UNIVERSITI PUTRA MALAYSIA

SOIL AND WATER QUALITY OF AN ACID SULFATE SOIL AREA AND THEIR EFFECTS ON THE GROWTH OF RICE IN THE KELANTAN PLAINS, MALAYSIA

PAYMAN HASSAN MOHAMMED ALI

FP 2016 13

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By

PAYMAN HASSAN MOHAMMED ALI

Thesis Submitted to School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the degree of Master of Science

January 2016

DEDICATION

To my beloved husband,
My lovely parents,
My brothers and sisters

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Shamshuddin Jusop, PhD
Faculty : Agriculture

Agricultural practices that depend on identifying soil quality has an effective role in sustaining plant growth. Soil quality has direct and indirect effects on water quality, plant growth, and the environmental. Acid sulfate soils are widespread along the coastal plains of the Malay Peninsula. Planting rice in these types of soils has some challenges as it has low pH, contains toxic amounts of Al and Fe, and inadequate amounts of Ca, Mg and K. This study focused on studying the quality of acid sulfate soils and their effects on both field water quality and rice production. The field under study was at Kg. Golok, Kemasin-Semerak, Kelantan, Peninsular Malaysia. The study was conducted in three stages. The first stage was a preliminary investigation about the important properties of acid sulfate soils by taking soil samples randomly from surface (0-15cm) and sub-surface soil (15-30 cm) in twelve plots. Second stage was a detailed analysis of soil quality using some physical and chemical indicators. In addition, various physical and chemical indicators of the soil were selected to assess soil quality to ensure the functionality of acid sulfate soil. The physical indicators were texture, bulk density, and particle density. Thus, for chemical indicators, soil pH, EC, CEC, N, P, K, Ca, Mg, Al, and total N, C, and S were determined. Then, was followed by detailed water quality analysis to study the effect of acid sulfate soil on field water quality by taking ten surface water samples randomly from different places in the area under the study to see the impacts of acid sulfate materials on field water quality. Oxidation of acid sulfate soils form sulphuric acid, which will result in releasing metals, acidity, and nutrients into the soil, surface water, and ground water. These surface water sample were collected and analysed for pH, EC, cations (Ca, Mg, K, Al and Fe), anions (F, Cl, Br, NO_2, NO_3, PO_4, and SO_4), and heavy metals (As, Cd, Cr, Cu, Mn, Pb, and Zn). The final stage involved conducting a glasshouse experiment at Universiti Putra Malaysia, in five treatments with three replications. The treatments were ground magnesium limestone (GML) at rates 0, 2, and 4 t/ha. They were with and without organic fertilizer at rates 0 and 0.25 t/ha. Rice variety MR 219 was tested in this study. Glasshouse experiment was done by CRD, which was replicated three times. After one month of adding lime and organic fertilizer, the soil samples were analyzed to determine the effect of adding

lime with organic fertilizer in changing the quality of acid sulfate soil, and to determine how it enhance the growth of rice.

The results gained from this study showed that physical properties of acid sulfate soils were in appropriate conditions for planting rice. The texture of the soil was silty clay loam to clay loam. This type of texture has more capacity for water retention to fill the need of rice from water. Bulk density seems be at good levels. Thus, it is a very important property affecting the structural support, water and solute movement, and the soil aeration. Chemically, as these types of soils contain pyrite and due to its oxidation process, high acidity (pH 3-4) with toxic amounts of aluminum and iron will be released into the environment, making these soils infertile for plant growth if it is not ameliorated with an appropriate amendment. The infertility of these types of soils came as a result of high acidity (pH 3-4). Exchangeable Al was high in most plots, which reached 9.87 $cmol_c$/kg. The concentration of Al was much higher than the critical level for rice production. Thus, they contained low amounts of essential nutrients for plant growth. Fe concentration ranged from 134 to 335 mg/kg. The initial top soil exchangeable Ca was less than 2 $cmol_c$/kg soil, which is the required level for rice growth. Exchangeable Mg was almost less than 1 $cmol_c$/kg, which is the required level. Field water quality was strongly affected by acid sulfate materials through decreasing pH, which in most samples was less than 4. Most cations were in water samples: Ca concentration ranged from 26.22-48.71 mg/L, Mg ranged from 13.75-17.82 mg/L, while Al ranged from 203.07-465.76 µM. Iron ranged from 77.46 to 163.90 µM. Furthermore, most anions were lower than the critical levels, except for chloride that had a high value ranging from 20.10 to 47.42 mg/L. Sulfate was very high in all water samples ranged from 283.80-629.80 mg/L, which is mainly due to the composition of acid sulfate soils of sulfate. Nitrate ranged from 1.09-3.90 mg/L. Generally, heavy metals were low in concentration, indicating that acid sulfate soil deposits did not release extra amounts of heavy metals into water bodies that have a problematic impact on soil, plant, and the environment. Manganese (Mn) ranged from 0.198-0.906 mg/L, zinc (Zn) ranged from 0.018-0.191 mg/L, aluminium (Al) ranged from 0012-0.077 mg/L, and copper (Cu) ranged from 0.020-0.087 mg/L.

Glasshouse experiment results showed that rice yield was significantly increased by adding lime with organic fertilizer ($P < 0.05$). Liming had a clear role in increasing pH and essential nutrients, and in decreasing the toxic amounts of Al in the soil. Applying GML at the rate of 4 t/ha in combination with organic fertilizer, increased soil pH from 3.73 to 5.45 and Ca concentration from 0.37 to 1.53 $cmol_c$/kg, and decreased Al concentration from 2.52 to 1.87 $cmol_c$/kg.

The findings of this project suggested the quality of acid sulfate soil has many problems that should be treated to be used for rice production, and the best management practice to help reducing problematic effects of these problems is adding ground magnesium limestone in combination with organic fertilizer. In addition, water quality of acid sulfate area has significantly affected by sulfuric materials in an acid sulfate soils. Adding lime, particularly GML in combination with organic fertilizer at the rate of 4 t/ha had positive effects in improving the quality of these soils.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KUALITI TANAH DAN AIR TANAH SULFAT BERASID DAN KESAN-KESANNYA KE ATAS PERTUMBUHAN PADI DI KELANTAN PLAINS, MALAYSIA

Oleh

PAYMAN HASSAN MOHAMMED ALI

Januari 2016

Pengerusi : Shamshuddin Jusop, PhD
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Amalan-amalan pertanian yang bergantung kepada pengenalpastian kualiti tanah mempunyai peranan yang efektif dalam mengekalkan pertumbuhan tanaman. Kualiti tanah mempunyai kesan langsung dan tidak langsung ke atas kualiti air, pertumbuhan tanaman dan alam sekitar.Tanah sulfat berasid adalah luas, di sepanjang dataran pantai Semenanjung Malaysia. Penanaman padi dalam tanah-tanah seperti ini mempunyai beberapa cabaran seperti ia mengandungi pH yang rendah, mengandungi bahan toksik Al dan Fe, dan amaun Ca, Mg and K yang tidak mencukupi. Kajian ini menjurus kepada pengkajian kualiti tanah sulfat berasid dan kesan-kesannya ke atas kualiti air di bendang dan pengeluaran padi. Bendang yang dikaji adalah kawasan Kg. Golok, Kemasin-Semerak, Kelantan, Semenanjung Malaysia. Kajian ini dijalankan dalam tiga peringkat. Peringkat pertama ialah kajian awal tentang kepentingan ciri-ciri tanah sulfat berasid dengan mengambil sampel tanah secara rawak dari permukaan (0-15cm) dan tanah di bawah permukaan (15-30 cm) untuk duabelas plot. Peringkat kedua ialah analisis terperinci kualiti tanah menggunakan beberapa petunjuk fizikal dan kimia. Tambahan pula, pelbagai petunjuk kimia dan fizikal tanah telah dipilih untuk menilai kualiti tanah dalam memastikan kefungsian tanah sulfat berasid. Petunjuk-petunjuk fizikal adalah tekstur, ketumpatan pukal dan kepadatan partikel. Maka itu, untuk petunjuk-petunjuk bahan kimia, pH tanah, EC, CEC, N, P, K, Ca, Mg,Al, dan jumlah N, C, and S telah ditentukan. Kemudian, diikuti dengan analisis kualiti air yang terperinci untuk mengkaji kesan tanah sulfat berasid ke atas kualiti air bendang dengan mengambil sepuluh sampel air di permukaan dari tempat-tempat yang berlainan di kawasan itu untuk melihat impak bahan sulfat asid ke atas kualiti air di bendang. Pengoksidaan tanah sulfat berasid membentuk asid sulfurik, yang akan membawa kepada pembebasan logam, keasidan dan nutrient ke dalam tanah, air permukaan dan air dari dalam tanah. Sampel air permukaan ini dikumpul dan dikaji dari aspek pH, EC, kation (Ca, Mg, K, Al dan Fe), anion (F, Cl, Br, NO_2, NO_3, PO_4, dan SO_4), dan logam berat (As, Cd, Cr, Cu, Mn, Pb, dan Zn). Peringkat terakhir melibatkan pengendalian satu eksperimen rumah kaca ke atas plot yang mengandungi beberapa bahan sulfat asid di Universiti Putra Malaysia, dalam lima rawatan dengan tiga replikasi. Rawatan-rawatan tersebut adalah batu kapur tanah (GML) pada kadar 0, 2,

and 4 t/ha. Rawatan-rawatan tersebut menggunakan, atau tidak menggunakan baja organik pada kadar 0 and 0.25 t/ha. Variasi padi MR 219 telah diuji dalam kajian ini. Eksperimen rumah kaca dibuat oleh CRD, yang telah direplikasi sebanyak tiga kali. Selepas sebulan menambah kapur dan baja organik. sampel tanah telah dikaji untuk menentukan kesan menambah kapur dengan baja organik dalam menukar kualiti tanah sulfat berasid, danmenentukan bagaiman ia boleh meningkatkan pertumbuhan padi.

Keputusan yang diperolehi dari kajian ini menunjukkan bahawa curu-ciri fizikal tanah sulfat berasid berada dalam keadaan yang sesuai untuk menanam padi. Tekstur tanah ialah dari lom tanah liat berkelodak kepada lom tanah liat. Tekstur jenis ini mampu menyimpan air untuk memenuhi keperluan air padi ini. Ketumpatan pukal berada pada aras yang baik. Oleh itu, ia menjadi satu ciri yangs angat penting dalam memberi kesan kepada sokongan struktur, air dan pergerakan bahan larut dan pengudaraan tanah. Dari aspek kimia, oleh kerana jenis-jenis tanah ini mengandungi pyrite dan berikutan proses pengoksidaannya, keasidan yang tinggi (pH3-4) dengan amaun toksik aluminum dan besi akan dibebaskan ke alam sekitar, menjadikan tanah ini tidak subur untuk pertumbuhan tanaman jika ia tidak diperbaiki melalui kaedah yang sesuai. Ketidaksuburan jenis-jenis tanah ini terhasil dari keasidan tinggi (pH 3-4). Kebolehtukaran Al adalah tinggi dalam kebanyakan plot, yang mencapai 9.87 $cmol_c$/kg. Konsentrasi Al adalah lebih tinggi dari aras kritikal pengeluaran padi. Oleh itu, ia mengandungi kandungan nutrient yang rendah untuk pertumbuhan tanaman. Konsentrasi Fe adalah dari 134 sehingga 335 mg/kg. Tanah terbaik Ca yang boleh ditukar pada mulanya adalah kurang dari 2 $cmol_c$/kg tanah, iaitu aras yang diperlukan untuk padi. Mg yang boleh ditukar ialah hampir kurang dari 1 $cmol_c$/kg, iaitu aras yang diperlukan. Kualiti air di sawah sangat terjejas oleh bahan sulfat asid melalui pH yang berkurangan, yang mana dalam kebanyakan sampel ia kurang dari 4. Kebanyakan kation adalah rendah dalam sampel air: konsentrasi Ca berjulat dari 26.22-48.71 mg/L, Mg berjulat dari 13.75-17.82 mg/L, sementara Al berjulat dari 203.07-465.76 µM. Besi berjulat dari 77.46 kepada 163.90 µM. Tambahan pula, kebanyakan anion adalah lebih rendah dari aras yang kritikal, melainkan forklorida yang mempunyai nilai yang tinggi dari 20.10-47.42 mg/L. Sulfat adalah tinggi dalam semua sampel air dari 283.80-629.80 mg/L, disebabkan oleh komposisi sulfat dalam tanah sulfat berasid. Nitrat adalah dari 1.09-3.90 mg/L.Umumnya, logam-logam berat adalah rendah dalam konsentrasi, dan ini menunjukkan bahawa pembuangan tanah sulfat berasid tidak membebaskan amaun tambahan logam berat ke dalam air, yang memberi kesan yang memberi masalah kepada tanah, tanaman dan alam sekitar. Manganese(Mn) berjulat dari 0.198-0.906 mg/L, Zink (Zn) berjulat dari 0.018-0.191 mg/L,Aluminium (Al) berjulat dari 0012-0.077 mg/L, dan Kuprum (Cu) berjulat dari 0.020-0.087 mg/L.

