UNIVERSITI PUTRA MALAYSIA

EFFECTS OF WATER QUALITY ON WATERBIRD DIVERSITY IN CONVERTED OIL PALM PLANTATIONS

PETRA SULAI

EFFECTS OF WATER QUALITY ON WATERBIRD DIVERSITY IN CONVERTED OIL PALM PLANTATIONS

By

PETRA SULAI

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

April 2017

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

EFFECTS OF WATER BIRDS DIVERSITY TOWARDS THE WATER QUALITY IN CONVERTED OIL PALM PLANTATIONS

By

PETRA SULAI

April 2017

Chairman : Professor Mohamed Zakaria Hussin, PhD
Faculty : Forestry

Oil palm extension is a major driver for habitat loss in the tropics. Yet, while a number of studies have focussed on the consequences for terrestrial biodiversity, the impacts on waterbirds habitats and their associated fauna are less well described. Little information is available to guide the management of waterbirds and their habitat in oil palm production landscapes, particularly on those converted from natural wetlands such as mangrove and peat swamp forests. This study aims to determine the conservation value of flood-control drainage channels for waterbirds in oil palm plantations. This study also

measured the water quality indicators (water temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), salinity, water depth, conductivity, turbidity) and habitat characteristics (vegetation cover and channel width)to determine the relationships between waterbird species richness, water quality and habitat characteristics. Birds were surveyed along twenty five line transects within the peat swamp-converted and mangroves-converted oil palm smallholdings. Water quality parameter was measured in the middle of each line transects. Data was collected in seven smallholdings between March and December 2013. This study was recorded a total of 1111 waterbirds from eight resident species. Both mangrove forest-converted smallholdings and peat swamp-converted smallholdings had similar waterbirds diversity. Waterbirds species richness increased with increasing DO and decreased with water depth, temperature and conductivity. This association may be because of the suitability of the flood-control channels for aquatic invertebrates and fish, both of which are consumed by waterbirds and depend on sufficient levels of DO in the water to survive.

The most parsimonious predictive model (minimum AIC = 476.48) explained 52.39% of the variation in the species richness. The data suggest that even man-made aquatic habitats, such as flood control channels, can be important for some conserving waterbirds in oil palm smallholdings. However, given the relatively small gains in terms of increased waterbird species richness in channels, the most successful strategy for conserving waterbirds still require the protection of intact wetlands that supported by better management of drainage channels in oil palm smallholdings.

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

KESAN KEATAS KEPELBAGAIAN BURUNG AIR TERHADAP KUALITI AIR DI LADANG KELAPA SAWIT

Oleh

PETRA SULAI

April 2017

Pengerusi : Profesor Mohamed Zakaria Hussin, PhD
Fakulti : Perhutanan

Penanaman kelapa sawit merupakan antara faktor utama kehilangan habitat di kawasan tropika. Walaupun beberapa kajian telah memberi tumpuan kepada kesan-kesan ke atas biodiversiti daratan, kesan ke atas habitat tanah lembap dan fauna berkaitan, kurang diperjelaskan. Kajian ini bertujuan untuk menentukan nilai pemuliharaan saluran perparitan kawalan banjir di kebun kecil kelapa sawit ke atas burung air. Kajian ini juga mengukur penunjuk kualiti air (suhu air, pH, oksigen terlarut (DO), jumlah pepejal terlarut (TDS), kemasinan, kedalaman air,

kekonduksian, kekeruhan) dan ciri-ciri habitat (litupan tumbuhan dan lebar saluran) untuk mengenalpasti hubungan diantara kekayaan spesies burung air, kualiti air dan ciri-ciri habitat . Kajian burung dijalankan di sepanjang dua puluh lima transek garis di paya gambut dan paya bakau yang telah ditukar kepada kebun kecil kelapa sawit. Data dikumpulkan dari tujuh kebun kecil antara Mac dan Disember 2013. Kajian ini mencatatkan sejumlah 1111 burung air tergolong dalam lapan spesies burung residen telah direkodkan. Kedua-dua kawasan kajian mempunyai kepelbagaian burung air yang sama. Spesies burung air meningkat dengan peningkatan DO dan menurun dengan kedalaman air, suhu dan kekonduksian. Model ramalan paling hampir (minima AIC = 476,48) menjelaskan 52,39% daripada variasi dalam kekayaan spesies. Data kajian ini menunjukkan bahawa walaupun terdapat infrastruktur buatan manusia terhadap habitat akuatik, seperti saluran kawalan banjir, amat penting untuk pemuliharaan beberapa burung air di kebun kelapa sawit. Walaupun peningkatan spesies burung air agak kecil, ianya merupakan strategi yang paling berjaya untuk pemuliharaan burung air, disokong oleh pengurusan yang lebih baik daripada saluran perparitan di kebun kelapa sawit.

