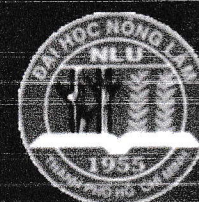
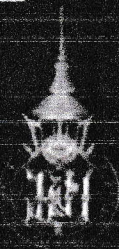




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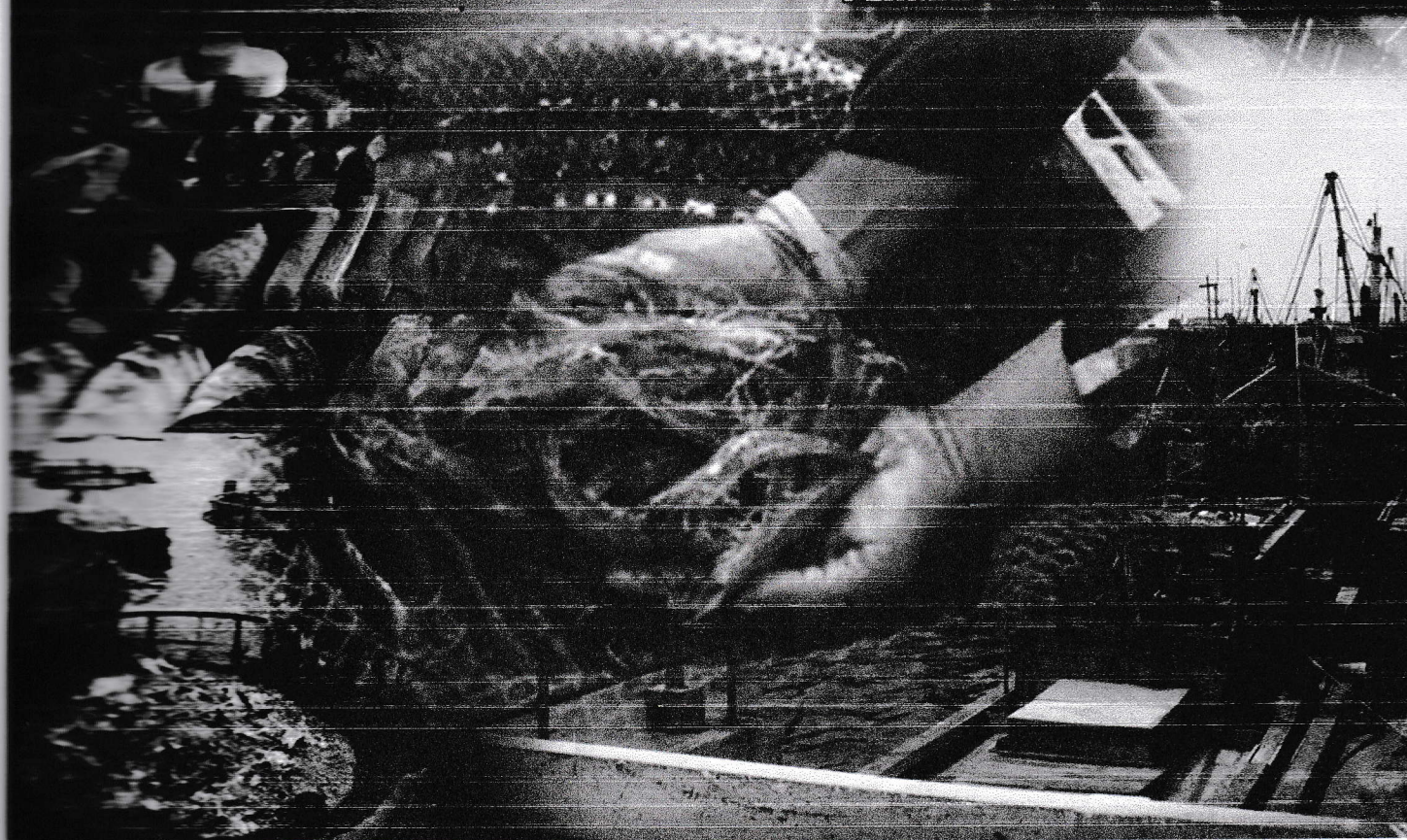


