high (very acid). Results of soil analyses from composite samples are presented in Table 1. The composite samples were taken from each Soil Mapping Unit (SPT).

Soil reaction is closely related to some soil chemical properties, such as solubility H, organic matter content, the content of the bases, saturation-Al and so others. Soils which content of high hydrogen ion solubility and high organic acids, low bases content and high Al saturation generally reacted as acid to very acid. Instead the soils which have properties opposite to those above generally reacted neutral. The average value of pH H₂O and pH KCl are 3.82-4.71 and 3.39-3.78 respectively which indicated that this soil is generally classified as acid. Value of pH and CEC data was connected each other. This is also an indication that the oxidation of Fe and Al-free on these lands is rather high. This condition is possible because the circulation of water in this area is poor.

Organic matter content and N-total clearly showed the influence of organic matter for plant growth both in terms of physical, physical-chemical and biological. Mineralization of organic matter is

important to produce plant nutrients. Organic matter is the main source of N elements. Therefore the total-N content is correlated with soil organic matter. In addition to adding a number of nutrients in a pool, organic matter plays a role in oxidation-reduction process that will help the nutrient concentrations still in soil solution. In general, organic content and N-total in the study area is relatively moderate.

The levels of organic C ranged 2.45 % (low) to 6.41 % (medium). Organic material on the top layer is still relatively moderate; the decomposition process is not perfect because the land is often flooded. Condition of land has not been clearly opened, dominated by Gelam forest and tidal swamp grass. This condition is reflecting that soil organic matter content influenced by vegetation, it is very possible because at a certain location that has vegetation growing shrubs and grasses are not good because often flooded. Soil organic matter content is derived from vegetation growing on it, the more and varied vegetation that will grow more and more soil organic matter content (Table 2). Organic materials have a significant role both in chemistry, namely as a provider of nutrients and soil nutrient buffer as well as physically, that is capable of improving the condition of soil structure and water absorption.

Table 1. Results of laboratory analyses and soil texture

laboratory analyses and its unit		Results of laboratory analyses			
		SPT*/1	SPT 2	SPT 3	SPT 4
pH H ₂ O (1:1)	-	4.26-4.71	3.90-4.16	3.82-4.44	4.14-4.18
pH KCl (1: 1)	-	3.52-3.78	3.42-3.52	3.39-3.77	3.39-3.45
C-organic	%	5.51-6.41	3.98-5.12	4.51-5.28	2.45-4.44
N-Total	%	0.22-0.48	0.35-0.40	0.37-0.43	0.19-0.34
P-Bray I	ppm	25.95-38.70	9.75-19.50	13.80-18.00	5.10-7.65
K-dd **/	me/100g	0.26-0.32	0.32-0.38	0.32-0.64	0.19-0.32
Na	me/100g	0.55-0.65	0.55-0.65	0.55-1.09	0.33-0.66
Ca	me/100g	1.21-1.65	0.63-1.45	0.83-1.30	0.63-0.78
Mg	me/100g	0.65-1.00	0.27-0.80	0.27-0.55	0.15-0.22
KTK	me/100g	14.23-18.05	16.40-17.23	15.58-16.05	16.88-19.05
Al-dd	me/100g	2.32-2.80	4.52-5.88	3.96-6.52	5.82-6.60
H-dd	me/100g	0.16-0.56	0.32-1.32	0.40-0.88	0.16-0.26
Texture					
Sand	%	25.10-50.61	36.83-31.63	38.83-42.32	25.69-37.79
Silt	%	32.13-39.06	35.44-39.04	34.80-38.61	32.72-40.90
Clay	%	17.26-35.84	27.73-29.33	22.56-22.88	29.49-33.41

Explanation: */ SPT: Soil Mapping Unit, **/ dd: exchangeable

Source: Results of laboratory analyses (2011).

N content can be predicted from the levels of C-organic. The high value of C-organic N was also followed by the value of the total. Soils with shrubs and tidal swamp grass proved to have a value of N-high total in the upper layer compared with the bottom layer, N-total analysis shows the range of 0.3 % seen in both the upper layer and only 0.1 % at the bottom. This suggests that the availability of nutrient nitrogen in tidal wetlands is influenced by the presence of organic material because the main source of soil N was organic material. On the soils that have high organic matter content will be followed by a high total N concentration as well. With the parameter value of N is clearly shown that the quality of land there has been no signs of environmental damage.