ACKNOWLEDGEMENTS

Thanks to Almighty Allah, for seeing me through this work. I acknowledge with great appreciation to my supervisor, Prof Madya Dr. Mohamed Zakaria, my co-supervisor Dr Badrul Azhar and Dr Siti Nurhidayu for their constructive criticism, meticulous guidance and patience during this project. My appreciation also goes to my research partner Mr Affendi and Miss Sharifah Atikah, my colleagues and friends.

I am greatly indebted to my family for their support, my mum Hjh Jijah, My wife Saidatul Azura, my kids Aimy Nurdeeni and Muhammad Amru Firas, for assistance and their unconditional support, both financially and emotional throughout my study. The patience and understanding shown by my family is greatly appreciated. I am also indebted to those who helped me in completing this study especially my friends Miss Tuhaila for her moral support and most of all her invaluable friendship. Words are not enough to express my gratitude and appreciation for the help that everyone have provided. Thanks for everything.

I certify that a Thesis Examination Committee has met on 13 April 2017 to conduct the final examination of Petra bin Sulai on his thesis entitled "Effects of Water Quality on Waterbird Diversity in Converted Oil Palm Plantations" 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.

Members of the Thesis Examination Committee were as follows:

Mohamad Azani bin Alias, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Mohamad Roslan bin Mohamad Kasim, PhD
Senior Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Internal Examiner)

Rosli Ramli, PhD
Associate Professor
University of Malaya
Malaysia
(External Examiner)

NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 4 September 2017

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Mohamed Zakaria Hussin, PhD
Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Badrul Azhar Md. Shariff, PhD
Senior Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Member)

Siti Nurhidayu Abu Bakar, PhD
Senior Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Member)

____
ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ________________________ Date: __________________

Name and Matric No : Petra Sulai, GS35473

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: ______________________________
Name of Chairman of Supervisory Committee: Professor Dr. Mohamed Zakaria Hussin

Signature: ______________________________
Name of Member of Supervisory Committee: Dr. Badrul Azhar Md. Shariff

Signature: ______________________________
Name of Member of Supervisory Committee: Dr. Siti Nurhidayu Abu Bakar

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Anova	Analysis of variance
AIC	akaike information criterion
DO	dissolve oxygen
cm	centimeter
etc.	*et cetra*, and the rest
et al.,	*at alli and other people*
m	meter
mg	milligram
CMF	converted mangrove forest
CPSF	converted peat swamp forest

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Oil palm expansion is the main cause of habitat loss in the tropics. A number of studies have been carried out on the extensiveness of the damage to terrestrial biodiversity. However, the impacts on wetland habitats such as peat lands and associated fauna are less well described hence, this study aims to determine the value of conserving flood-control drainage channel in oil palm smallholdings for water birds.

1.2 Background of the study

Throughout the history of birds' migration, many birds migrate in response to biological requirement, such as the need to find a suitable location for breeding and raising their young, and to be in a favorable area for feeding at other times of the year. In certain cases, these specific requirements are fulfilled in location separated by distance of thousands of kilometers.

Some aspects of the ecology of water birds make them useful as bio-indicators. First, water birds have been shown to track environmental variations, at short (months) and long (years) temporal scales, and at both species and community level. Second, as many species are top predators and several contaminants often accumulate along the tropic chain, such species may be used as indicators of changes occurring at the lower tropic level. And third, either the water birds themselves or their prey is exploited by humans (e.g. hunting and fisheries), so that hunting bags of water birds may be indicator of productivity in nesting or wintering areas (Miller et al., 1998) or breeding parameters of birds may inform on fish stock.