# INTERNATIONAL FISHERIES SYMPOSIUM PROGRAMME AND ABSTRACTS

TOWARDS A SUSTAINABLE FISHERIES IN  
SOUTH EAST ASIA

03-05 OCTOBER 201

PERMAI HOTEL KUALA TERENGGANU





## IFS2011 ORAL PRESENTATION PROGRAM SCHEDULE

MONDAY, OCTOBER 3

### Keynote Address

10:00 – 11:00 Y.H. Dato' Ahamad Sabki bin Mahmood, Director General, Department of Fisheries Malaysia  
Chairman: Prof. Dr. Sakri Ibrahim, Universiti Malaysia Terengganu

Venue : Berlian Hall

### PLENARY 1

14:00 – 14:50 Plenary Lecture I: Fisheries Economic and Marketing  
Dr. Stephen J. Hall, Director General, The WorldFish Center, Malaysia  
Chairman: Prof. Dr. Faizah Shaharom, Universiti Malaysia Terengganu

Venue : Berlian Hall

### SESSION 1 : FISHERIES AND MARINE SCIENCE

Monday, October 3 15:20 – 17:40 Venue : Berlian Hall  
Chairman : Assoc. Prof. Dr. Thumronk Amornsakun

- 15:20 – 15:40 [001] Analysis of  $\alpha$ -linolenic acid from *Monostroma nitidum* as a mitigation agent to remove harmful algal bloom species of *Fibrocapsa japonica*  
**Moch Amin Alamsjah**
- 15:40 – 16:00 [002] Effects of vegetation and water dynamics on pyrite ( $\text{FeS}_2$ ) oxidation in reclaimed tidal lowlands, South Sumatra  
**Edi Armanto M., Adzemi Mat Arshad, Imanudin M.S. and Elisa Wildayana**
- 16:00 – 16:20 [003] Fish forecasting system using sea surface temperature and chlorophyll satellite images: A statistical model approach  
**Raja Bidin Raja Hassan and Mohamed Rawidean Mohd Kassim**
- 16:20 – 16:40 [004] Possible fisheries in the deep sloping areas of the Malaysian EEZ in the South China Sea  
**Samsudin B. and Rosidi A.**
- 16:40 – 17:00 [005] Types and diversity of phytoplankton in different zones of the Koto Panjang reservoir, Riau, Indonesia  
**Madju Siagian and Syamarudddin Siregar**
- 17:00 – 17:20 [006] Seagrass biversity in Port Dickson, Malaysia with notes on the biological aspects of *Thalassia hemprichii* Ascherson  
**Abu Hena M. K., Japar Sidik B., Misri K and Hishamuddin O.**
- 17:20 – 17:40 [007] Diversity of seaweeds on the lower south on Gulf of Thailand Coast  
**Rapeeporn Ruangchuay, Mantana Nualcharoen, Prateep Nualcharoen and Chokchai Lueangthuwapranit**

## Effects of Vegetation and Water Dynamics on Pyrite ( $\text{FeS}_2$ ) Oxidation in Reclaimed Tidal Lowlands, South Sumatra

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### Abstract

*The research aimed to analyze effects of vegetation and water dynamics on pyrite ( $\text{FeS}_2$ ) oxidation in reclaimed tidal lowlands. The research was carried out in tidal lowland Pulau Rimau, South Sumatra from February to December 2010. The field observations are done by exploring several transect on land units. The field description refers to Soil Survey Staff (1993). Water and soil samples were taken from selected key areas for laboratory analysis. The vegetation data was collected by making sample plots (squares method) placed on each vegetation type with plot sizes depending on the vegetation type, namely 10 x 10 m for secondary forests and 5 x 5 m for shrubs and grass. The observations of surface water level were done during the river receding with units of m above sea level (m asl). The research results showed that (1) Pyrite formation is largely determined by the availability of natural vegetation as Sulfur (S) donors, climate and uncontrolled water balance and supporting faunas such as crabs and mud shrimp. Climate and water balance as well as supporting faunas is the main supporting factors to accelerate the process of formation pyrite, (2) Oxidized pyrite serves to increase soil acidity, becomes toxic to fish ponds and arable soils, plant growth and disturbing the water and soil nutrient balances. Oxidized pyrite is predominantly accelerated by the dynamics of river water and disturbed natural vegetation by human activities, and (3) The pyrite oxidation management approach is divided into three main components of technologies, namely water management, land management and commodity management.*