Keputusan eksperimen rumah kaca menunjukkan bahawa hasil padi meningkat dengan ketara dengan cara menambah kapur dan baja organik ($P < 0.05$). Kapur mempunyai peranan yang jelas dalam meningkatkan pH dan nutien-nutrien penting, dan dalam mengurangkan amaun toksik Al dalam tanah. Melalui pengaplikasian GML pada kadar 4 t/ha digabungkan dengan baja organik, meningkatkan pH tanah dari 3.73 kepada 5.45 dan konsentrasi Ca dari 0.37 kepada 1.53 $cmol_c$/kg, dan mengurangkan konsentrasi Al dari 2.52 kepada 1.87 $cmol_c$/kg.

Dapatan projek ini mencadangkan bahawa kualiti tanah sulfat berasid mempunyai beberapa masalah yang perlu dirawat untuk digunakan untuk pengeluaran padi, dan amalan pengurusan yang terbaik untuk membantu mengurangkan kesan-kesan masalah ini ialah dengan menambah batu kapur magnesium tanah dan baja organik. Tambahan lagi, kualiti air kawasan sulfat asid telah menerima kesan yang signifikan dari bahan-bahan sulfur dalam tanah sulfat berasid. Dengan menambah kapur, khususnya GML berserta baja organik pada kadar 4 t/ha mempunyai kesan positif dalam menambahbaik kualiti tanah-tanah ini.

ACKNOWLEDGEMENTS

In The Name Of Allah, Most Gracious, Most Merciful

I would like to express my sincere gratitude to my project supervisor Prof.Dr. Shamshuddin Jusop for his continuous support and encouraging. All steps taken on the way to finishing this thesis were under his direct guidance. special thank to the other members of the supervisory committee, Dr. Ahmad Zaharin and Dr. Roslan Ismail, who never came short answering my questions and giving helpful comments. I am also thankful to the laboratory assistant, Mrs. Rusnah, who endured with great patience in all my laboratory tasks.

I would like to express special thanks to Universiti Putra Malaysia and the Ministry of Education Malaysia (LRGS – Food Security) for financial and technical support.

A very special thank to my dear husband for his uncountable supporting and encouraging Similarly, many thanks go to my beloved parents, brothers and sisters who supported me with prayers and endured the pain of being away for two years. My friends, who was there for me and helped me with all what they got, are people whom I will never forget.

Finally, I thank the Kurdistan regional government's Human Capacity Development Program who sponsored my master's studies.

I certify that a Thesis Examination Committee has met on 27 January 2016 to conduct the final examination of Payman Hassan Mohammed Ali on his thesis entitled "Soil and Water Quality of an Acid Sulfate Soil Area and their Effects on the Growth of Rice in the Kelantan Plains, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science.
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SQ	Soil Quality
ASS	Acid sulfate soil
AP	Available phosphorus
BD	Bulk density
Ca	Calcium
Mg	Magnesium
TN	Total Nitrogen
CEC	Cation Exchange Capacity
cm	Centimeter
ha	Hectare
Kg	Kilogram
m	Meter
SAS	Statistical Analysis System
PCA	Principal Component Analysis

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Soil is an unconsolidated mineral body on the earth's surface which has been influenced by both genetic and many environmental elements. Also, it has its own physical, chemical, and biological properties which differ from the source which was derived from during a specific time. Soil is a very important natural source as its role to filter water, support plant growth, provides habitat for many types of organisms, and sequester carbon from the atmosphere. Depending on the functions that a soil performs, we can assess the quality of that particular soil. Consequently, the soil's ability to perform these critical functions can be described by the term "soil quality" (Gaskell et al., 2000). Throughout the history of agriculture and cultivation, many management practices have been used to increase food production. This is for the rapid growth of the population without taking in mind the importance of protecting natural resources such as soil and water. Soil degradation is one of the most important indicators in assessing environmental quality. Poor land management, including unreasonable land use, has caused the deterioration of soil quality, resulting in soil structure degradation and organic matter loss. Thus, this affects water, air, and nutrient fluxes in the soil, in addition to the plant growth (Golchin et al., 1995; Tejada et al., 2006). In addition to that, changes in soil quality are not only associated with management, but also with the environmental context, such as temperature and precipitation (Andrews et al., 2004).

Soil quality term can be defined as the capacity of a soil to function within the ecosystem and land use boundaries. This is aimed to sustain biological productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin, 1994). The importance of soil quality generally comes from four important functions, which are environmental quality, productivity and sustainability, and biodiversity and human safety (Parr et al., 1992). The quality of a soil cannot be assessed directly; it needs a combination of chemical, physical, and biological factors that gives the soil the ability to perform a wide range of functions (Tamm et al., 2006). Many studies have been conducted concerning soil quality, but there is still no well-defined universal methodology to characterize soil quality by means of a set of clear indicators (Bouma, 2002). Furthermore, lack of knowledge about the soil's nature and properties and excessive human use of management practices to increase income, leads to a decline in the quality of the soils. There is a strong link between soil quality and land management in which both have a direct influence on water and atmospheric quality, and by extension, on human and animal health (Doran and Parkin, 1994; Kennedy & Papendick, 1995). Therefore, the quality of any soil mainly depends on genetic characteristics. Nevertheless, human management practices also have a clear effect on the soil quality (Pierce and Larson, 1993; Masciandaro, 1999). All natural resources such as soil, air, and water have a close relationship by which all have effects on each other. As soil quality improves, the quality of the other resources will also improve. Decline in soil and water quality can have a risk on aquatic ecosystem, industrial, agricultural, and on human health. In addition, heavy metals will be released to the ground water and the nearby environment.

Acid sulfate soils are those soils that occur naturally and contain iron sulfides. Sulfides are formed by bacterial sulfate-reduction, a process requiring anaerobic conditions, sulfate, and degradable organic matter (Cook et al., 2000). Sulfur will be stored safely in these soils if it is not exposed to air and oxidized. Therefore, if it exposed to air for management purposes or any other purpose, iron sulfides will react with oxygen and water, produce sulphuric acid, and iron compounds that affects both soil and water quality. These types of soils have a specific quality whereby they are considered as the most problematic type among many types of soils. Thus, this is because of the bad impacts they have on plants, humans, and the environment. This impact occurs because they have pH less than 4, high amounts of toxic Al and Fe, and low quantities of essential elements for plant growth. No problems will appear if this type of soils is not exposed to the oxidation process. Acid sulfate soils are widespread in Malaysia, occurring almost exclusively along its coastal plains (Shamshuddin & Auxtero, 1991; Shamshuddin et al., 1995; Muhrizal et al., 2006; Enio et al., 2011). Therefore, growing rice in acid sulfate soil is very common in Malaysia as the warm weather and continuous raining create a good environment for rice production. In general, acid sulfate soils do not fit into the desired characteristics for plant growth, unless in doing some improvement practices. Some of these practices include ground magnesium limestone (GML) liming, flooding, leaching, and applying manganese dioxide (Park & Kim, 1970). However, rice can be planted in acid sulfate soils because it is known to have a tolerance of relatively high acidity conditions, but the quantity of ferrous sulfate produced during the oxidation of pyrite process showed the adverse effect on rice growth (Kobayashi, 1939).

According to Zhang et al. (2004), soil quality regarding soil productivity is a function of various factors, such as parent material, physical properties, chemical properties, and topography. Soil physical properties strongly influence soil function and determine potential land uses (Fernández-Ugalde *et al., 2009;* Griffiths *et al.,* 2010). The total quality of agro-ecosystems occurs due to the significant effects of physical and chemical properties and biological soil processes (Flores-Delgadillo *et al.,* 2011). Soil with good physical quality also has fluid transmission and storage characteristics that permit the correct proportions of water, dissolved nutrients, and air for both maximum crop performance and minimum environmental degradation (Topp *et al*., 1997). For planting rice in acid sulfate soil, chemical soil indicators have stronger role in affecting on rice yield than physical soil indicators. Thus, this happens because the main problems of these soils come from nutrients imbalance and high acidity. A high quality soils not only produce food and fiber, but also play an important role in stabilizing the natural ecosystem and in enhancing water and air quality (Griffiths *et al.,* 2010). Good soil quality is characterized by maintaining high productivity without significant soil or environmental degradation (Govaerts *et al*., 2006). Meanwhile, a better knowledge of agricultural soil quality is essential for designing farming systems, which effectively maintains or improves soil quality and crop production (Qi *et al*., 2009; Bonanomi *et al*., 2011). Loss in soil fertility directly affects the reduction of rice yields due to the reduction in soil quality (Lal, 2004). On other hand, adding of organic matter and careful management of fertilizers, pesticides, and tillage will protect the soil and improve the soil quality.

Water quality means the features of a water resource that will affect its fitness for a definite usage. Therefore, it can be defined as a certain physical, chemical, and biological properties combined to assess the quality of the water. The most obvious function of water is the transportation of nutrients into plants through their roots. It also supports the plant on their cellular components. Thus, plant wilting will be the result of the absence of water. However, the plant will not be able to process the water correctly for use if the water is too acidic or too alkaline. As a result, the quality of water has a direct effect on the overall life of the plant. The drainage discharged from acid sulfate soils are a serious environmental concern in many regions worldwide with pH often less than 4 and concentrations of iron and aluminum that are high enough to cause serious downstream impacts on flora and fauna (Callinan *et al*., 1993; Wendelaar Bonga and Dederen, 1986). Surface water in acid sulfate soils is fresh during rainy seasons because the rain would wash toxic substances to a definite depth of the soil. However, during the dry season, toxic elements which have a harmful effect on the plant will move back to the surface. The moving of sulfuric acid through the soil will release iron, aluminium, and in some cases manganese. Sulfuric acid usually lowers soil pH, resulting in decreasing the availability of nutrients. In addition, acidity will dissolve aluminum and iron, and make them more available to plants in a toxic amount. Generation of acidic metal-rich drainage, results from the oxidation of pyrite and other iron-bearing sulfide minerals and the consequent release of sulfuric acid and dissolved iron in solution (Evangelou, 1995; Appelo and Postma, 1999). Acidity and low dissolved oxygen can deteriorate water and damage its quality. In addition, due to the oxidation of the metal bearing sulfides and exposure of silicate minerals to extreme acidity, very large quantities of metals are mobilized and leached to watercourses from these soils (Sundstro¨m et al., 2002; Osterholm and Astrom, 2004; Sohlenius and Oborn, 2004). Pyrite oxidation produces high concentrations of ferrous ions and sulfuric acid, which attacks clay minerals and produces high concentrations of monomeric aluminum and other acid-soluble metals. Subsequent leaching of these toxic products into adjacent water bodies is rapidly increasing the stress on ecosystems. Drainage from acid sulfate soils has been associated with effects on plant growth (Moore and Patrick, 1991), acidification of water bodies (Sammut *et al*., 1996; Nguyen and Wilander, 1995; Astrom and Bjorklund, 1995; Wilson *et al*., 1999; Cook *et al*., 2000), and mortality of fish (Sammut *et al*., 1995). Many environmental problems are associated with the discharging of these acidic products into nearby rivers or lakes where fishes and some other marine creatures are tolerant to acidity. However, the damage on concrete and steel is as a result of these acidic drainages. Hence, the purpose of this study is to determine the water properties of acid sulfate soil area and their effects on heavy metals concentrations.