Due to the fast expansion of oil palm production areas in the tropics, peat swamps and mangrove areas have been cleared extensively to make way for economic development. Thus, an estimated 50% of the global wetland area has been lost due to human activities, including commercial agriculture (Zedler and Kercher 2005). In Southeast Asia, at least 60% of the original peat swamp forest cover and approximately 30% of the original mangrove forest cover have been lost during recent decades (Valiela et al., 2001; Posa et al., 2011).

Previous studies have been carried out to document avian diversity in oil palm plantation estates or smallholdings (Azhar et al., 2011; Jambari et al., 2012). Azhar et al. (2013) reported that the occurrence of water birds in both large scale oil palm plantations and smallholdings due to the existence of aquatic habitats in the forms of flood-control drains and ponds. However overuse of agrochemicals (e.g. pesticides and fertilizers) may have adverse effects on waterbird populations and aquatic habitats within oil palm smallholdings (Aratrkorn et al., 2009).

Despite this situation, no previous study had reported the effects on aquatic habitat and waterbirds in oil palm agriculture. Therefore, the focus of this study is to provide baseline information with respect to the species diversity of water birds in oil palm smallholdings. Specifically, a study was conducted to compare the influence of water quality measurement and drain morphology to water birds presence in converted peat swamp forest and converted mangrove forest smallholdings.

1.3 Statement of the Problem

Aquatic biodiversity, including water birds has enormous economic and aesthetic value and is largely responsible for maintaining and supporting overall environmental health. Humans have long depended on aquatic resources for food. Also, there are dependent on aquatic resources for medicines, materials, recreation and commercial purposes (fishing and tourism). In the other hand, aquatic organisms also rely upon the great diversity of aquatic habitats and resources for food and breeding grounds.

Factors including overexploitation of species, the introduction of exotic species, pollution from urban, industrial, and agricultural areas, as well as habitat loss and alteration through damming and water diversion contribute to the pollution from agricultural and urban areas, the invasion of exotic species, and the creation of dams and water diversion have been identified as the greatest challenges to freshwater environments (Allan and Flecker, 1993). . As a result, valuable aquatic resources are becoming increasingly susceptible to both natural and artificial environmental changes. Thus, conservation strategies to protect and conserve aquatic life are necessary to maintain the balance of nature and support the availability of resources for future generations. Human activities are causing species to disappear at an alarming rate. Aquatic species are at a higher risk of extinction than mammals and birds. Losses of this magnitude impact the entire ecosystem, depriving valuable resources used to provide food, medicines, and industrial materials to human beings.

Over exploitation of aquatic organisms for various purposes is the greatest threat to marine environments, thus the need for sustainable exploitation has been identified by the Environmental Defense Fund as the key priority in preserving marine biodiversity. Other threats to aquatic biodiversity include urban development and resource-based industries, such as mining and logging that destroy or reduce natural habitats. In addition, air and water pollution, sedimentation and erosion, and climate change also pose as a threat to aquatic biodiversity.

The need for maintaining and enhancing urban and suburban populations of wildlife has greatly increased in almost four decades (Washington, 1978), but planning for wildlife in urban areas is often stifled by inadequate support from resource agencies and lack of awareness and expertise in wildlife matters by urban planners (Davey, 1967; Geis, 1980). The solution to this dilemma is either to encourage greater collaboration between wildlife regulatory agencies and municipal planners or, as discussed in this study, to familiarize the planners with the wildlife resources through literature relevant to both the disciplines (Greer 1983). Man-made conservation reservoirs play an important role in sustaining both human and bird life.