*Keywords*---Effects, vegetation, water dynamics, pyrite oxidation, tidal lowlands

### Introduction

Tidal lowland is a swamp that receives direct or indirect influence by the tides of sea water or river nearby. The management principle of tidal lowlands is how to manage excess water, to avoid the emergence of risks and toxins such as the acidity, oxidation pyrite (pyrite or  $\text{FeS}_2$  is the chemical formula for different crystal systems of iron sulfide) and pollution to the environment due to Al and Mn [2]. Reclamation of the tidal lowlands is essentially to lower the ground water level or drying with making drainage channel. The drainage channel also functions not only to dry the tidal lowlands, but also to provide sufficient water for fishery and plant growth as well as to conserve land resource itself. Thus, water management of tidal lowlands is including water conservation, understanding and managing soil acidity and managing acid sulfate soils [1].

Mostly tidal lowlands in Pulau Rimau are developed for fishery and agricultural

purposes, in order to prevent some failures of reclaimed tidal lowlands, thus we need to carry out a comprehensive research to analyze effects of vegetation and water dynamics on pyrite ( $\text{FeS}_2$ ) oxidation because pyrite is the most risks and toxins for fishery and plant growth. Besides that, pyrite is a basic materials for making acid sulfate soils with low pH. In the rainy season, oxidized pyrite can be washed into the rivers and can disturb a life of aquatic fauna as well as accumulate sediments in the rivers. Thus the purpose of this research is to analyze effects of vegetation and water dynamics on pyrite ( $\text{FeS}_2$ ) oxidation in reclaimed tidal lowlands South Sumatra.

### Materials and Methods

This research has been conducted from February to December 2010 in tidal lowlands Pulau Rimau, South Sumatra. The research method was detail field survey aided by interpretation of landsat imagery approach (landsat TM 7 with scales of 1:250,000, multi-



temporal) and topographic maps (scale of 1:50,000). Field description was done by exploring several transect on land units and refers to Soil Survey Staff (1993). Soil characteristics were recorded in the soil profile card. Water and soil samples were taken from several observations in selected key areas for labor analysis. The vegetation data was collected by making sample plots (squares method) placed on each type of vegetation with plot sizes depending on the type of vegetation, i.e. 10 x 10 m for secondary forests (dominated by trees) and 5 x 5 m for shrubs and grass (dominated by shrubs). The observations of surface water level were recorded during the river receding with units of m above sea level (m asl). It was determined 5 (five) point locations of water level observations, each obtained from upstream to downstream observations.

## Results and Discussion

### General Description of Research Sites

Approximately 40,263 ha of tidal lowlands area in Pulau Rimau, Banyuasin South Sumatra has been cultivated for transmigration program since 1960 for fishery and food crops, namely paddy, corn and cassava. Now the land use has undergone many changes due to the rapid growth of population and behavioral patterns of different communities. From the field experience, it showed that the reclaimed tidal lowland is less suitable for fishery and food crops. The main failure factor of the reclaimed tidal lowland is that the lands are less really understood in terms of the soil character and properties as well as their tidal swamp water either in form of spatial or attribute phenomena, thus the reclamation program tends to be forced on the biophysical conditions that do not fit with the needs of fishes and plants. In other words, the soils are not really suitable with the planted fishes and crops.

### Pyrite Formation

Tidal lowlands experienced intensive interactions between river water and sea water, so it gives an optimum place for the formation of sulfides. Sulfide will be reduced or oxidized based on water movement between river water and sea water and forms mineral pyrite or iron pyrite [5]. The mineral pyrite or iron pyrite is an iron sulfide with the formula  $\text{FeS}_2$ . Pyrite will be exposed to the atmosphere during land clearing or water dynamics of rivers and reacts with oxygen and water to

form sulfate, resulting in acid drainage water. Besides tidal movement between river water and sea water, pyrite will be strongly influenced also by natural vegetation, climate and supporting fauna.