Crop yield is strongly affected by soil quality, climate, and farm management practices (FAO, 1985). Therefore, the quality of acid sulfate soil has a very close relation to rice cultivation. Rice in nature is known to have a tolerance towards acidity. Properties that naturally exist in acid sulfate soils like hydromorphic, topographic, and hydrologic settings make these soils favorable for rice production. However, if the pH is so low, the rice will be adversely affected. Another property of soil that affects the quality of acid sulfate soil for rice planting is toxic amounts of Al. Similar findings reported by Shamshuddin et al. (2013) and further by; Shamshuddin et al. (2014), stated that Al concentration under field condition in acid sulfate soil areas in Malaysia is more than 800 µM, which is much bigger than the critical level which is 15 µM (Elisa Azura *et al*., 2011). The properties which are not suitable for cultivation in these types of soils should be treated with some practices to make them an acceptable environment for rice planting. Among these practices, application of ground magnesium limestone (GML), submergence, leaching, phosphate application, and applying of basalt were commonly addressed. Hence, the study was conducted on assessing the quality of acid sulfate land to determine the quality of both soil and water and addressing the proper method to be used for rice cultivation.

1.2 Objectives

The general objective of the study was to determine the quality of soil in an acid sulfate area in the Kelantan Plains, Malaysia and how it affects the growth of rice.

Thus, the specific objectives were:

1. To determine soil and water quality in an acid sulfate soil area cropped to rice;
2. To study the effect of ground magnesium limestone in combination with organic fertilizer on the rice growth.

1.3 Hypothesis

Land quality has very strong relation with soil productivity. Thus, it is very important to identify soil and water quality status in order to choose the best management practices. The fertility of acid sulfate soil should be improved in order to be used for rice cultivation. Adequate amount of lime in combination with organic fertilizer may lead to an improvement in the quality of these soils. This is because lime has the ability to correct soil acidity and hence soil quality, enhances the amount of essential nutrients such as calcium and magnesium, and decreases the toxic amounts of certain elements in the soil such as aluminum, manganese, and iron. In addition to that, it has the ability to increase the bacterial activity that encourages a favorable soil structure, thereby supporting rice growth.

REFERENCES

Abdu, A. 2005. Effects of Sewage Sludge on Tree Growth, Soil Properties and Groundwater Quality. Master's thesis, Universiti Putra Malaysia.

Accornero, A. and Manfra, R.L. 2008. Sediment Concentrations of Trace Metals in the Berre Lagoon (France): An Assessment of Contamination. *Archives of Environmental Contamination and Toxicology*. 54 (3): 372–85.

Ahmed, F. and Khan, H.R. 2010. Response of Mineral Nutrient of Rice to Sulfidic Material as Sulfur. *Nature and Science* .8 (8): 31–40.

Ahmed, F. and Khan, H.R. 2010. Threatening of the Severity of Acid Sulfate Soils to the Adjacent Environment in the Cox' S Bazar Coastal Plains of Bangladesh. *New York Science Journal* .3(9): 22–27.

Ahmed, Z. A., Lim, W.Y., Praveena, S.M., Yussoff, M.K., Ramli, M.F. and Juahir, H. 2014. Water Quality Status of Selected Rivers in Kota Marudu, Sabah, Malaysia and Its Suitability for Usage. *Sains Malaysiana*. 43(3): 377–388.

Al-Balwai, H., Alkkahem, F., Al-Misned, F., Ahmad, Z., Al-Ghanim, Kh. and Mahboob, Sh. 2013. A Study on the Concentration of Heavy Metals in Water and Sediments of Natural Water Reservoir in Wadi Hanefah, Saudi Arabia and Uptake of Metals by a Fish, Poecilia Latipinna. *Pakistan Journal of Zoology* .45 (3): 589–593.

Alexakis, D., Gotsis, D. and Giakoumakis, S. 2012. Assessment of drainage water quality in preand post-irrigation seasons for supplemental irrigation use. *Environmental Monitoring and Assessment*. 184(8): 5051-5063.

Alia, F.J., Shamshuddin, J., Fauziah , C.I., Husni , M.H.A. and Panhwar ,Q.A. 2015. Effects of aluminum, iron and/or low pH on rice seedlings grown in solution culture. Int. *Journal of Agriculture and. Biology*. 17: 702-710.

Alva A.K., Asher, C.J. and Edwards , D.G. 1986. The role of calcium in alleviating aluminum toxicity. *Australian Journal of Soil Research*. 37: 375-383.

Ameen, H. 2012. Effects of Tillage Methods, Fertilizer and Crop Protection Practices on Soil Quality Indicators. Master's thesis. School of Agriculture, Food and Rural Development. Newcastle University.

Andrews, S.S., Karlen, D.L. and Cambardella, C.A. 2004. The soil management assessment framework: Aquantitative soil quality evaluation method. *Soil Science Society of America Journal*. 68:1945-1962.

Antonio, S. 1992. Proceedings of the Soil Quality Standards Symposium, 82nd Annual Meeting of the Soil Science Society of America October 2 1-27.

Appelo, C.A.J. and Postma , D. 1999. Variable dispersivity in a column experiment containing MnO_2 and FeOOH coated sand. *Journal of Contaminant Hydrology*. 40: 95 -106.

Appelo, C.A.J., Van der Weide, M.J.J., Tournassat, C. and Charlet, L. 2002. Surface complexation of ferrous iron and carbonate on ferrihydrite, and the mobilisation of arsenic. *Environmental Science Technology*. 36: 3096-3103.

Aris, A.Z., Ismail, T.T., Harun, R., Abdullah, A.M. and Ishak, M.Y. eds. 2013. From Sources to Solution: Proceedings of the International Conference on Environmental Forensics 2013. Springer Science and Business Media.

Aris, A.Z., Lim , W.Y., Praveena, S.M., Yusoff , M.K., Ramli, M.F. and Juahir, H. 2014. Water quality status of selected rivers in Kota Marudu, Sabah, Malaysia and its suitability for usage. *Sains Malaysiana* .43: 377-388.

Arshad, M.A. and Coen, G.M. 1992. Characterization of soil quality: physical and chemical criteria. Am. *J. Alternative Agriculture*. 7, 12–16.

Arshad, M.A., Lowery, B., and Grossman , B. 1996. Physical tests for monitoring soil quality. p.123- 142. In: J.W. Doran and A.J. Jones (eds.) Methods for assessing soil quality. Soil Sci. Soc. Am. Spec. Publ. 49. SSSA, Madison, WI.

Astrom, M. and Bjorklund, A. 1995. Impact of acid sulfate soils on stream water geochemistry in western Finland. *Journal of Geochemical Exploration*. 55, 163–170.

Aweng, Er., Karimah, M. and Suhaimi, O. 2011. Heavy Metals Concentration of Irrigation Water, Soils and Fruit Vegetables in Kota Bharu Area, Kelantan, Malaysia. *Journal of Applied Science* .6 (4): 463–70.

Ayers, R.S. and Westcot, D.W. 1985. Water Quality for Agriculture. FAO of the United Nations, Rome, Italy 97.

Azman, E.A., Jusop, S., Ishak, C.F. and Ismail, R. 2014. Increasing rice production using different lime sources on an acid sulphate soil in Merbok, Malaysia. *Pertanika Journal of Tropical Agricultural Science*. 37(2): 223-247.

Barnhisel, R. and Bertsch, P.M. 1982. Methods of soil analysis. Part 2. Chemical and microbiological properties. American Society of Agronomy Inc. and Soil Science Society of America, Inc. Madison, Wisconsin USA pp. 275-300.

Beare, M.H. and Bruce, R.R. 1993. A comparison of methods for measuring water-stableaggregates: Implications for determining environmental effects on soil structure. *Geoderma*. 56:87-104.

Bennett, H.H. and Chapline, W.R.. 1928. Soil Erosion: A National Menace. USDA Circular 33. Washington, DC: US Government Printing Office.

Benton, Jr. J. 2001. Laboratory Guide for Conducting Soil Tests and Plant Analysis. New York, USA:CRC Press LLC.Soil science: Methods & applications D. L. Rowell, Longman Scientific and Technical, Longman Group UK Ltd, Harlow, Essex, UK (co-published in the USA with John Wiley and Sons Inc. New York.

Bhagat, R.M., Bhuiyan, S.I. and Moody, K. 1996. Water, tillage and weed interactions in lowland tropical soils. *Agriculture and Water Management*. 31: 165-184.

Bharti N. and Katyal, D. 2011. Water Quality Indices Used for Surface Water Vulnerability Assessment. *International Journal of Environmental Sciences*. 2(1): 0976–4402.

Biswas, A.K. 1993. Water for Agricultural Development: Opportunities and Constraints. *International Journal of Water Resources Development*. 9 (1): 3–12.

Blake, G.R. and Hartge, K.H. 1986. Bulk Density, in A. Klute, ed., Methods of Soil Analysis, Part I. Physical and Mineralogical Methods. *Agronomy Monograph*. 9 (2nd ed.), pp. 363-375.

Bloomfield, C. and Coulter, J.K. 1973. Genesis and management of sulphate soils. *Advances in Agronomy*. 25: 265-326.

Boehm M.M. 1995. The Long-Term Effects of Farming Practices on Soil Quality, as Influenced by Farmer Attitude and Farm Characteristics. Ph.D. Thesis. The University of Saskatchewan, Canada. p.197.

Bonanomi, G., D'Ascoli, R., Antignani, V.and Zoina, A. 2011. Assessing soil quality under intensive cultivation and tree orchards in Southern Italy. *Applied Soil Ecology*. 47: 184-194.

Borba, B. M.D., Later, W., Rohrer, J.S., Pohl, A. and Peter, E. 2004. Determination of Common Inorganic Anions in Environmental Waters. Thermo Fisher Scientific, Sunnyvale, CA, USA.

Bouma, H.R. 2002. Ground-based GPS in climate research, Lic. Thesis, Tech. Rep. L. 456, School of Electrical and Computer Engineering, Chalmers University of Technology, Sweden.

Brady, N.C. 1990. Soil Colloids: Their Nature and Practical Significance. *Nature and Properties of Soils*, pp.177-212.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Science*. 59: 39-45.

Bray, R.H. and L.T. Kurtz. 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Science*. 59: 39-45.

Breemen, N. Van. 1993. Environmental Aspects of Acid Sulphate Soils. Selected Papers from the Ho Chi Minh City Symposium on Acid Sulphate Soils. 391–402.

Bremer, E. 2004. Review of Soil Quality Indices for Agricultural Ecosystems in Alberta. Alberta Environmentally Sustainable Agriculture Soil Quality Program, Alberta Agriculture, Food and Rural Development.

Brockett, B. 2009. Soil Quality Analysis - Chemistry Case Study Sustainability Street. *Soil*. 502.

Bucher, E. 2002. Soil Quality Characterization and Remediation in Relation to Soil Management. Doctor of Philosophy. Department of Crop and Soil Sciences. The Pennsylvania State University.

Burger, J.A. and Kelting, D.L. 1999. Using soil quality indicators to assess forest stand management. *Forest Ecology and Management*. 122, 155- 156.

Cai, Meijun. 2010. Long-Term Acid Deposition Effects on Soil and Water Chemistry in the Noland Divide Watershed , Great Smoky Mountains

National Park , USA." Doctoral Dissertations. University of Tennessee, Knoxville Trace: Tennessee Research and Creative Exchange.

Callinan, R.B., Fraser, G.C. and Virgona, J.L. 1992. Seasonally recurrent fish mortalities and ulcerative disease outbreaks associated with acid sulphate soils in Australian estuaries. Paper presented at the Fourth International Symposium on Acid Sulphate Soils, Ho Chi Minh City, Vietnam, March 2-6, The Working Group on Acid Sulphate Soils of the International Society of Soil Science.

Campbell, C.A. and Zentner, R.P. 1993. Soil organic matter as influenced by crop rotations and fertilization. *Soil Science Society of America Journal*. 57: 1034-1040.

Chapman, H.D. 1965. Determination of cation exchange capacity. In C.A. Black (Ed), Methods of soil analysis. *Agronomy Monograph.* 2(1), 891-900.

Chau Minh Khoi, Vo Thi Guong a, Pham Nguyen, Minh Trung, and Ingvar Nilsson, S. 2010. Effects of Compost and Lime Amendment on Soil Acidity and N Availability in Acid Sulfate Soil. *World*. 52–55.

Chigor, V.N., Umoh, V.J., Okuofu, C.A., Ameh, J.B., Igbinosa, E.O., Okoh, A.I. 2012 Water quality assessment: surface water sources used for drinking and irrigation in Zaria, Nigeria are a public health hazard. *Environmental Monitoring* and *Assessment*. 184:3389–3400

Clesceri, L.S. 1999. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, American Water Works Association, Water Environment Federation.