The population of waterfowl at artificial wetlands, mainly reservoirs and canals, was studied in Gujarat, western India, from 1988 to 2000 (reference). Habitat size and complexity were important factors influencing the species diversity, while factors contributing to waterbirds presence including abundant food supply and safe roosting sites. In addition to reservoirs, flooded set-aside farmlands were of immense importance to more than 30 000 waterbirds of 66 species, suggesting that fallow inundated fields serve as a key supplementary habitat for the waterbirds, especially during the dry period. Both site specific and broad based strategies are suggested for future management. Narda Reservoir is a 57 ha storage reservoir designed for irrigation purposes with a discharge which averages 65 CFs. The water quality is good and is used for fisheries. In summer, the reservoir becomes shallow and overgrown with aquatic vegetation. The surrounding area is agricultural landscape and the main crop grown is a paddy rice Oryza sativa. Pariej Reservoir is a 445 ha perennial water storage reservoir for the district, fulfilling the drinking water requirement of the surrounding 52 villages. The surrounding area is mostly saline and as a result, no crops are grown. Due to water seepage from the reservoir, the whole area is waterlogged and behaves as a permanent marsh with a heavy growth of the reed *Typha angustata* and other aquatic vegetation. Commercial fishing is practiced in this reservoir. Kanewal Reservoir, with an area of 625 ha, is the largest reservoir in the district. The land surrounding the reservoir is salt affected and remains dry during summer. During the monsoon, the whole area is inundated and migratory waterfowl enjoy a temporary wetland. The reservoir provides drinking water to 57 villages, and there is occasional fishing. Waterfowl counts were made in alternate weeks in January from 1988 to 2000. Plant composition and vegetation cover for the entire study area was also recorded. Paddy rice and wheat are the principal cultivated crops in the district. Undisturbed vegetation was found mostly on the banks of reservoirs.

Observations of the three sites showed that the waterfowl initiated their activity in early morning about 30 min before sunrise. Most of the activities (foraging, preening, swimming and feeding) ceased within 15 min after initiation. The movements of the birds were a function of their feeding preference. Morning counts were best because they included all birds utilizing the reservoir, and there was little human disturbance. At Narda Reservoir, the waterfowl were attracted due to shallow aquatic vegetation, especially Cyperus species. Migratory waterfowl arrived in October and diversity increased significantly to between 12-36 species over the winter months. The density of ducks ranged between 0.2–15.4 per ha, and for other waterbird species was 1.7–78.2 per ha. Coots Fulica atra. We're the most abundant species. Ducks were mostly found feeding in the adjacent paddy fields because these provided secure food supplies and a relatively fixed water depth (less than 1 m). Pariej Reservoir had a comparatively higher diversity than Kanewal and Narda, with between 36 and 85 species. The Dalmatian Pelican *Pelecanus Crispus* was attracted to this reservoir due to its abundant fish supply. However, coots were dominant all year. Gadwall *Anas strepera, Northern Shoveler Anas clypeata*, Northern Pintail *Anas acuta, Eurasian Wigeon Anas Penelope* were also common and regularly observed; the density of ducks ranged from 0.3–9.0 individuals per ha and other waterbirds between 9.6–59.1 per ha. The reservoir is a potential breeding site for Great-crested Grebe.

Podiceps cristatus Carnival Reservoir, having short grass and emergent vegetation, attracted many migratory waterfowl, with densities of 1.0–9.0 individuals per ha. Ducks congregated mostly to feed on tubers of *Najas minor.* The number of species varied from 26 to 95 because this is the only water body in the area, and is shallow with abundant food. The density of other waterbirds was 20.0–64.0 individuals per ha.

Oil palm (*Elaeis guineensis*) cultivation is seen as the major cause of the current biodiversity crisis in tropical Southeast Asia. Oil palm cultivation is becoming a more widespread worldwide despite being considered by environmental NGOs as a serious threat to forest biodiversity (Lambert and Collar, 2002; Sodhi et al., 2004; Sodhi and Brook, 2006; Fitzherbert et al., 2008; Danielsen et al., 2009; Rudel et al., 2009). As of 2008, the planted area of oil palm in Malaysia alone covered approximately 4.5 million ha and produced 18 million tonnes of palm oil per year (Malaysia Palm Oil Board, 2009).

Over the next 50 years, rapid and widespread agricultural expansion will pose as a serious threat to natural ecosystems worldwide (Tilman et al., 2001). During the past few decades, the oil palm has become one of the most rapidly expanding equatorial crops in the world. The global amount of oil palm cultivation increased from 3.6 million ha in 1961 to 13.2 million ha in 2006 (FAO, 2007). Today, oil palm is grown in 43 countries with a total cultivated area accounting for nearly one-tenth of the world's permanent cropland (FAO, 2007; WRI, 2007).