### Natural Vegetation

Natural vegetation has a very important role as a basic ingredient in the pyrite formation. To reduce sulfate, sulfide is needed by organic matter as electron donor. Number of Mangrove and Nipah (density: 7 and relative Frequency: 1.8) play an important role in the pyrite formation because of the roots and high primary production, so there is a supply of organic matter for sulfate reduction freely. Specific influence of certain types of Mangrove and Nipah may be associated with peat formation of fine roots and the plant is below ground level, which is an additional source of energy for the formation of sulfur (S) and pyrite. Acid sulfate soils can usually be known by the typical vegetation such as *Phragmites* (Perumpung), *Cyperus* (Teki), *Fimbristylis* (Belidang), *Melaleuca* (Gelam), *Melastoma* (Seduduk) and the like which is an indicator plant for infertile soils.

The results of vegetation analysis are performed in Table 1; it appears the structure of vegetation as indicated by the Density Value (K), Frequency (F) and Domination (D). Based on the Important Value Index (INP) of each natural vegetation species showed that Belidang and Gelam were the dominant species and had the highest interest in the structure of vegetation communities found in the area with a value of 74% and 56.9% respectively.

Results of vegetation analysis showed that vegetation community Diversity Index (H) is 2.53, indicating that the vegetation communities that exist in the ecosystem is relatively stable ( $> 2.00$ ). However, there are species that dominate namely Belidang (*Fimbristylis annua*), Paku Gambut (*Blechnum orientale*) and Gelam Rawa (*Melaleuca leucadendra* sp). The next type of the dominant views of its importance is Perumpung (*Phragmites karka*) and Teki 1 (*Cyperus eragrostis*). The dominant vegetation is a major contributor in the pyrite formation. In other words, the dominant vegetation plays a big role in pyrite formation.

### Climate and Water Balance

Climate plays an important role in the pyrite formation associated with the production of organic material. The type of



climate in Pulau Rimau is almost everything including Type B Climate [9]. Type B Climate is a type of dry climates which have a dry month on average less than 3 (three) months of the year. Dry months are the months with rainfall < 70 mm (evaporation exceeds precipitation). In the Type B Climate, the monthly rainfall distribution is uneven throughout the year. In the rainy season, monthly rainfall values can reach 300-400 mm/month. By contrast, in the dry season the monthly rainfall is very low (< 70 mm/month). Rainy days ranges from 6-19 days per month depending on the season.

In this research, only rainfall patterns are analyzed because these characteristics most closely associated with pyrite oxidation. Based on climate data, the research site is included in aquatic moisture regime (saturated water). The temperature regime belongs to the isohyperthermic because the annual average temperature is always > 25 °C with a difference < 5 °C. Relative humidity throughout the year is ranging between 70-90% with daily average temperatures which show little variation, which is about 32 °C as maximum temperatures and an average minimum temperature of around 29 °C. The length of day varies under 12 hours throughout the year. The result of climate data analysis conducted by the JICA Study Team (2002) is presented in Figure 1. The average rainfall is 2870 mm/year with no dry months (< 70 mm). The wettest months are November to April. The driest months are July (88 mm) and August (119 mm).

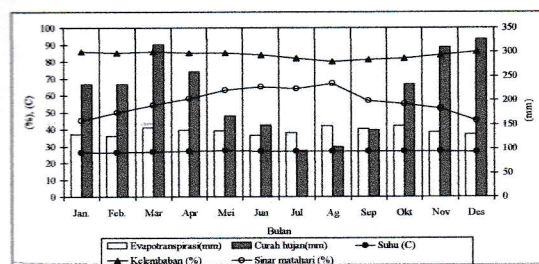


Figure 1. Analysis of climatic data [3]

The result of the water balance will give an overview of the condition of lack or excess of water to fishery and cultivated crops. This value can be approached from the other crops data by taking the maximum allegations. The results of water balance for the food crops (fishery, sweet corn, soybeans, peppers, peanuts, melons, bananas and oranges) are presented in Table 2. Determination of the period of growing crops in water balance analysis is based on the planting habit by

farmers in the field and the analysis of climate data.