Collins, C. 2002. Water Quality Monitoring in Acid Sulfate Soil Areas. Test. Columbia Basin Trust. 1-4.

Cook, F.J., Hicks, W., Gardner, E.A., Carlin, G.D. and Froggatt, D.W. 2000. Export of acidity in drainage water from acid sulphate soils. *Marine Pollution Bulletin*. 4: 319-326.

Crosson, P. and Stout, A.T. 1983. Productivity effects of cropland erosion in the United States Resources for the future. Washington, D. C. 103pp.

Curtin, D. and Smillie, G.W. 1986. Effects of Liming on Soil Chemical Characteristics and Grass Growth in Laboratory and Long-Term Field-Amended Soils - II. Growth of Italian Ryegrass (Lolium Multiflorum) and Bentgrass (Agrostis Tenuis). *Plant and Soil* . 95 (1): 23–31.

D'Hose, T., Cougnon, M., Vliegher, A.D., Vandecasteele, B., Viaene, N., Cornelis, W., Bockstaele, E.V. and Reheul, D. 2014. The Positive Relationship between Soil Quality and Crop Production: A Case Study on the Effect of Farm Compost Application. *Applied Soil Ecology* .75:189–98.

DeBano, L.F. and Wood, M.K., 1992. Soil loss tolerance as related to rangeland productivity. ln: Proceedings of the Soil Quality Standards Symposium, San Antonio, Texas, October 23, 1990. USDA Forest Service Watershed and Air Management WO-WSA-2, pp.15-27.

De Lima, R. Ana Cláudia, H. Willem, and B. Lijbert. 2008. Soil Quality Assessment in Rice Production Systems: Establishing a Minimum Data Set. *Journal of Environment Quality*. 37 (2): 623.

Dederen, L.H.T., Leuven, R.S.E.W., Wendelaar, S.E. and Oyen, F.G.F. 1986. Biology of the acid-tolerant fish species Umbra pygmaea. *Journal of Fish Biology*. 28: 307-326.

Delgadillo. J.A. 2011. Environmental and social cues can be used in combination to develop sustainable breeding techniques for goat reproduction in the subtropics. *Animal*. 5:74–81

Dent, D.L. 1986. Acid Sulfate Soils: A Baseline for Research and Development. ILRI Publ. 39. International Institute for Land Reclamation and Improvement. Wageningen, The Netherlands.

Dent, D.L. and Mensvoort, V. 1993. Selected Papers of the Ho Chi Minh City Symposium on Acid Sulfate Soils. 95-101. Wageningen, the Netherlands.

Dent, D.L. and Pons, L.J. 1995. A world perspective on acid sulphate soils. *Geoderma*. 67: 3-4, 263–276.

Dent, D.L. and Van Mensvoort, M.E.F. 1993. Selected Papers of the Ho Chi Minh City Symposium on Acid Sulfate Soils. 95-101. International Institute for Land Reclamation and Improvement, P. O. Box 45, 6700 A. A, Wageningen, The Netherlands.

Dent, D.L. and Pons, L.J. 1995. A World Perspective on Acid Sulphate Soils. *Geoderma*, 67: 263–76.

Djia, H.D. 1973. Geomorphology. In Geology of the Malay Peninsula, ed. D.S. Gobbet and C.S. Hutchison. 13-14. John Wiley and Sons.

Dobermann, A. and Fairhurst, T.H., 2000. Nutrient disorders and nutrient management. Potash and Phosphate Institute, Potash and Phosphate Institute of Canada and International Rice Research Institute, Singapore.

DOE. 2008. National Water Quality Standards. Ministry of Natural Resources and Environment, Kuala Lumpur, Malaysia. p. 86.

Doran, J. W. and Jones, A. J. 1996. Methods for Assessing Soil Quality. SSSA Spec. *Soil Science Society of America*.

Doran, J.W., Safley, M., Pankhurst, C., Doube, B.M. and Gupta, V.V.S.R. 1997. Defining and assessing soil health and sustainable productivity. *Biological indicators of soil health.*, pp.1-28.

Doran, J.W. and Parkin, T.B. 1994. Defining and assessing soil quality.Defining soil quality for a sustainable environment, (definingsoilqua), pp. 1-21.

Doran, J.W. and Jones, A.J. 1992. Methods for assessing soil quality. *Soil Science Society of America*. Special Publication no. 49. Madison, WI.

Doran, John W., and Michael, R. Z. 2000. Soil Health and Sustainability: Managing the Biotic Component of Soil Quality. *Applied Soil Ecology*. 15 (1): 3–11.

Doran, R.L. 1980. Basic Measurement and Evaluation of Science Instruction. National Science Teachers Association, 1742 Connecticut Ave., NW, Washington, DC 20009 (Stock No. 471-14764; no price quoted).

Douglas, L. and Karlen. 2008. Soil Quality Assessment: Past, Present and Future. *Journal of Integrative Bioscience.* 6 : 3–14.

Dove, M.C. and Sammut, J. 2013. Acid Sulfate Soil Induced Acidification of Estuarine Areas Used for the Production of Sydney Rock Oysters, Saccostrea glomerata. *Journal of Water Resource and Protection*. 5: 320-335.

Duke, J.A. 1979. Ecosystematic data on economic plants. Quart. *Journal Crude Drug Research*. 17(3–4):91–110.

Edén, P., Kjell, W., and Sinikka, J. 1999. Natural and Land-Use Induced Load of Acidity, Metals, Humus and Suspended Matter in Lestijoki, a River in Western Finland. *Boreal Environment Research*. 4 (1): 31–43.

Edwards, P.J. and Wood, F. 1992. The effects of watershed acidification on soil water and stream water chemistry. In Proc. 1992 Spring Meeting of American Geophysical Union, Canadian Geophysical Union and Mineralogical Society of America (Vol. 12, p. 16).

Eldardiry, E. I., El-hady, M. A. and Zaghloul, A. M. 2013. Relationship between Soil Physical and Chemical Properties and Hydrophysical Soil Properties under Reuse of Agricultural Drainage Water. *American-Eurasian Journal Agriculture and Environmental Science*. 13(1): 1-6.

Elisa, A. A., Shamshuddin, J. and Fauziah, C.I. 2011. Root elongation, root surface area and organic acid exudation by rice seedling under Al^{3+} and/or H^{+} stress. *American Journal of Agricultural Biology Science*. 6: 324-331.

Elisa, A.A., Shamshuddin J., Fauziah, C.I. and Roslan I. 2014. Increasing Rice Production Using Different Lime Sources on an Acid Sulphate Soil in Merbok, Malaysia, *Pertanika Journal of Tropical Agricultural Science*. 37: 223–47.

Elizabeth, A. M., Jeffrey, S. B., Dennis, C. B., Timothy, K. H. and Denisona, R. F. 2004. Yield Increases during the Organic Transition: Improving Soil Quality or Increasing Experience? *Field Crops Research*, 86: 255–66.

El-Nahhal, I., Al-Najar, H. and El-Nahhal, Y. 2014. Cations and Anions in Sewage Sludge from Gaza Waste Water Treatment Plant. *American Journal of Analytical Chemistry*. 5: 655-665.

Elsacker, S.V. 2011. Effects of Land Use and Soil Management on Soil Quality in the Mekong Delta , Vietnam. Master's thesis. Universiteit Gent.

Enio, K.M.S., Shamshuddin, J., Fauziah, C.I. and Husni, M.H.A. 2011. Pyritization of the coastal sediments in the Kelantan plains in the Malay peninsula during the Holocene. Amerca *Journal of. Agriculture and Biology Sciences*. 6: 393–402.

Etteieb, S., Semia, C. and Jamila, T. 2015. Hydrochemical Assessment of Water Quality for Irrigation: A Case Study of the Medjerda River in Tunisia. *Applied Water Science.* 10.1007/s13201-015-0265-3

Evangelou, V.P. 1995 .Pyrite Oxidation and its Control. CRC Press, NewYork.

Fageria, N.K. and Baligar, V.C. 2008. Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production. *Advances in Agronomy*. 99:345-431.

Fageria, N.K., and Barbosa Filho, M.P. 2008. Influence of pH on Productivity, Nutrient Use Efficiency by Dry Bean, and Soil Phosphorus Availability in a No‐Tillage System. *Communications in Soil Science and Plant Analysis*. 39 (7-8): 1016–25.

Fältmarsch, R.M., Åström, E.M. and Kari, M.V. 2008. Environmental Risks of Metals Mobilised from Acid Sulphate Soils in Finland: A Literature Review. *Boreal Environment Research*. 13 (5): 444–56.

FAO. 1985. The ICS: The Interlinked Computerized Storage and Processing System of Food and Agricultural Commodity Data Users' Manual. FAO/ESS, Rome.

Farhana, J.A., Shamshuddin, J., Fauziah, C.I., Husni, .H.A. and Panhwar, Q.A. 2015. Effects of Aluminum, Iron And/or Low pH on Rice Seedlings Grown in Solution Culture. *International Journal of Agriculture and Biology*. 17 (4): 702–10.

Fernández-Ugalde, O., Virto I., Bescansa, P., Imaz M.J., Enrique, A., and Karlenb, D.L. 2009. No-tillage improvement of soil physical quality in calcareous, degradation-prone, semiarid soils. *Soil and Tillage Res*. 106: 29-35.

Fipps, G. 2003. Irrigation water quality standards and salinity management strategies. Texas FARMER Collection.

Flores-Delgadillo, L., Fedick, S.L., Solleiro-Rebolledo, E. S., Palacios, M., Ortega-Larrocea, P., Sedov, S. and Osuna-Ceja, E. 2011. A sustainable system of a traditional precision agriculture in a Maya homegarden: Soil quality aspects. *Soil and Tillage Research*. 113:112-120.

Friedman, D., Hubbs, M., Tugel, A., Seybold, C. and Sucik, M. 2001. Guidelines for soil quality assessment in conservation planning. *B.* Joubert. NRCS SQI (Eds). Washintong DC.

Gaskell, G., Allum, N., Bauer, M., Durant, J., Allansdottir, A., Bonfadelli, H., Boy, D., de Cheveigne, S., Fjaestad, B., Gutteling, J. M., Hampel, J., Jelsoe, E., Jesuino, J. C., Kohring, M., Kronberger, N., Midden, C., Nielsen, T. H., Przestalski, A., Rusanen, T., Sakellaris, G., Torgersen, H., Twardowski, T., and Wagner, W. 2000. Biotechnology and the European public. *Nature Biotechnology*, 18(9), 935-938.

Gazzaz, N. M., Mohd Kamil, Y.H., Mohammad, J. F. R. and Ariz, A.Z. 2011. Water Quality Assessment and Analysis of Spatial Patterns and Temporal Trends. *Water Environment Research*. 85(8):751-766.

Gee, G.W. and Bauder, J.W. 1986. Particle-size analysis. p. 383–411.InA. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. *Agronomy.Monograph*. 9. ASA and SSSA, Madison, WI.

Glamore, W. and Indraratna, B. 2001. The impact of floodgate modifications on water quality in acid sulphate soil terrains, Coasts and Ports. Canberra, Australia: *The Insitution of Engineers*. 265-270.

Golchin, A., Oades, J. M., Skjemstad, J.O. and Clarke, P. 1995. Structural and dynamic properties of soil organic matter as reflected by 13C natural abundance, pyrolis is mass spectrometry and solid state 13C NMR spectroscopy in density fractions of an oxisolunder forest and pasture. *Australian Journal of Soil Research*. 33: 59-76.

González, I., Emilio, G. and Antonio, R. 2011. Assessing Soil Quality in Areas Affected by Sulfide Mining. Application to Soils in the Iberian Pyrite Belt (SW Spain). *Minerals* .1 (1): 73–108.

Govaerts, B., Sayre, K. and Deckers, J. 2006. Minimum data set for soil quality assessment of wheat and maize cropping in the highlands of Mexico. *Soil Tillage Research*. 87: 163–174.

Green, R., Waite, T.D. and Melville, M.D. 2007. Treatment of acid sulfate soil drainage by direct application of alkaline reagents. *Water, Air, and Soil Pollution*. 178(1-4): 59-68.

Gregorich, E.G. and Carter, M.R. 1997. Soil quality for crop production and ecosystem health. New York, NY: Elsevier. pp. 21-58.

Gregorich, E.G. and Carter, M.R. 2002. Soil Quality for Crop Production and Ecosystem Health. Developments in Soil Science, vol. 25. Elsevier, New York. pp. 21-58.