Oil palm contributes to deforestation and biodiversity loss in several ways. First, oil palm expansion can be a direct motive to replace forests, and it is easy to attribute oil palm as the cause of deforestation and habitat destruction in this sense. However, there are also more indirect ways by which oil palm can lead to deforestation, making the quantification of the impacts of oil palm expansion difficult (Fitzherbert et al., 2008). For example, oil palm expansion may create road access into otherwise inaccessible forests, facilitating logging. Additionally, oil palm expansion may be used as an excuse to clear a patch of forest for timber, but in the end the area never gets developed into oil palm – this is especially widespread in Kalimantan, where corruption, relaxed regulations, and weak governance is prevalent (Laurance, 2007; Sandker et al., 2007). Several recent initiatives are aimed at reducing oil palms impact on biodiversity. For example, the Roundtable on Sustainable Palm Oil (RSPO) was established as a certification scheme for palm oil, and many large palm oil companies have adopted zero-net-deforestation policies, though this is not currently enforced (Butler, 2014).

Koh and Wilcove (2008), suggested that oil palm plantations in Malaysia and Indonesia have replaced forests and, to a smaller extent, pre-existing cropland. Species richness of forest birds in primary forests, secondary (logged) forests, rubber plantations, and oil palm plantations were sampled and the study exposes that the main forest conversion and logged forests to oil palm plantations decreases the species richness of forest birds by 73 and 77%, respectively, whereas the conversion of rubber plantations to oil palm plantations results in only 14% decline in species richness of the remaining forest birds.

The rapid expansion of oil palm (*E. guineensis*) into habitats across the tropics has led to widespread concern about the consequences of this land conversion for biodiversity (Donald , 2006; Koh and Wilcove, 2008; Turner et al., 2008; Sayer et al., 2012; Savilaakso et al., 2014). Biodiversity-rich wetland ecosystems such as peat swamp forest and mangrove forest have been cleared to establish oil palm cultivation by both private businesses and small-scale farmers (Giri et al. 2008; Koh et al. 2011). Universally, wetlands cover a small portion of the earth's surface yet provide a range of ecosystem services, including biodiversity support, water quality protection and reduction in flood risk (Zedler and Kercher, 2005). An estimated 50% of the global wetland area has been lost due to human activities, including commercial agriculture (Zedler and Kercher, 2005). In Southeast Asia, at least 60% of the original peat swamp forest covers approximately 30% of the original mangrove forest cover which have been lost over recent decades (Valiela et al., 2001; Posa et al., 2011). ratrakorn et al., (2006) studied the changes in bird's communities following conversion of lowland forest to oil palm and rubber plantation in the southern part of Thailand. From his studies, bird's communities in oil palm and rubber plantation were extremely similar and there was a strong positive correlation across species in their relative abundance in each plantation type. The results indicates high proportion of species formal present in the region which are unable to adapt to conversion of forest oil palm and rubber plantation which result in high losses of bird species and family richness and replacement of species with restricted ranges and high conservation status by those with extensive ranges and low conservation status.

Also, Aromoro et al., (2009) studied the feeding interaction among functional feeding group (FFG) of macro invertebrates which are indicators of aquatic ecosystem interactions. His study provided information regarding organic matter processing habitat condition and trophic dynamics. Omnivores feeding behavior of macro invertebrates was noted for the upstream site whereas clear trophic guilds of FFGs where suggested for the wetlands affected river zones by the stable isotope results. His results showed that pollution gradient analysis and feeding interaction among FFGs revealed that the urban-impacted sites showed weaker interaction when compared to upstream and wetlands influenced site. This affirms the potential importance of feeding interactions among FFGs of macro invertebrates in water quality monitoring.