Cation Exchange Capacity (CEC) reflects the amount of surface charge. This value is strongly influenced by clay content, clay mineralogy, and organic matter content and alkali-action exchanged. The finer the soil texture is and the higher organic matter will be and both components generally increase the value of CEC. The CEC is closely related to soil pH value. In soils with high pH, sorption complex of silicate clay minerals are generally dominated by 2:1 or 2:2 types with permanent charge. In acid/very acid soils, their charge is generally dominated by variable charge of the oxidation or Fe hydroxide, and Al, silicate clay mineral type of 1:1 silicate clay or a mixture with oxidation/iron hydroxide Al. CEC values of soils at study sites are in ranges (14.23-18.05 me/100 g). This condition occurs because the levels of base cations (like Ca, Na, K, and Mg) are low. Thus the sorption complex soils are believed to be dominated by 1:1 clay minerals or mixed oxidation/hydroxide of Fe and Al.

Phosphorus (P) in the soil is generally found in the forms of organic and inorganic fraction, depending on the levels of organic material. Organic P was found in the form of "surface-P" which is

relatively more available than "sub-surface". Forms of inorganic P are composed of Al-P, Fe-P and Ca-P. Availability of P for plant is influenced by several factors, namely soil pH, content of Fe, Al and Mn in solution, the amount and rate of decomposition of organic matter, Ca available and the activity of soil organisms. The P-Bray I analyses have an average rating of low to moderate (5.10-38.70 ppm P₂O₅). This condition is probably due to the influence of tidal flood water. This is consistent with low soil pH, which is usually followed by very low Ca content and an acidic parent material determines the availability of the P element. Bray I method usually extracts forms of Ca-P soluble and the new Al-P formed. Extraction is difficult to extract Ca-P forms which are alkaline and Fe-P. **Potassium (K)** of soils is connected to sediment types and vegetation types that will influence nutrient availability, including nutrients K. Potassium content is around 0.19-0.64 me/100g (classified as low).

Aluminum (Al-dd) belongs to micro nutrients which is needed by plant in very little amount, and if available Al in the soil is much, it will be toxic and inhibiting factors for plant growth. The Al content is fluctuated depending on the process of soil development process. The Al content is increasing if drainage is in bad condition (land is often flooded). Therefore, it can be concluded that the soils should be in good drainage system.

Pyrite will explain levels of soil development and its levels increased with soil depth. At a depth of < 41 cm, its levels ranged from 0.05-0.08 % pyrite, while starting 41 cm depth levels it ranged from 2.72-5.02 % pyrite. Based on the criteria above sulfidic material limitation, the soil contains pyrite (sulfidic material) was found in the soil depth of 50-70 cm.

Limiting Factors of Land Suitability for Paddy

The most important paddy growing environment is the climate, physical conditions and soil fertility. Based on these factors it is classified into 4 classes of land capability, i.e. Class of S1 (highly suitable), S2 (suitable), S3 (marginally suitable), and N (not suitable). Based on the comparison criteria of land quality and land use requirements [4] and Land Mapping Unit (SPT) according to paddy, land suitability for paddy in Delta Saleh is classified as highly suitable classification (S1). Soil class at the suitable (S2) is found on almost the entire Delta Saleh and the marginally suitable (S3) area is located along the borders of the River Saleh. Land suitability classes are completely presented in Table 2 and described spatially as maps in Figure 3. Based on Table 2, the potential land for development of the paddy can be further elaborated in the form of high-potential land, potential for medium and low potential, which is as follows:

- 1) Highly potential land has land suitability classes (LSC) for paddy, 75 % is classified suitable and < 25 % belongs to marginally suitable.
- 2) Moderately potential land has land suitability classes (LSC) for paddy, 25-50 % is classified suitable and 50-75 % belongs to marginally suitable.
- 3) Lowly potential land has land suitability classes (LSC) for paddy, 50-75 % belongs to marginally suitable and 25-50 % is classified as not suitable.