Griffiths B.S., Ball, B.C., Daniell, T.J., Hallett, P.D., Neilson, R., Wheatley, R.E., Osler, G. and Bohanec, M. 2010. Integrating soil quality changes to arable agricultural systems following organic matter addition, or adoption of a ley-arable rotation. *Applied Soil Ecology*. 46: 43–53.

Grist DH (1975). Rice, 5th ed, Orient Longman, London and New York.

Grossman, R.B. and Reinsch, T.G. 2002. 2.1 Bulk density and linear extensibility. *Methods of Soil Analysis: Part 4 Physical Methods*, (methodsofsoilan4), pp.201-228.

Grutzmacher, G., Hindel, R., Kantor, W., and Wimmer, R. 2001. Chemical investigations of aquifers affected by pyrite oxidation in the Bitterfeld lignite district. *Waste Management*. 21, 127–137.

Gupta, G., Panwar, J., Akhtar, M.S. and Jha, P.N. 2012. Endophytic Nitrogen-Fixing Bacteria as Biofertilizer. (E. Lichtfouse, Ed.). *Sustainable Agriculture Reviews*, Springer Netherlands 11: 183-221.

Haefele, S.M., Nelson, A. and Hijmans, R. J. 2014. Soil Quality and Constraints in Global Rice Production. *Geoderma*. 235-236: 250–59.

Hagen, L.L. and Dyke T. 1980. Merging resources data from disparate sources. *Agricultural and Economic Resource*. 32: 45 – 49.

Halder, J.C. 2013. Land Suitability Assessment for Crop Cultivation by Using Remote Sensing and GIS. *Journal of Geography and Geology*. 5 (3): 65–74.

Hanhart, K, Duong, V.N., Bakker, N., Bil, N., Postma, L. and van Mensvoort, M.E.F. 1997. Surface water management under varying drainage conditions of rice on an acid sulfate soil in the Mekong Delta, Vietnam. *Agriculture and Water Management*. 33, 99–116.

Hariprasad, N.V. and Dayananda, H.S. 2013. Environmental Impact due to Agricultural Runoff Containing Heavy Metals – A Review. *International Journal of Scientific and Research Publications*. 3 (5): 1–6.

Haynes, R.J. and Naidu, R. 1998. Influence of Lime, Fertilizer and Manure Applications on Soil Organic Matter Content and Soil Physical Conditions: A Review. *Nutrient Cycling in Agroecosystems*. 51 (2): 123–37.

Hazelton, P. and Murphy, B. 2007. Interpreting soil test results; what do all the numbers mean? CSIRO, Collingwood.

Hedin, R.S. and Watzlaf, G.R., 1994. The effects of anoxic limestone drains on mine water chemistry. *USBM SP A*, *6*, pp.185-194.

Hedlund, A., Witter, E. and An, B.X. 2003. Assessment of N, P and K management by nutrient balances and flows on peri-urban smallholder farms in southern Vietnam. *European Journal of Agronomy*. 20: 71–87.

Hillel D.J. 1991. Out of the earth-civilization and the life of the soil. The Free Press, New York, NY.

Hopkins, B.G., Horneck, D.A., Stevens, R.G., Ellsworth, J.W. and Sullivan, D.M. 2007. Managing irrigation water quality for crop production in the Pacific Northwest. [Covallis, Or.]: Oregon State University Extension Service.

Hose, T., Cougnon, D., Vliegher, A.D., Vandecasteele, B., Viaene, N., Cornelis, W., Bockstaele, E.V. and Reheul, D. 2014. The positive relationship between soil quality and crop production:A case study on the effect of farm compost application. *Applied Soil Ecology*. 75: 189– 198.

Indraratna, B., Blundern, B. and Nethery, A. 1999. Nature and Properties of Acid Sulphate Soils in Drained Coastal Lowlands in New South Wales. *Australian Geomechanics*. 34 (1): 61–78.

International, Tenth, and Water Technology. 2006. Tenth International Water Technology Conference, IWTC10, Alexandria, Egypt 845, 845–63.

Isaac, R.K., Khura, T.K. and Wurmbrand, J.R. 2009. Surface and subsurface water quality appraisal for irrigation. *Environmental Monitoring and Assessment*. 159: 465-473.

Jacobson, L.D., Moon, R., Bicudo, J., Janni, K., Zhu, J., Schmidt, D., Goodrich, P., Nicolai, R., Clanton, C., Davis, K. and Brosseau, L., 1999. Generic Environmental impact statement on animal agriculture. A summary of the literature related to air quality and odour (H), Department of Animal Science. Minnesota, USA: University of Minnesota, Minnesota, p.177.

Janssen, J.A.M., Andriesse, W., Hendro P. and Bregt, A.K. 1992. Guidelines for soil surveys in acid sulphate soils in the humid tropics; the main problems considered. AARDiLAWOO Research Program on Acid Sulphate Soils in the Humid Tropics. AARD, Bogor. (In preparation).

Johnson, D.L., Ambros, S.H., Bassett, T.J., Bowen, M.L., Crummey, D.E., Isaacson, J.S., Johnson, D.N., Lamb, P., Saul, M. and Winter-Nelson, A.E. 1997. Meaning of environmental terms. *Journal of Environment Quality*. 26 (3) pp. 581-589.

Johnston, S. G., Slavich, P.G. and Hirst, P. 2005. The impact of controlled tidal exchange on drainage water quality in acid sulphate soil backswamps. *Agricultural Water Management*. 73(2): 87-111.

Jurjovec, J., Ptacek, C.J. and Blowes, D.W. 2002. Acid neutralization mechanisms and metal release in mine tailings: A laboratory column experiment. *Geochimica et Cosmochimica Acta*. 66, 1511–1523.

Kalay, M. and Canli, M. 2000. Elimination of essential (Cu, Zn) and nonessential (Cd, Pb) metals from tissue of a freshwater fishTilapia zilli. *Turkish Journal of Zoology*. 24, 429–436.

Kang, B.T.and Balasubramanian, V. 1990. Long term fertilizer Trial on Alfisols in Wester Africa. In Transactions of XIV International Soil Science Society (ISSSS) Congress, Kyoto, Japan. P. 350.

Kang, G.S., Beri, V., Sidhu, B.S. and Rupela, O.P. 2005. A New Index to Assess Soil Quality and Sustainability of Wheat-Based Cropping Systems. *Biology and Fertility of Soils*. 41 (6): 389–98.

Karlen, D.L., Andrews, S.S., Brian, J.W. and Zobeck, T.M. 2008. Soil Quality Assessment: Past, Present and Future. *Journal of Integrity and Bioscience.* 6 (1): 3–14.

Kennedy, A.C. and Papendick. R.T. 1995. Microbial characteristics of soil quality. *Journal of Soil and Water Conservation*. 50:243-248.

Kilminster, K., Norto, S. and Miller, F. 2011. Assessing the Influence of Acid Sulfate Soils on Water Quality in South-Western Australian Catchments and Estuaries. Perth, W.A.: Dept. of Water.

Kilminster, K.L. and Cartwright, I. 2011. A sulfur stable isotope based screening tool for assessing impact of acid sulfate soils on waterways. *Marine and Freshwater Research*, 62: 152-161.

Kim, A.G. and Cardone, C.R. 2005. Scatterscore: A Reconnaissance Method to Evaluate Changes in Water Quality. *Environmental Monitoring and Assessment*. 111 (1-3): 277–95.

Kinyangi, J., 2007. Soil health and soil quality: a review. Available on http://www. cornell. edu. org.

Klute. 1986. Methods of soil analysis. Part 1. 2nd ed. American Society of Agronomy-*Soil Science Society of America*. 9.

Knight, C.J.K., Lalor, G.C., Robotham, H. and Witter, J.V. 1997. Heavy Metals in Surface Water and Stream Sediments in Jamaica, *Environmental Geochemistry and Health.* 19(2) 63–66.

Kobayashi, T. 1939. Reclamation of barren polder soil in Tbaragi Prefecture Special Rept. Ibaragi Agric.Exp.Sta. 3 (in Jap.)

Konsten, C.J.M., van Breemen, N., Suping, S., Aribawa, I.B., Groenenberg, J.E. 1994. Effects of flooding on pH of riceproducing, acid sulfate soils in Indonesia. *Soil Science Society of America Journal.* 58, 871 – 883.

Kroon, F.J. 2005. Behavioural Avoidance of Acidified Water by Juveniles of Four Commercial Fish and Prawn Species with Migratory Life Stages. *Marine Ecology Progress Series* 285. (Dawson 2002) 193–204.

Kyuma, K. 2004. Paddy Soil Science, Kyoto University Press. P.226

Lal, R. 2004. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science*. 304(5677): 1623-1627.

Larson, W.E. and Pierce, F.J. 1991. Conservation and enhancement of soil quality. In Evaluation for sustainable land management in the developing world: proceedings of the International Workshop on Evaluation for Sustainable Land Management in the Developing World, Chiang Rai, Thailand, 15-21 September 1991. [Bangkok, Thailand: International Board for Soil Research and Management, 1991].

Lee, J.H., Kim, M.H. and Lee, Y.J. 1993, Information Retrieval Based on Conceptual Distance in IS-A Hierarchies. *Journal of Documentation*. 49(2): 188-207.

Leskey, R. Blaine, M.C.C. and James, W.B. 2010. Challenges in the Analysis and Interpretation of Acidic Waters". Mine Water and Innovative Thinking 379–82Letey, J, R E Sojka, D R Upchurch, D K Cassel, K R Olson, W a Payne, S E Petrie, et al. 2003. Deficiencies in the Soil Quality Concept and Its Application. *Journal of Soil and Water Conservation.* 58 (4): 180–87.

Lewandowski, A., and Zumwinkle, M. 1999. Assessing the Soil System - a Review of Soil Quality Literature. Energy and Sustainable Agriculture Program.

Lim, W.Y., and Aris. A.Z. 2013. Irrigation water quality assessment of a trans-state river basin in western part of malaysia by integration of hydrochemical and chemometric analysis. *Fresenius Environmental Bulletin*. 22(1 A): 267-278.

Lima, A. C. R., Brussaard, W. B., Hoogmoed, L. and Anjos, F.S. 2011. Farmers' assessment of soil quality in rice production systems. Njas-Wageningen *Journal of Life Sciences*. 58(1-2): 31-38.

Liu, Z.J.,W. Zhou, J.B. Shen, Li, S.T., Liang, G.Q., Wang, X. B., Sun, J.W. 2014. Soil Quality Assessment of Acid Sulfate Paddy Soils with Different Productivities in Guangdong Province, China. *Journal of Integrative Agriculture*. 13(1): 177-186.

Lombin, C.G., Adepetu, J.A. and Ayotade, K.A. 1991. Complementary use of organic manure and inorganic fertilizers in arable crop production. Proceedings of a national organic fertilizer seminar, Kaduna Nigeria. pp. 146-162.

Lowdermilk, W.C. 1999. Conquest of the land through 7,000 years. US Department of Agriculture, Natural Resources Conservation Service.

Lowery, B., Arshad, M.A., Lal, R. and Hickey, W.J. 1996. Soil water parameters and soil quality. p.143-157. In: J.W. Doran and A.J. Jones (eds.) Methods for assessing soil quality. Soil Sci. Soc. Am. Spec. Publ. 49. SSSA, Madison, WI.

Madison A.S.A., Golchin, W.I., Oades, A.J.M., Skjemstad, J.O. and Clarke, P. 1995. Structural and dynamic properties of soil organic matter as reflected by 13C natural abundance, pyrolis is mass spectrometry and solid state 13C NMR spectroscopy in density fractions of an oxisolunder forest and pasture. *Australian Journal of Soil Research*. 33: 59-76

Magdoff, F. 1993. Building soils for better crops: organic matter management. *Soil Science*, 156(5), p.371.

Maral, N. 2010. Soil and water analysis techniques for agricultural production (Doctoral dissertation, MSc. Thesis, Graduate School of Sciences, Department of Chemistry, Middle East Technical University, Turkey).

Mark A.W. 2013. Investigating Soil Property And Quality Changes From Samples. Master Thesis. The School Of Human Resource Education and Workforce Development. Louisiana State University.