From the both studies available, there has not been any study showing the relationship between water birds and water quality in oil palm vegetation. Attention has to be given to this study so as to have a better understanding on their relationships and diversifications

1.4 Objectives of the study

1.4.1 General Objective

This study aims to study the aquatic habitat characteristics and their relation to water bird at oil palm smallholdings in Tanjung Karang, Selangor. As natural wetlands continue to decline worldwide, there is an urgent need to investigate the waterbirds perseverance following landscape transformation.

1.4.2 Specific objective

1.4.2.1 To determine the conservation value of flood-control drainage channels for waterbirds in oil palm smallholdings.

1.4.2.2 To examine the relationship between water bird richness, water quality and drain morphology.

1.5 Research questions

1.5.1 To what extent will waterbirds be able to survive in man-made aquatic habitats associated with oil palm cultivation?

1.5.2 How does flood-control channels affect water quality index and watebirds species richness and abundance.

1.6 Research hypothesis

Based on the research questions above, the hypotheses of the research are:

1.6.1 Ho1: There is no significant evidence that the waterbirds are able to persevere in man-made aquatic habitats associated with oil palm cultivation

1.6.2 Ho2: There is no significant evidence that the water quality influence the waterbird species richness.

1.7 Significance of the Study

This study attempts to understand the effects conversion on resident waterbirds and water quality by collecting data from existing oil palm landscapes. As the ecological species response to variances in water quality differently, the use of whole communities to indicate changes in water or habitat quality is likely to be more reliable than the use of single species indicators (Ormerod and Tyler 1993).

A better understanding of the associations between water quality, habitat quality and waterbird populations may assist commercial oil palm growers to preserve a wider range of waterbird species on the farms.

1.8 Limitations of the Study

This study is far from a perfect one considering several limitations of the researcher's knowledge and also some objective and subjective limitations.

1.9 Definition of terms

In this section, the researcher will define and explain the scope of studies intended in this proposed study by looking at the working definition of the keywords.

1.9.1 Oil Palm

Oil palm (*E. guineensis*) was initially introduced to Malaysia as a decorative plant in 1870 and now is one of the quickest expanding crops in the region. The oil palm planted currently is the genera hybrid which yields about 4.0 t of palm oil per hectare, together with 0.5 t palm kernel oil and 0.6 t palm kernel cake. Oil palm has an economic life of about 25 years. The harvesting of the palm could begin 30 months after field planting.

1.9.2 Waterbirds

The term water bird, waterbird or aquatic bird used to refer to birds that live on or around water. Some definitions apply the term especially to birds in freshwater habitats, though others make no distinction from birds that inhabit marine environments. In addition, some water birds are more terrestrial or aquatic than others, and their adaptations will vary depending on their environment.

1.9.3 Peat Swamp

Peatlands are wetlands with a thick water-logged organic soil layer (peat) made up of dead and decaying plant material. Peatlands include moors, bogs, mires, peat swamp forests and permafrost tundra. Peat swamp forests have not been disturbed as this land is not suitable for agriculture process. However, increasing international demand on biofuel plus with lack of land and mineral soils has accelerated the conversion of peat land, into oil palm plantations. (Sheil et al., 2009; Tan et al; 2009).

1.9.4 Drainage

The drainage results in rapid peat subsidence and compaction were led to various changes in its physical properties. These were including greater bulk density and less total porosity, oxygen diffusion as capacity available water volume and water infiltration rate (Rieley et al., 2007).

1.9.5 Biodiversity

Biodiversity refers to the variety of all forms of life on earth, including the different plants, animals, micro-organisms, the genes they contain and the ecosystem they form. It is considered at three main levels including species diversity, genetic diversity and ecosystem diversity. Relative to the variety of habitats, biotic communities and ecological processes in the biosphere, biodiversity is vital in a number of ways including promoting the aesthetic value of the natural environment, contribution to our material well-being through utilitarian values, maintaining the integrity of the environment through; maintaining CO2/O2 balance, regulation of biochemical cycles, absorption and breakdown of pollutants and waste materials through decomposition, determination and regulation of the natural world climate, protective services, e.g. by acting as wind breaks and acting as indicators of environmental changes. Despite the benefits from biodiversity, today's threats to species and ecosystems are the greatest recorded in recent history and virtually all of them are caused by human mismanagement of biological resources often stimulated by misguided economic policies, pollution and faulty institutions in-addition to climate change. To ensure intra and intergenerational equity, it is important to conserve biodiversity. Some of the existing measures of biodiversity conservation include; zoological gardens, botanical gardens/arboretums, seed banks and national parks and game reserves.