Table 2. Water balance summary for fishery and some food crops

Fish/Crops	Fishes and crops period	Water supplies	Water need
Fish	Nov to March	> 743 mm	Drainage
	May to August	< 120 mm	Irrigation
Corn	May to August	< 90 mm	Irrigation
Soybean	Mei-June-July	< 105 mm	Irrigation
Chili	Mei-June-July	< 150 mm	Irrigation
	May to Sept	> 837 mm	Drainage
Peanuts*/	Nov to March	< 129 mm	Irrigation
	May to Sept	> 743 mm	Drainage
Melon */	Nov to March	< 93 mm	Irrigation
	May to Aug	> 705 mm	Drainage
Banana*/	Nov to Febr	> 1251 mm	Drainage
Orange*/	Jan to Dec	> 939 mm	Drainage

Source: Calculated from climatic data, \*/ [5]

Evaporation and transpiration (evapotranspiration) on the research site are approached by the existing of climate data. The used method in evaporation calculating is a modified Penman for Evapotranspiration (ET<sub>o</sub>). Variations of this ET<sub>o</sub> value in relation to rainfall provides a description of the general condition of lack or excess of water at the sites.

Monthly potential evapotranspiration ranges from 107 mm/month in February to 142 mm/month in August. This value varies from 103-111 mm/month. Potential evapotranspiration data are then used in the calculation of consumptive water needs of some types of vegetations. Table 3 explains that the water needs of crops in the dry season cannot be met if only relying on existing rainfall. Conversely, planting in the rainy season is potential in terms of water availability. In the rainy season is very much excess water to flow away into the rivers and swamps. In this case the system is required water disposal from root zone on the land to be cultivated. The same case for fishery, if very much excess water exist, this condition is not suitable for fishery, in dry season fishery needs water from irrigation in order to maintain pyrite in anaerobic condition and it is not oxidized.

Drought conditions are a serious threat if the rain does not fall within 10-15 days. This can be calculated based on rooting depth, water available and the rate of crop evapotranspiration. For example, if water is available 15% at 30 cm of root depth, it means water availability of 45 mm (0.15 x 30 cm) in the root zone of crops. Assuming that the rate of evaporation and transpiration is 4 mm/day,



the availability of this water will run out for  $45/4 = 11$  days [4].

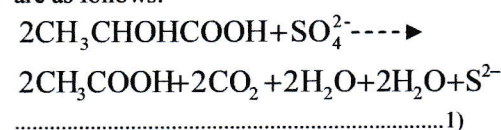
If the observed conditions of climate data and water balance associated with fishery and crops needs, the climate is passive factor and cannot be changed. However, the climate can be integrated with existing condition. It means that it opens the possibility that pyrite will be oxidized and will go to nearby rivers to form very acid river water. This acid water will flow to fishery area and support the formation of acid sulfate soils if we do not treat the water and the soils careful and pay special attention. Therefore, it is strongly recommended that appropriate technologies for crop water requirements are integrated with prevention or avoiding of pyrite oxidation. If pyrite is oxidized and acid sulfate soils will be stimulated and formed, so it will happen again the some failure of the management of tidal lowlands as we are finding now in the field and may be even worse than current conditions.

### Supporting Faunas

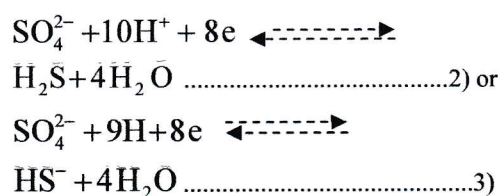
Faunas such as crabs and mud shrimp can make holes in the soil and the soils were excavated and stockpiled into small mountains. These mountains particularly under the Nipah and Mangrove vegetation cover 30-60% of the land surface. The excavated soils typically contain pyrite which is then oxidized to produce very acid water and to form acid sulfate soils [8].

Sulfur compounds are often found in tidal lowlands originating from the sea. The content of S (sulfur) in sea water is very high, ranging from about 885 ppm, around 4 times higher than those levels in the crust of the earth, granite, basalt or shale. The process of sulfide formation is started from the accumulation of sulfate arising by the processes of reduction into sulfides and S-elementary. This process is performed by bacteria *Desulfovibrio* and *Desulfomaculum* in reduction condition at pH 7 to 8.5 and the presence of organic material.