Table 2. Potency and land suitability for paddy

Nr	Potency and land suitability	Class of land suitability */	Acreages (ha)	Percentage (%)	Productivity (ton paddy/ha/year)
1.	High potency (S1, S2)	Highly suitable (S1)	13,900.3	52.1	> 10
		Suitable (S2)	4,082.0	15.3	6-9
2.	Middle potency (S2, S3)	Suitable (S2)	3,415.1	12.8	4-5
		Marginally suitable (S3)	1,974.3	7.4	2-3
3.	Low potency (S3)	Marginally suitable (S3)	3.308,3	12.4	1-2
4.	Less potency (N)	Temporary not suitable (N1)	0.0	0.00	< 1
		Permanently not suitable (N2)	0.0	0.00	Very low
Total			26.680	100,0	

Source: */ Land suitability is based on topographic maps of Indonesia scale 1:50.000, landsat imaginary analyses (2010), soil maps, geology maps, field observations and laboratory analyses (2011)

More than 52.1 % of the research area belongs to highly suitable (S1) that means it is very likely to be developed for paddy. By considering the factors of land suitability, we can obtain maximum yields of paddy. Theoretically predicted with high-potential land suitability it can produce > 10 tons per ha per year. For some areas with suitable class (S2), which is about 15.3 %, and is large enough also to be developed and it is considered theoretically to produce 6-9 tons paddy per ha per year.

As for areas of moderate to low potential which have some limiting factors for the development of paddy, namely: 1) the roots condition (r) that includes inhibiting factors, namely soil drainage class, soil texture and rooting depth. Rooting depth is an indicator for effectively shallow depth of soils, especially in areas with high pyrite content and poor drainage, 2) Holding capacity of soil nutrients (f), which include inhibiting factor is the CEC and soil pH, 3) Poisoning (x), which include inhibiting factor is the salinity, 4) Existence of potential acidic sulfate soil. The lower potential suitability means it needs more input to make the land becomes suitable for the growth and development of paddy. To soil class of N (not suitable), then the constraints are permanent and very difficult to be reclaimed or require a very high cost. Based on the character of both physical and chemical properties, the research location does not have soils that belong to not suitable N (Table 3).

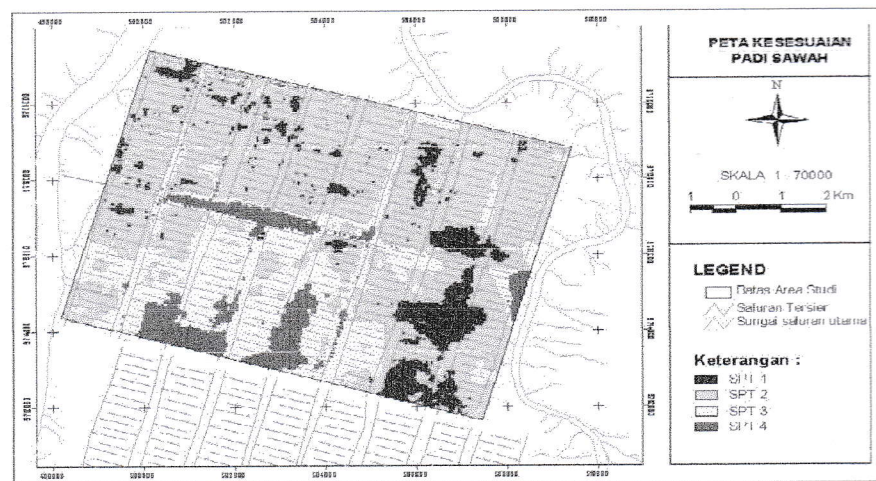


Figure 3. Land suitability map for paddy in Delta Saleh

Table 3. Limiting factors of land suitability classes for paddy in the research site

Class	Sub class */	Limiting factors	SPT	ha	Acreages %
S3	S3-anfx	Soil acidity, soil fertility, flood (water stagnant) and Al, Fe toxicity	1	3,308.3	12.4
S2	S2-anfx	Soil acidity, soil fertility, flood (water stagnant) and Al, Fe toxicity	2	13,900.3	52.1
S2	S2-nfx	Soil fertility, flood (water stagnant) and Al, Fe toxicity	3	1,974.3	7.4
S1	S1-nx	Soil fertility and Al, Fe toxicity Amount	4	7,497.1 26,680	28.1 100.00

Explanation: */ a: Very acid soil acidity and difficult to be managed

n: Very low to low soil fertility

f: Flood (frequency and duration), flood air depth and water flow should be considered in order to determine this limitation.

x: Salinity, high salt content which limits crop growth.