Martini, E.A., Jeffrey S. Buyer, Dennis C. Bryant, Timothy K. Hartz, and R. Ford Denison. 2004. Yield Increases during the Organic Transition: Improving Soil Quality or Increasing Experience? *Field Crops Research*. 86 (2-3): 255–266.

Masciandaro, G. and Ceccanti, B. 1999. Assessing soil quality in different agro-ecosystems through biochemical and chemical structural properties of humic substances. *Soil Tillage Research*. 51:129–137.

Matsuno, Y. 1999. Case study in Sri Lanka: irrigation and drainage water quality and impacts of human activities on the aquatic environment in a southeastern part of Sri Lanka (No. H024793). International Water Management Institute.

McBroom, M., Thomas, T. and Zhang, Y., 2012. Soil erosion and surface water quality impacts of natural gas development in East Texas, USA. *Water*, 4(4), pp.944-958.

McKenzie, D., Gedalof, Z.M., Peterson, D.L. and Mote, P. 2004. Climatic change, wildfire, and conservation. *Conservation Biology*. 18:890-902.

Merhaut, D.J. 2003. Runoff Water Quality in California - Laws, Regulations, and Their Implementation. *Acta Horticulturae* 627: 43–47.

Miguel, A.A. and C.I. Nicholls. 2012. Sustainable Agriculture Reviews, Sustainable Agriculture Reviews.

Mikhail V. Kozlov, Elena L. Zvereva, Vitali E. Zverev. 2009. Impacts of Point Polluters on Terrestrial Biota, Springer Netherlands. Section of Ecology, Department of Biology, University of Turku, Finland.

Mikhail, V.K., Elena, L.Z. and Vitali, E.Z. 2009. Methodology of Pollution Ecology: *Problems and Perspectives*. Springer Netherlands. 15: 323-337.

Miller, G.H., Alley, R.B., Brigham-Grette, J., Fitzpatrick, J.J., Polyak, L., Serreze, M. and White, J.W.C.. 2010. Arctic Amplification: can the past constrain the future? *Quaternary Science Reviews*. 29, 1779-1790.

Mitsios, I.K., Golia, E.E. and Tsadilas, C.D. 2005. Heavy Metal Concentrations in Soils and Irrigation Waters. *Communications in soil science and plant analysis*. 36: 487-501.

Moebius-Clune, B.N., 2010. Applications of integrative soil quality assessment in research, extension, and education (Doctoral dissertation, Cornell University).

Mohamed, A.I. 2013. Irrigation Water Quality Evaluation in El-Salam Canal Project. *International Journal of Engineering and Applied Sciences*. 3 (1): 21–28.

Mokhtar, M.B., Aris, A.Z., Abdullah, M.H., Yusoff, M.K., Abdullah, M.P., Idris, A.R. and Raja Uzir, R.I. 2009. A pristine environment and water quality in perspective: Maliau Basin, Borneo's mysterious world. *Water and Environment Journal*. 23(3): 219-228.

Moomaw, J.C. and Vergara, B.S., 1965. The environment of tropical rice production. In Proceedings of a symposium on the mineral nutrition of the rice plant (pp. 3-13).

Moore, G., Dolling, P., Porter, B. and Leonard, L. 1998. Soil Acidity. In Soilguide. A handbook for understanding and managing agricultural soils. (Ed. G Moore) Agriculture Western Australia Bulletin No. 4343.

Moore, P. A. and Patrick, W. H. 1991. Aluminum, boron and molybdenum availability and uptake by rice in acid sulphate soils. *Plant and Soil*. 136, 171–181.

Moore, P. A., Attanandana, T. and Patrick, W. H. 1990. Factors Affecting Rice Growth on Acid Sulfate Soils. *Soil Science Society of America Journal*. 54 (6): 1651.

Moore, P.A., Patrick, W.H. 1989. Iron availability and uptake by rice in acid sulfate soils. *Soil Science Society of America Journal*. 53, 471 – 476.

Moore Jr, P.A. and Patrick Jr, W.H., 1993. Metal availability and uptake by rice in acid sulphate soils. Publication. International Inst. for Land Reclamation and Improvement (Netherlands).

Moormann, F.R. and Van Breemen, N. 1978. Rice: Soil, Water, Land. International Rice Research Institute Los Baños, Laguna, Philippines

Mosley, L.M., Zammit, B., Jolley, A.M., Barnett, L. and Fitzpatrick, R. 2014. Monitoring and assessment of surface water acidification following rewetting of oxidised acid sulfate soils. *Environmental Monitoring and Assessment*. 186(1): 1-18.

Muhrizal, S. 2001. Characterization and Amelioration of Selected Acid Sulfate Soils in Malaysia (Doctoral dissertation, Universiti Putra Malaysia).

Muhrizal, S., Shamshuddin, J., Fauziah, C.I. and Husni, M.H.A. 2006. Changes in iron-poor acid sulfate soil upon submergence. *Geoderma*. 131:110-122.

Mustapha, A., Aris, A.Z, Hafizan, J. and Mohammad, F.R. 2013. Surface Water Quality Contamination Source Apportionment and Physicochemical

Characterization at the Upper Section of the Jakara Basin, Nigeria. *Arabian Journal of Geosciences*. 6 (12): 4903–4915.

Mwegoha, W.J.S. and Kihampa, C. 2010. Heavy Metal Contamination in Agricultural Soils and Water in Dar Es Salaam City , Tanzania. *African Journal of Environmental Science and Technology*. 4 (11): 763–69.

Nakagawa, T., Satoshi, M. and Etsuro, Y. 2003. Amelioration of Aluminum Toxicity by Pretreatment with Phosphate in Aluminum ‐ Tolerant Rice Cultivar. *Journal of Plant Nutrition.* 26 (3): 619–28.

Nakasone, H. 1996. Runoff water quality characteristics in a small agriculture watershed. Paddy and Water Environment. *Journal of Japan Society on Water Environment.* 19(1): 56-62.

National Guidance for the Management of Acid Sulfate Soils in Inland Aquatic Ecosystems — Environment Protection and Heritage Council and Natural Resource Management Ministerial Council. 2011. https://www.environment.gov.au/water/information/acid-sulfate-soils/about-acid-sulfate-soils

National Research Council. 1993. Soil and water quality: an agenda for agriculture. Washington, DC: National Academy Press.

Nelson, D.W. and Sommers, L.E. 1996. Total carbon, organic carbon, and organic matter. In: Methods of Soil Analysis, Part 2, 2nd ed., A.L. Page et al., Ed. *Agronomy*. 9:961-1010.

Nguyen, T.T. and Wilander, A. 1995. Chemical conditions in acidic waters in the plain of reeds, Vietnam. *Water Resources.* 29, 1401–1408.

Nhung, M.M. and Ponnamperuma, F.N. 1966. Effects of calcium carbonate, manganese dioxide, ferric hydroxide, and prolonged flooding on chemi- cal and electrochemical changes and the growth of rice in flooded acid soil. *Soil Science.* 102: 29-41.

Nolan, B.T., Dubus, I.G., Surdyk, N., Fowler, H.J., Burton, A., Hollis, J.M., Reichenberger, S. and Jarvis, N.J. 2008. Identification of key climatic factors regulating the transport of pesticides in leaching and to tile drains. *Pest Management Science.* 64(9): 933-944.

Nyberg, M.E., Österholm, P. and Nystrand, M.I. 2012. Impact of acid sulfate soils on the geochemistry of rivers in south-western Finland. *Environmental Earth Sciences*. 66(1): 157-168.

Oades, J. M. 1989. An introduction to organic matter in mineral soils. Minerals in Soil Environments, (mineralsinsoile) pp.89–159.

Ooi, J.B. 1964. Land, People and Economy of Malaya. London: Longmans. Green.

Osman, and Alaa, G.M. 2010. Water Quality and Heavy Metal Monitoring in Water, Sediments, and Tissues of the African Catfish Clarias Gariepinus (Burchell, 1822) from the River Nile, Egypt. *Journal of Environmental Protection.* 01 (04): 389–400.

Österholm P. and Åström, M. 2004. Quantification of current and future leaching of sulfur and metals from Boreal acid sulfate soils, western Finland. *Australian Journal of Soil Research*. 42: 547–551.

Palhares, M. 2000. Recommendation for fertilizer application for soils via qualitative reasoning. *Journal of Agricultural Systems*. 67: 21-30.

Panhwar, Q., Umme Naher, O., Othman, R., Shamshuddin, J. and Ismail, R. 2015. Eliminating Aluminum Toxicity in an Acid Sulfate Soil for Rice Cultivation Using Plant Growth Promoting Bacteria. *Molecules*. 20 (3): 3628–46.

Panhwar, Q.A., Shamshuddin, J., Naher, U.A., Radziah, O. and Mohd Razi, I. 2014. Biochemical and molecular characterization of potential phosphate-solubilizing bacteria in acid sulfate soils and their beneficial effects on rice growth. *PLoS One*. 9(10): e97241.

Pankhurst, C., Doube, B.M. and Gupta, V.V.S.R.. 1997. Biological indicators of soil health. Wallingford, UK: CAB International. p. 1–28.

Park, C.N. and Nerida, S. 2012. Inland acid sulfate soil and water quality fact sheet. Department of Sustainability, Environment, Water, Population and Communities. Fact Sheet.

Park, Y.D. and Kim, Y.S. 1970. The effect of wollatonite and manganese dioxide on rice grown on a flooded acid sulphate soil. *Journal of Korean Society of Soil Science and fertilizer*. 3(1), 23-28.

Parr, J.F., Papendick, R.I., Hornick, S.B., and Meyer, R.E. 1992. Soil quality: Attributes and relationship to alternative and sustainable agriculture. *America Journal of Alternative Agriculture*. 7:5-11.

Partnership, B.P. 2012. Nutrient Concentrations in Surface Water and Groundwater, and Nitrate Source Identification Using Stable Isotope Analysis, in the Barnegat Bay-Little Egg Harbor Watershed, New Jersey. *Scientific investigation Report*. 2012-5287.

Patrick, M.S. 2013. Biological Assessment of the Effects Of Toxic Metals On Plant, *International Journal of Environment*. 3(1): 56–67.

Peli Mat and C.B.S. Suswanto, T.T., Shamshuddin, J.and Syed Omar, S.R. 2007. Effects of Lime and Fertiliser Application in Combination with Water Management on Rice (Oryza Sativa) Cultivated on an Acid Sulfate Soil. *Malaysian Journal of Soil Science*. 11, 1–16.

Pfaff, J.D. 1993. Determination of inorganic anions by ion chromatography. *EPA method*, *300*.

Phillips, D.J. and Rainbow, P.S. 2013. *Biomonitoring of trace aquatic contaminants* (Vol. 37). Springer Science and Business Media.

Phong, N.D., Hoanh, C.T., Tuong, T.P., Malano, H. and Weaver, T., 2007, December. Modelling acidity propagation in a coastal zone with acid sulphate soils. In *MODSIM 2007, International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand* (pp. 74-80).

Pierce, F. J., Larson, W. E., Dondy, R. H. and Graham, W. A. P. 1983. Productivity of soils: assessing long-term changes due to erosion. *Journal of Soil Water Conservation*. 38: 39 – 44.

Pierce, F.J. and Larson, W.E. 1993. Developing criteria to evaluate sustainable land management. p. 7-14. In: J. M. Kimble (ed), Proceedings of the Eighth International Soil Management Workshop: Utilization of Soil survey Information for Sustainable Land Use, May 3, 1993. USDA Soil Conservation Service, National Soil Survey Center, Lincoln, NE.

Pineros, M.A. and Kochian, L.V. 2009. Overview of the structure-function relations underlying functionality of ALMT and MATE-type transporters involved in the organic acid release Al tolerance response. In: Plant-Soil Interactions at low pH: A nutriomic approach; Proc. of the 7th Int. Symposium on Plant-soil Interactions at Low pH, pp: 55-56. Liao, H., X. Yan, L.V. Kochian, (eds.). Guangzhou, China.

Ponnamperuma, F.N., Attanandana, T. and Beye, G., 1973. Amelioration of three acid sulphate soils for lowland rice. In Acid sulphate soils. Proceedings of the International Symposium, Wageningen, *ILRI Publ*. 18, pp. 391-406.

Powell, B. and Martens, M. 2005. A Review of Acid Sulfate Soil Impacts, Actions and Policies That Impact on Water Quality in Great Barrier Reef Catchments, Including a Case Study on Remediation at East Trinity. *Marine Pollution Bulletin*. 51 (1-4): 149–164.