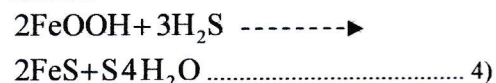
Vegetation of *Rhizopora racemosa* (Mangrove), *Nipah pruticans* (Nipah) and *Avicenia* sp. are the sources of organic matter needed by these bacteria. The general reactions are as follows:



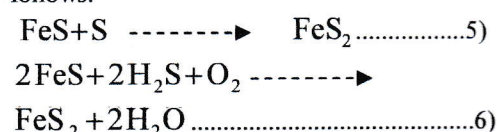
Formation of  $\text{H}_2\text{S}$  occurred at  $\text{Eh} = 0.0$  to 200 mv, pH 7.0, and if the situation is less reductive. It can occur also  $\text{HS}^-$ , i.e. on  $\text{Eh} = 200\text{-}300$  mv, pH 7.0 according to the reaction:



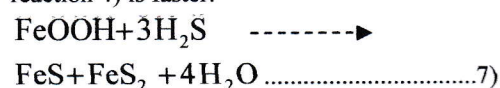
If there are nearby iron compounds, for example Goethite,  $\text{FeOOH}$ , it can form compounds Mackinowit ( $\text{FeS}$ ) and pyrite ( $\text{FeS}_2$ ). The formation reaction of  $\text{FeS}$  is as follows:



A similar reaction may take place with other heavy metal hydroxides (Cu, Zn, etc.). The next stage pyrite is formed from the reaction between  $\text{FeS}$  and S or the reaction between  $\text{FeS}$  and  $\text{H}_2\text{S}$  which take place around the area of contact between sediment and water on it. The reaction is approximately as follows:



If the order is acid (pH 4.0), then the reaction 4) is faster.



It is assumed that the reaction mechanism is as follows 5):



This mechanism shows that at high pH the pyrite formation occurs difficult. Oxidation of  $\text{H}_2\text{S}$  or  $\text{HS}^-$  to S-elementary is important for the pyrite formation, and if there is no oxidation of the match such as Fe (III) hydroxide and  $\text{Fe}^{3+}$ , the compound  $\text{FeS}$  will remain stable for a long enough period.

### Pyrite Oxidation and Water Dynamics

#### Water Dynamics of Observed Rivers

Pyrite oxidation in tidal lowlands is due to tidal movement of sea water. In this research site, there are several main rivers (i.e. Calik, Senda, Betung and Primary Channels) that their water surface height can directly affect pyrite oxidation. Height of the surface ground water in the tidal lowlands is strongly influenced by the seasons and river water. In the rainy season, the surface water can reach



+0.5 m asl, but in the dry season it could come down to -1.5 m below sea level (m bsl).

The highest dynamics of surface water level was found in the location of Senda river, which is +7 m asl. There is a tendency that the area around the large rivers flow, the dynamics of the surface water level is lower, which is seen at points along the Calik river which is the largest river in the research location. In general, the all main rivers and primary channels go to the Calik river. Amount of rivers in this area is more than 20 large and small rivers. Rivers are classified as large, i.e. Calik, Sendan and Betung.

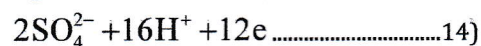
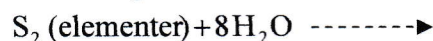
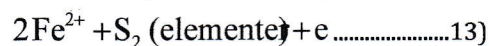
Based on observations of the river water dynamics at the research site (Table 4), it showed that fluctuations in river water at high tide and low tide varies widely (ranging from 0.5-2 m). Water fluctuations play a role as trigger to form pyrite oxidation and dissemination throughout the research sites. At low tide, the pyrite will be easy to contact with oxygen from the atmosphere and the oxidation of pyrite occurs because of water and soil in aerobic conditions. At high tide, then pyrite is difficult to be formed because of reduction conditions, but pyrite that has been oxidized at low tide will be carried by the tide and will flow throughout the research site. Incidence of such a process occurs continuously until the base material for pyrite formation is not there anymore. Therefore, it is not surprising that almost all research sites are polluted by pyrite oxidation both at high tide or low tide. Likewise, events it occurs in the rainy season and dry season.