Source: Results of field observation, laboratory and image analyses (2011).

Efforts to Increase the Tidal Lowland Capability for Paddy

All areas are suitable for paddy with some biophysical soil and climate constraints to determine the level of suitability. Efforts to improve the ability of land for paddy are presented in full in Table 4. Table 4 states clearly that paddy is highly suitable (S1) for the soils if organic material, lime and fertilizer P are given. Land suitability for paddy is found on flat land until the slope (0-10 %). For a

more sloping land (> 10 %) it is needed a simple conservation efforts, such as individual terrace to anticipate soil erosion.

Conclusions

Limiting factors of land suitability for paddy are high soil acidity, very low soil fertility, depth of flood water, surface water flow and salinity, meanwhile the total area of high potential land is 17,982.3 ha (67.4%), around 5,389.4 ha (20.2%) is classified as middle potential land, around 3,308.3 ha (12.4%) belongs to low potential land and less potential land is not found in the field. The soil productivity of the high potential land is 6.0 tons Milled Dry Paddy (MDP) per ha/year, 2-5 tons MDP per ha/year are for middle potential land, 1-2 tons MDP per ha/year are found in low potential land and less than <1 ton MDP per ha/year belong to less potential land, respectively. Efforts to improve the land capability from the actual to the potential suitability are to make drainage channels, to apply the water barrier to flow water into cultivated land, to apply agricultural lime, to add and to maintain soil organic materials, to wash Na and H cations and to give N, P and K fertilizers.

Table 4. Efforts to increase land capability for paddy

SPT	Land suitability Potential	Actual*/	Efforts to increase land capability for paddy from actual suitability to potential land suitability
1	S2	S3-anfx	1) Make drainage channels 2) Make barriers for holding of water which going to the land 3) Give agriculture lime 4) Give and maintain organic matters in the soils 5) Do not burn biomass and do not wash elements of Na and H 6) Fertilize soils with N, P and K fertilizers
2	S1	S2-anfx	1) Make drainage channels 2) Make barriers for holding of water which going to the land 3) Give agriculture lime 4) Give and maintain organic matters in the soils 5) Do not burn biomass and fertilize with N, P and K fertilizers
3	S1	S2-nfx	1) Make drainage channels and give agriculture lime 2) Give and maintain organic matters in the soils 3) Wash Na and H ions and fertilize with N, P and K fertilizers
4	S2	S1nx	1) Make drainage channels and give agriculture lime 2) Give and maintain organic matters in the soils 3) Fertilize soils with N, P and K fertilizers

Explanation: */ a: Very acid soil acidity and difficult to be managed

n: Very low to low soil fertility

f: Flood (frequency, duration, water velocity and salt intrusion), flood air depth and water flow should be considered in order to determine this limitation.

x: Salinity, high salt content which limits crop growth.

Source: Results of field observation, laboratory and image analyses (2011).

Acknowledgements

The authors wish to acknowledge the financial supports provided through Competitive National Strategy Grant Scheme Nr. 514/SP2H/PP/DP2M/VII/2009 on 24 July 2010 by Directorate of Higher Education (DIKTI), Ministry of National Education, Indonesia.

References

- [1] P. Lagacherie, Mcbratney, A.B. and M. Voltz (Eds.), Digital Soil Mapping: An Introductory Perspective. Developments in Soil Science, Vol. 31. Elsevier, Amsterdam, 2006. 350 pp.
- [2] A.B. Mcbratney, Mendonça Santos, M.L. and B. Minasny. On Digital Soil Mapping. *Geoderma* 117(1-2):3-52. 2003.
- [3] M.E. Armanto, M.S. Imanudin, S.M. Bernas and R.H. Susanto, Land evaluation as a basic for directing of landuse to support an increase of cropping index in Reclaimed tidal land area. Final Report of Competitive National Strategy Grant, DIKTI, Jakarta, Indonesia. 2011, p. 158.
- [4] Soil Survey Staff, Keys to soil taxonomy. 11th ed. USDA-National Resources Conservation Service, Washington DC, USA, 2010.
- [5] D.L. Sparks, Methods of Soil Analysis, Part 3, Chemical Methods, ASSA and SSSA, Madison, Wisconsin, USA, 1996, p. 1264.