Power, J. F, Doran, J. W. and Wilhelm, W.W. 1986. Uptake of nitrogen from soil, fertilizer, and crop residue by no-till corn and soybean. *Soil Science Society of America Journal*. 50, 137–142.

Praveena, S.M., Radojevic, M., Abdullah, M.H. and Aris, A.Z. 2008. Application of sediment quality guidelines in the assessment of mangrove surface sediment in Mengkabong lagoon, Sabah, Malaysia. *Journal of Environmental Health Science and Engineering*. *5*(1), pp.35-42.

Praveena. S.M., Ahmed, A., Radojevie, M., Abdullah, M.H. and Aris, M.H. 2008. Heavy Metals in Mangrove Surface Sediment of Mengkabong Lagoon , Sabah : *Multivariate and Geo-Accumulation Index Approaches*. 2 (2): 139–48.

Proffitt, T. 2014. Assessing soil quality and interpreting soil test results. www.winewa.asn.au

Putnam, J., Dyke, P. and Wistrand, G., 1985. Erosion-productivity index simulator (EPIS). Economic Research Service, US Department of Agriculture, Washington, DC Monitoring Soil Erosion's Impact on Crop Productivity, 263.

Qi Zhang. 2009. Assessment of Surface Water Quality Using Multivariate Statistical Techniques in Red Soil Hilly Region: A Case Study in Xiangjiang Watershed, China. *Environ Monit Assess*. 152:123.

Qi, H., Yao, C., Cai, W., Girton, J., Johansen, K.M., and Johansen, J. 2009. Asator, a tau-tubulin kinase homolog in Drosophila localizes to the mitotic spindle. *Developmental Dynamics*. 238(12): 3248--3256.

Rahman, M.A., Meisner, C.A., Duxbury, J.M., Lauren, J. and Hossain, A.B.S., 2002, August. Yield response and change in soil nutrient availability by application of lime, fertilizer and micronutrients in an acidic soil in a rice-wheat cropping system. In *17th World Congress on Soil Science (WCSS)* (pp. 14-21).

Rajashekhara Rao, B.K., and Siddaramappa, R. 2008. Evaluation of Soil Quality Parameters in a Tropical Paddy Soil Amended with Rice Residues and Tree Litters. *European Journal of Soil Biology*. 44 (3): 334–40.

Rastija, D., Zebec, V. and Rastija, M., 2014. Impacts of liming with dolomite on soil reaction and availabilities of phosphorus and potassium. *Növénytermelés*. *63*, pp.193-196.

Rathore, D.P.S. 2013. Interpretation and Evaluation of the Variations in Uranium, Major Cations and Anions Content of Hydrogeochemical Samples With Reference To the Time Interval Between Sampling and Analysis. *Exploration and Research for Atomic Minerals*. 23: 207–15.

Rattanapichai, W., Kren, J., Duangpatra, P., and Kanghae, P. 2013. Effects of Soil Conditioner On Growth And Yield Of Rice Grown Under Acid Sulfate Soil Department of Agrosystems and Bioclimatorogy. Faculty of Agronom. *Mendel*, 147–51.

Rayment, G.E. and Higginson, F.R. 1992. Australian laboratory handbook of soil and water chemical methods. Inkata Press Pty Ltd.

Rengasamy, P. and Churchman, G.J. 1999. Cation exchange capacity, exchangeable cations and sodicity. *Soil analysis: an interpretation manual*, pp.147-157.

Rhoades, J.D., Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T. and Sumner, M.E. 1996. Salinity: Electrical conductivity and total dissolved solids. *Methods of soil analysis. Part 3-chemical methods.* pp.417-435.

Rhoton, F.E., Lindbo, D.L. 1997. A soil depth approach to soil quality assessment. *Journal of Soil and Water Conservation*. 52, 66-72.

Ridolfi, L., D'Odorico, P., Porporato, A. and Rodriguez-Iturbe, I. 2000. Impact of climatevariability on the vegetation water stress. *Journal Geophysics Research*. 105 (14): 18013–18025.

Rosa, D.D. and Ramon, S. 2008. Soil Quality and Methods for Its Assessment. *Soil Science*. 167–200.

Rosilawati, A.K., Shamshuddin, J. and Fauziah, C.I. 2014. Effects of Incubating an Acid Sulfate Soil Treated with Various Liming Materials under Submerged and Moist Conditions on pH, Al and Fe. *African Journal of Agricultural Research.* 9 (1): 94–112.

Rout, G.R., Samantaray, S. and Das, P. 2001. Aluminium Toxicity in Plants: A Review. *Agronomie.* 21 (1): 3–21.

Rowell, D.L. 1994. Soil Science: Methods and Applications; Longman: Harlow, UK.

Rutger J N, Charnahan H L. 1981. A fourth genetic element to facilitate hybrid cereal production—recessive tall in rice. *Crop Science*, 21: 373-376.

Sadiq, A.A. And Babagana, U. 2012. Influence of Lime Materials o Ameliorate Acidity on Irrigated Paddy Fields: A Review. *Academic Research International*. *3*(1), P.413.

Sahrawat, K.L. 2005. Managing iron toxicity in lowland rice: the role of tolerant genotypes and plant nutrients. Rice is life: scientific perspectives for the 21st century, IRRI, Los Banos, pp.452-454.

Sahrawat, K.L. 2005. Iron Toxicity in Wetland Rice and the Role of Other Nutrients. *Journal of Plant Nutrition*. 27 (8): 1471–1504.

Sammut, J. and Melvile, M.D. 1995. Impacts of poor water quality on fish.Geomorphology and River Health in New South Wales (Eds GJ Brierly and F. Nagel). Macquarie University Working Paper, (5).

Sammut, J., I. White, and Melville, M.D. 1996. Acidification of an estuarine tributary in eastern Australia due to drainage of acid sulfate soils. *Marine and Freshwater Research.* 47: 669-684.

Sammut, J., Melville, M.D., Callinan, R.B. and Fraser, G.C. 1995. Estuarine acidification: Impacts on aquatic biota of draining acid sulfate soils. *Australian Geographical Studies.* 33, 89–100.

Sanchez, P.A. 1977. Properties and management of soils in the tropics. *Soil Science*. 124(3), p.187.

Sarwani, M. 2001. Characterization and Amelioration of Selected Acid Sulfate Soils. Ph.D. Thesis. Universiti Putra Malaysia.

Sarwani, M. 2001. Characterization and Amelioration of Selected Acid Sulfate Soils in Malaysia. Ph.D. Thesis. Universiti Putra Malaysia.

Satawathanant, S. 1986. Redox, pH and Ion Chemistry of Acid Sulfate Rice Soils in Thailand. Ph.D. Dissertation. Lousiana State University, Baton Rouge, USA.

Schoenholtz, S.H, Van Miegroet, H. and Burger, J.A. 2000. A Review of Chemical and Physical Properties as Indicators of Forest Soil Quality: Challenges and Opportunities. *Forest Ecology and Management*. 138 (1-3): 335–56.

Scotti, R. 2010. Effects of Sustanaible Soil Management on Soil Quality. Ph.D. Dissertation. University of Naples Federico II Faculty of Agriculture.

Serban, A.S. 2011. surface water pollution with heavy metals in the lower catchment of jiu river basin, according to the water framework directive (2000/60/EC).Aerul si Apa. *Componente ale Mediului*, p.357.

Shaff, J.E., Schultz, B.A., Craft, E.J., Clark, R.T. and Kochian, L.V. 2010. Geochem-Ez: A chemical speciation program with greater power and flexibility. *Plant and Soil*. 330(1): 207-214.

Shamshuddin, J. 2006. Acid Sulfate Soils in Malaysia. Serdang: UPM Press.

Shamshuddin, J. and Auxtero, E.A. 1991. Soil solution composition and mineralogy of some active acid sulfate soil as affected by laboratory incubation with lime. *Soil Science.* 152: 365-376.

Shamshuddin, J., and Anda, M. 2012. Enhancing the productivity of Ultisols and Oxisols in Malaysia using basalt and/or compost. *Pedologist*. 55(3): 382-391

Shamshuddin, J., and Edgardoa, A. 1991. Laboratory Studies on the Release of Cations and Anions in Acid Sulfate Soils. *Pertanika* 14(3), 257-264

Shamshuddin, J., Elisa, A.A., Ali, M., Siti, R. and Fauziah, C.I. 2013. Rice defense mechanisms against the presence of excess amount of Al^{+3} and Fe^{+2} in the water. *Australian Journal of Crop Science*. 7(3): 314-320.

Shamshuddin, J., Elisa, A.A., Shazana, M. A. R. S., Fauziah, C. I., Panhwar, Q.A. and Naher, U.A. 2014. Properties and management of acid sulfate soils in Southeast Asia for sustainable cultivation of rice, oil palm, and cocoa. *Advances in Agronomy*. 124: 91-142.

Shamshuddin, J., Fauziah, C. I., Anda, M., Kapok, J. and Shazana, M. A. R S. 2011. Using Ground Basalt And/or Organic Fertilizer to Enhance Productivity of Acid Soils in Malaysia for Crop Production. *Malaysian Journal of Soil Science*. 15 (1): 127–46.

Shamshuddin, J., Fauziah, C.I. and Sharifuddin, H.A. H. 1991. Effects of limestone and gypsum application to a Malaysian Ultisol on soil solution composition and yields of maize and groundnut. *Plant and Soil*. 134: 45-52.

Shamshuddin, J., Fauziah, C.I., Sharifuddin, H.A.H. 1991. Effects of limestone and gypsum application to a Malaysian Ultisol on soil solution composition and yields of maize and groundnut. *Plant Soil*.134: 45-52.

Shamshuddin, J., Jamilah, I. and Ogunwale, J.A. 1995. Formation of hydroxy-sulfate from pyrite in coastal acid sulfate soil environments in Malaysia. C*ommunications* in *Soil Science and Plant Analysis*, 26:2769 –2782.

Shamshuddin, J., Elisa, A.A., Shazana, M. A. R.S. and Fauziah, I.C. 2013. Rice Defense Mechanisms against the Presence of Excess Amount of Al and Fe in the Water. *Australian Journal Of Crop Science*. 7, 314–20.

Shamshuddin, J., Azura, A.E., Shazana, M.A.R.S., Fauziah, C.I., Panhwar, Q.A. and Naher, U.A. 2014. Properties and management of acid sulfate soils in Southeast Asia for sustainable cultivation of rice, oil palm and cocoa. *Advances in Agronomy*. *124*, pp.91-142.

Sharma, K.L., Venkateswarlu, B. and Mandal, B. 2012. Soil Quality and Productivity Improvement Under Rainfed Conditions-Indian Perspectives. INTECH Open Access Publisher.

Shazana, M.R.S., Shamshuddin, J., Fauziah, C.I. and Syed Omar, S.R. 2013. Alleviating the Infertility of an Acid Sulphate Soil by Using Ground Basalt with or without Lime and Organic Fertilizer under Submerged Conditions. *Land Degradation and Development*. 24 (2): 129–40.

Sikora, L.J. and Stott, D.E. 1996. Soil organic carbon and nitrogen. In: DOI-an, J.W., Joncs. A.J. (&is.). Methods for Assessing Soil Quality. Special Publication No. 49. *Soil Science Society of America*. Madison, WI, pp. 157 167.

Singh, P.A., Tiwari, K. and Singh, P.K. 2014. Hydro chemical characteristic and Quality Assessment of Groundwater of Ranchi Township Area, Jharkhand, India. *Current World Environment*; 9(3), p. 804.

Singh, A.K., Beenu Raj, A., Tiwari, K. and Mahato, M.K. 2013. Evaluation of Hydrogeochemical Processes and Groundwater Quality in the Jhansi District of Bundelkhand Region, India. *Environmental Earth Sciences.* 70 (3): 1225–47.

Slattery, W.J., Conyers, M.K. and Aitken, R.L., 1999. Soil pH, aluminium, manganese and lime requirement. Soil analysis: an interpretation manual, pp.103-125.

Smith, J.L. and Doran, J.W. 1996. Measurement and use of pH and electrical conductivity for soil quality analysis. In Methods for assessing soil quality. *Soil Science Society of America Special Publication* 49: 169-182.

Smyth, A.J. and Dumanski, J., 1993. FESLM: An international framework for evaluating sustainable land management (p. 76). Rome,, Italy: FAO.