### Chemical Reactions of Pyrite Oxidation

In the anaerobic conditions in the field, pyrite ( $\text{FeS}_2$ ) is stable and not dangerous for fishery and food crops, but if there is oxidation, then the situation becomes unstable. The first level of iron sulfide oxidation is the formation  $\text{S}_2$  (elementary) which occurs below the zone of weathering environment [7].

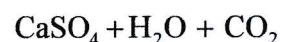


Oxidation of these requires weak acidic to neutral. Pyrite seems neutral in the soils which react quite neutral although it is aerobic condition. In contrast the acid condition is as follows:



Reaction (12) and (14) are reactions of continuing oxidation and helped by *Thiobacillus ferrooxydaus* and *Thiobacillus thiooxydaus*. Therefore, it can be seen that the  $\text{Fe}^{2+}$  and  $\text{S}_2$  (elementary), which formed in the soils, oxidized by micro-biological into  $\text{Fe}^{3+}$  (12) and (14). The reactions mentioned above is for pH 2-4, while for higher pH ( $\text{Fe}^{3+}$ ) is usually reduced due to the formation of  $\text{Fe}(\text{OH})_3$ . Thus it affects the reaction (13).

Production of sulfuric acid is what causes the pH of soil to be low at all and harmful and dangerous to water, soils and plants because it will disturb soil nutrients. In the case like this will cause soil pH less than 4. In addition, the influence of sea water will neutralize the alkaline nature of the influence of acid produced.



Marine clay can contain as many as 75-200 bases me/100 g due to 2:1 type clay mineral. Giving  $\text{CaCO}_3$  to these soils is also greatly reducing the activity of sulfuric acid. Liming treatment is able to raise the pH of the acid sulfate soils from pH 3.5 to 5.6 and the sulfate is lost after a flooded for 24 hours. That means reduction conditions are needed to prevent or to avoid pyrite oxidation.

Based on the above chemical reactions, in the fact that nature has taught us to see and to treat the pyrite in accordance with desired conditions (reduced or anaerobic conditions). During the reduction condition is maintained properly, then the threat of pyrite as poison and disturb the balance of soil nutrients and water can be optimally eliminated. In other words, pyrite is demanding to always be submerged by water either in a state of high tide or low tide, as well as during the rainy season or dry season. In addition, pyrite is the main indicator of success for tidal lowland utilization (for fisheries, agricultural activities as well as for the environment).

### Management Strategy of Pyrite Oxidation

Management strategy of pyrite oxidation aims to regulate the land resources utilization, to obtain optimum production and simultaneously to maintain the sustainability



of land resources. Therefore, pyrite oxidation management requires a careful planning, monitoring and application of appropriate technology, well-balanced land development, and management of land and water regulations. This is purposed that the pyrite is maintained as in reduction conditions and is not as toxic for fishery and cultivated crops and does not influence other nutrients balance. The pyrite oxidation management approach is divided into three main components, namely; Water Management Technologies, Technology of Land Management, and Commodity Management Technology.

## Conclusions

Pyrite formation is largely determined by the availability of natural vegetation as Sulfur (S) donors, climate and uncontrolled water balance and supporting faunas such as crabs and mud shrimp. Climate and water balance as well as supporting faunas is the main supporting factors to accelerate the process of formation pyrite. Oxidized pyrite serves to increase soil acidity, becomes toxic to fish ponds and arable soils, plant growth and disturbing the water and soil nutrient balances. Oxidized pyrite is predominantly accelerated by the dynamics of river water and disturbed natural vegetation by human activities. The pyrite oxidation management approach is divided into three main components of technologies, namely water management, land management and commodity management.