Sohleniusg, and Oborni. 2004. Geochemistryand partitioning of trace metals in acid sulphate soils in Sweden and Finland before and after sulphide oxidation. *Geoderma*. 122: 167–175.

Sojka , E., Upchurch, R. and N. E. 2003. Quality Soil Management Or Soil quality Management: Performance Versus Semanticsr". Borlaug" Northwest Irrigation And Soils Research Laboratory, Usda, Agricultural Research service, Kimberly, Idaho, Usa2003. *Quality Management*. 79: 1–68.

Staff, Soil Survey. 2007. "Site Contamination — Acid Sulfate Soil Materials". EPA 638/07

Steer, A. 1998. Making development sustainable. *Advances in Geo Ecology*. 31: 857–865.

Stone Aherrn, Y. and Blunden, B. 1998. Acid Sulfate Soil. New South Wales.

Stott, Diane E., Cynthia, A., Cambardella, M.D., Tomer, Douglas, Karlen, L. and Roger, W. 2011. A Soil Quality Assessment within the Iowa River South Fork Watershed. *Soil Science Society of America Journal.* 75 (6): 2271.

Stumm, W. and Morgan, J.J. 1996. Aquatic chemistry, chemical equilibra and rates in natural waters. Environmental Science and Technology Series.

Sullivan, L.A. and Bush, R.T. 2004 Iron precipitate accumulations associated with waterways in drained coastal acid sulfate landscapes of eastern Australia. *Marine and Freshwater research.* 55, 727-736.

Sundstrom, R. and Åström, M. 2006. Characterization of the Metal Leakage from Finnish Agricultural Acid Sulphate Soils in the Light of the European Water Framework Directive. *Boreal Environment Research.* 11 (4): 275–81.

Sundström, R., Åström, M. and Österholm, P. 2002. Comparison of the metal content in acid sulfate soil runoff and industrial effluents in Finland. *Environmental Science* and *Technology*.36: 4269–4272

Suswanto, T, Shamshuddin, J., Syed Omar, P.M. and Teh, C.B.S. 2007. Alliviating an Acid Sulfate Soil Cultivated to Rice (Oryza Sativa) Using Ground Manesium Limestone and Organic Fertilizer. *Jurnal Tanah Dan Lingkungan*. 9 (1): 1–9.

Suswanto, T, Shamshuddin, J., Syed Omar, P.M. and Teh, C.B.S. 2007. Effects of Lime and Fertiliser Application in Combination with Water Management on Rice (Oryza sativa). Cultivated on an Acid Sulfate Soil. *Malaysian Journal of Soil Science*. 11: 1 – 16.

Suswanto, T. 2005. A decision support system for rice cultivation on acid sulfate soils. *Jumal Tanah dan Lingkungan*. 7(1): 1-5

Sylvia, W., Col, A., Angus, M., Freeman, C., Heiner, F. and Rainer, H.E. 2010. Acid Sulfate Soil Remediation : Drainage Water Quality as Influenced by Tidal Forcing. *Life Sciences*. 13–16.

Tamm, L., Bruns, C., Leifert, C., Fuchs, J.G., Thürig, B., Specht, N. and Fliessbach, A. 2006. Impact of soil management practices on soil fertility and disease suppressiveness.

Tanaka, A. and Navasero, S.A. 1966. Growth of the rice plant on acid sulfate soils. *Soil Science and Plant Nutrition*. 3:23-30.

Tejada, M., Garcia, C., Gonzalez, J.L., and Hernandez, M.T. 2006. Use of organic amendment as a strategy for saline soil remediation: influence on the physical, chemical and biological properties of soil. *Soil Biology and Biochemistry*. 38: 1413–1421.

Tekin-Ozan, S. 2008. Determination of heavy metals in water, sediments, and tissues of tench (Tinca tica L., 1758) from Beysehir Lake (Turkey). *Environtal Monitoring Assessment*. 145: 259-302.

Tepe, Y. and Boyd, C.E. 2002. Sediment quality in arkansas bait minnow ponds. *Journal of the world aquaculture Society*. 33(3), pp. 221-232.

Tepe, Y. and Boyd, C.E. 2003. A Reassessment of Nitrogen Fertilization for Sunfish Ponds. *Journal of the World Aquaculture Society*. 34(4): 505-511.

Tesfahunegn, G.B. 2014. Soil Quality Assessment Strategies for Evaluating Soil Degradation in Northern Ethiopia. *Applied and Environmental Soil Science*. 2014.

Thomas, L.G., Nick, C., Charles, K., Amy, P. and Joshua, B.T. 2010. Probabilistic models of cognition: exploring representations and inductive biases. *Trends in Cognitive Science*. 14: 357–364.

Chaang, T.C., Saari, R.B., Diemont, H. and Yusoff, A.B. 1993. The development of an acid sulphate area in former mangroves in Merbok, Kedah, Malaysia. In *Selected Papers of the Ho Chi Minh City Symposium on Acid Sulphate Soils* (p. 95).

Tiwari, A.K. and Singh, A.K. 2014. Hydrogeochemical investigation and groundwater quality assessment of Pratapgarh district, Uttar Pradesh. *Journal of the Geological Society of India*, *83*(3), pp.329-343.

Tjia, H.D. 1973. Geomorphology. In Geology of the Malay Peninsula, ed. D.S.Gobbet and C.S. Wageningen, The Netherlands. p. 425–442.

Tobias, D.J., Jungwirth, P. and Parrinello, M. 2001. Surface Solvation of Halogen Anions in Water Clusters: An Ab Initio Molecular Dynamics Study of the Cl-(H2O)(6) Complex. *Journal of Chemical Physics.*114 (16): 7036–44.

Toh, P.Y. and Poon, Y.C., 1982. Effect of water management on field performance of oil palm in Peninsular Malaysia. In Proc. of Bangkok Symposium on Acid Sulfate Soils. Eds. H Dost and N van Breemen (pp. 260-212).

Tommy D'Hose. 2013. The Positive Relationship between Soil Quality and Crop Production: A Case Study on the Effect of Farm Compost Application. *Applied Soil Ecology*. 75 (2014), 189–98.

Topp, G.C., Reynolds, W.D., Cook, F.J., Kirby, J.M. and Carter, M.R. 1997. Physical attributes of soil quality. *Soil Quality for Crop Production and Ecosystem Health*. 25: 21–58

Topp, G.C., Reynolds, W.D., Cook, F.J., Kirby, J.M., Carter, M.R. 1997. Physical attributes of soil quality. In: Gregorich, E.G., Carter, M.R. (eds.). *Soil quality for crop production and ecosystem health*. New York, NY: Elsevier. pp. 21-58. (Development in soil science, 25).

Totok, S., Shamshuddin, J., Syed Omar, P.M. and Teh, C.B.S. 2007. Effects of Lime and Fertiliser Application in Combination with Water Management on Rice (Oryza Sativa) Cultivated on an Acid Sulfate Soil. *Malaysian Journal of Soil Science* Vol. 11: 1–16.

Suswanto, T., 2005. A Decision Support System for Rice Cultivation on Acid Sulfate Soils (Doctoral dissertation, Universiti Putra Malaysia).

Tran, K.T. and Vo, T.G., 2004, August. Effects of mixed organic and inorganic fertilizers on rice yield and soil chemistry of the 8th crop on heavy acid sulfate soil (Hydraquentic Sulfaquepts) in the Mekong Delta of Vietnam. In *A paper presented at the 6 th International Symposium on Plant-Soil at Low pH*.

USDA National Resources Conservation Service. (2008). Soil Quality indicators: Bulk Density. Availableat:http://soils.usda.gov/sqi/assessment/files/bulk_density_sq_physical_indicator_sheet.pdf. (Accessed 27 July 12).

Van Breemen, N.V., 1982. Genesis, morphology, and classification of acid sulfate soils in coastal plains. Acid Sulfate Weathering, (acidsulfateweat), pp.95-108.

Varol, M., Bülent, G. and Aysel, B. 2013. Dissolved Heavy Metals in the Tigris River (Turkey): Spatial and Temporal Variations. *Environmental Science and Pollution Research.* 20 (9): 6096–6108.

Virtanen, S., Asko, S., Helinä, H. and Markku, Y.H. 2014. Response of Pore Water Al, Fe and S Concentrations to Waterlogging in a Boreal Acid Sulphate Soil. *Science of the Total Environment.* 485-486 (1). Elsevier B.V.: 130–42.

Vuai, S.A., Nakamura, K. and Tokuyama, A. 2003. Geochemical characteristics of runoff from acid sulfate soils in the northern area of Okinawa Island, Japan. *Geochemical journal*. 37(5), pp.579-592.

Vuorinen, P., Marja, J.K., Seppo, P. and Christina, T. 1998. Effects of Iron, Aluminium, Dissolved Humic Material and Acidity on Grayling (Thymallus Thymallus) in Laboratory Exposures, and a Comparison of Sensitivity with Brown Trout (Salmo Trutta). *Boreal Environment Research*. 3 (4): 405–19.

Wagner, R.J., Boulger Jr, R.W., Oblinger, C.J. and Smith, B.A., 2006.Guidelines and standard procedures for continuous water-quality monitors: station operation, record computation, and data reporting (No. 1-D3).

Warkentin, B.P. and Fletcher, H.F., 1977. Soil quality for intensive agriculture. In Proceedings of the International Seminar on Soil Environment and Fertility Management in Intensive Agriculture.

Wasim, Aktar, Md., Paramasivam, M., Ganguly, M., Purkait, S. and Daipayan, S. 2010. Assessment and Occurrence of Various Heavy Metals in Surface Water of Ganga River around Kolkata: A Study for Toxicity and Ecological Impact. *Environmental Monitoring and Assessment*. 160 (1-4): 207–13.

Wendelaar Bonga, S.E. and Dederen. L.H.T. 1986. Effects of acidified water on fish. *Endeavour* 10:198-202.

Wilson, B.P., White, I. and Melville, M.D. 1999. Floodplain hydrology, acid discharge and change in water quality associated with a drained acid sulfate soil. *Mar. Freshwater Research*. 50, 149–157.

Wilson, W.A. 1999. Substrate targeting of the yeast cyclin-dependent kinase Pho85p by the cyclin Pcl10p. *Molecular Cell Biology*. 19(10):7020-30

Winder, J., 2003. Soil quality monitoring programs: A literature review. AESA.

Yang, C., Xu, H., Wang, L., Liu, J., Shi, D. and Wang, D. 2009. Comparative effects of salt-stress and alkali-stress on the growth, photosynthesis, solute accumulation, and ion balance of barley plants. *Photosynthetica*, 47: 79–86.

Yang, P.L., Baum, Bi. B.A., Liou, K.N., Kattawar, G.W., Mishchenko, M.I. and Cole, B. 2013. Spectrally consistent scattering, absorption, and polarization properties of atmospheric ice crystals at wavelengths from 0.2 to 100 μm. Journal *of the Atmospheric Sciences.* 70: 330-347.

Yoshida, S. 1981. Fundamentals of rice crop science. Los Baños, Philippines, IRRI. 269 pp.

Z J Liu. 2014. Soil Quality Assessment of Acid Sulfate Paddy Soils with Different Productivities in Guangdong Province, China', Journal of Integrative Agriculture. 13: 177–86.

Zhang, L., Rothman, N., Wang, Y., Hayes, R.B., Bechtold, W., Venkatesh, P., Yin, S., Wang, Y., Dosemeci, M., Li, G., Lu, W. and Smith, M.T. 1996. Interphase cytogenetics of workers exposed to benzene. *Environ Health Perspect.* 6: 1325-9.

Zhang, Y.C., Rossow, W.B., Lacis, A.A., Oinas, V. and Mishchenko, M.I. 2004. Calculation of radiative fluxes from the surface to top of atmosphere based on ISCCP and other global data sets: Refinements of the radiative transfer model and the input data. *Journal of Geophysics Research*. 109: D19105, doi:10.1029/2003JD004457

Zhou, W., Teng, F.L., Yong, C., Anthony, P. and Wan, J.R. 2014. Soil Physicochemical and Biological Properties of Paddy-Upland Rotation: A Review. *Scientific World Journal*. Article ID 856352, 8 pages.

Zornoza, R., Acosta, J.A., Bastida, F., Domínguez, S.G., Toledo, D.M. and Faz, A. 2015. Identification of Sensitive Indicators to Assess the Interrelationship between Soil Quality, Management Practices and Human Health. *Soil*. 1 (1): 173–85.