## Acknowledgements

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## References

- [1] Armanto, M.E., M.S. Imanudin, S.M. Bernas and R.H. Susanto. 2010. Land Evaluation as a Basic for Directing of Landuse to Support an Increase of Cropping Index in Reclamated Tidal Land Area. Final Research Report of Competitive National Strategy Grand. Research Center of Sriwijaya University, Indonesia.
- [2] Armanto, M.E. 2003. Existing Impacts of Reclamation Channels on Morphology and Classification Characters as well as Soil Productivity. *Journal of Environment Management & Natural Resources* 1(2):105-116, June 2003.
- [3] JICA Study Team. 2002. The Study on Comprehensive Water Management of Musi River Basin. Progress Report. Ministry of Settlement and Regional Infrastructure, The Republic of Indonesia.
- [4] Susanto, R.H., M.E. Armanto, Z.A. Samboe dan R.H. Purnomo. 1995. Tinjauan kondisi lingkungan dan usulan kebun penelitian UNSRI di Indralaya, Kabupaten Dati II OKI. FP, Unsri.
- [5] Borek, S.L. 1994. Effect of Humidity on Pyrite Oxidation. In: *Environmental Geochemistry of Sulfide Oxidation*. C.N. Alpers, D.W. Blowes (Eds), ACS Symposium Series 550, 31.
- [6] Soil Survey Staff. 1993. Soil Survey Manual. Agric. Handbook No. 18. USDA- SCS, Washington DC.
- [7] Wiese R.G., Powell M.A. and W.S. Fyfe. 1987. Spontaneous Formation of Hydrated Iron Sulfates on Laboratory Samples of Pyrite- and Marcasite-Bearing Coals. *Chem. Geol.* 63, 29-38.
- [8] Moses, C.O., D.K. Nordstrom, S. Herman and A.L. Mills. 1987. Aqueous Pyrite Oxidation by Dissolved Oxygen and by Ferric Ion. *Geochim. Cosmochim. Acta*, 51: 1561-1571.
- [9] Schmidt, F.A. and J.H.A. Ferguson. 1951. Rainfall types based on wet and dry period ratios for Indonesia with Western New Guinea. Publ. No. 42 Jaw Met & Geof, Jakarta.



Table 1. Results of vegetation analysis at research sites

Nr.	Type name	Analysis results							
		K	KR (%)	F	FR (%)	D	DR (%)	INP	H
1.	Alang-alang	54	9.0	5	2.2	244	0.5	3.6	0.05
2.	Belulang	24	4.0	10	44.0	76	1.0	4.9	0.07
3.	Belidang	3200	52.6	20	8.9	6,431	12.5	74.0	0.34
4.	Gelam Rawa	420	6.9	20	8.9	21,101	41.4	56.9	0.32
5.	Keladi Liar	15	0.2	6	2.7	577	1.1	4.0	0.06
6.	Kucingan	14	0.2	6	2.7	44	0.1	3.0	0.05
7.	Nipah	7	0.1	4	1.8	4,946	9.6	11.5	0.12
8.	Paku Gambut	360	5.9	20	8.9	916	1.8	16.6	0.16
9.	Paku Hurang	859	14.0	10	4.4	3,889	7.6	26.0	0.21
10.	Paku Laut	70	1.1	16	7.1	1,978	3.8	12.0	0.13
11.	Paku Tali	80	1.3	8	3.6	63	0.1	5.0	0.07
12.	Perumpung	230	3.8	5	2.2	1,625	3.2	9.2	0.11
13.	Pulai	6	0.1	6	2.7	1,884	3.7	6.5	0.08
14.	Rumput Pait	180	2.9	10	4.4	1,272	2.5	9.8	0.11
15.	Seduduk	32	0.05	18	8.0	628	1.2	9.7	0.11
16.	Serdang	5	0.1	5	2.2	565	1.1	3.4	0.05
17.	Sembung Rambat	30	0.5	12	5.3	94	0.2	6.0	0.08
18.	Sikejut Perdu	40	0.6	8	3.6	554	1.1	5.3	0.07
19.	Teki Rambat	56	0.9	10	4.4	44	1.1	5.4	0.07
20.	Teki 1	255	4.2	12	5.3	3,203	6.2	15.7	0.15
21.	Teki 2	175	2.8	14	6.2	1,236	2.4	11.4	0.12
Total		6,112	100	225	100	51,370	100	300	2.53

Source: Primary Data (2010).

Description: K: Density value, F: Frequency, KR: Relative density (%), FR: Relative frequency (%)  
D: Domination, DR: Relative dominance (%), INP: Important Value Index, H: Diversity index