1.9.6 Hydrogical process

Hydrological process within oil palm plantations are still not fully understood, and few studies have examined how agriculture practices on terrestrial hydrological functions and water quality affect the nearby aquatic ecosystem (Ah Tung et al., 2009) despite the aspects that impact on water quality are one of the largest component of an environmental risk register amounting to an estimation of 50% of all entries in oil palm plantation (Lord and Clay, 2006).

1.9.7 Water quality

Water is essential to human life and the health of the environment. As a valuable natural resource, it comprises marine, estuarine, freshwater (river and lakes) and groundwater environments that stretch across coastal and inland areas. Water has two dimensions that are closely linked: quantity and quality. Water quality is commonly defined by its physical, chemical, biological and aesthetic (appearance and smell) characteristics. A healthy environment is one in which the water quality supports a rich and varied community of organisms.

Despite the grave situation, no studies have reported the effects of water birds' aquatic habitat in oil palm agriculture. Therefore, the focus of this study is to have baseline information with respect to species diversity of water birds in oil palm smallholdings. This study is conducted to compare the influence of water quality measurement and drain morphology on water birds in converted peat swamp forest and converted mangrove forest smallholdings.

REFERENCES

Abrahams, M. & Kattenfeld, M. (1997). The role of turbidity as a constraint on predator-prey interactions in aquatic environments. *Behavioral Ecology and Sociobiology* . 40, 169–174.

Allan, A.D. (2004). Landscapes and Riverscapes: The influence of land use on stream ecosystems. Annual Review of Ecology, Evolution, and Systematics. 35: 257-284.

Amoah, F.M., Nuertey, B.N., Baidoo-Addo, K., Oppong, F.K., Osei-Bonsu, K., Asamoah, T.E.O. (1995). Underplanting oil palm with cocoa in Ghana. Agroforestry Systems. 30: 289-299.

Aratrakorn, S., Thunhikorn, S. & Donald, P.F. (2006). Changes in bird communities following conversion oflowland forest to oil palm and rubber plantations insouthern Thailand. Bird Conservation International. 16:71–82.

Arimoro, F.O. & Ikomi, R.B. (2009). Ecological integrity of upper Warri River, Niger Delta using aquatic insects as bioindicators. Ecological Indicators, 9: 455–461.

Azhar B., Lindenmayer D.B., Wood J. et al.,. (2011). The conservation value of oil palm plantationestates, smallholdings and logged peat swamp forest for birds. *Forest Ecology and Management*. 262:2306-2315.

Azhar B., Lindenmayer D.B., Wood J. et al. (2013).The influence of agricultural system, stand structural complexity and landscape context on foraging birds in oil palm landscapes. Ibis .155: 297–312.

Bancroft, G.T., Gawlik, D.E. & Rutchey, K. (2002). Distribution of wading birds relative to vegetation and water depthsin the Northern Everglades of Florida, USA. *Journal of the Waterbird Society*. 25: 265-391.

Benton, T.G., Vickery, J.A. & Wilson, J.D. (2003). Farmland biodiversity:is habitat heterogeneity the key?TRENDS in Ecology and Evolution.18:182-188.

Burnham, K.P. & Anderson, D.R.(2002). Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, second ed. *Springer,* USA.

Czech, H.A. & Parsons, K.C. (2002). Agricultural Wetlands and Waterbirds: A Review. Waterbirds: *The International Journal of Waterbird Biology*. 25: 56-65.

Davies, B., Biggs, J., Williams, P., Whitfield, M., Nicolet, P., Sear, D. & Bray, S., (2008). Comparative biodiversity of aquatic habitats in the European agricultural landscape. *Agriculture, Ecosystems & Environment.* 125: 1–8.

Dyke, F.D. (2008). Conservation Biology: Foundations, Concepts, Applications. *Springer*, UK.

Donald, P.F. (2004). Biodiversity impacts of some agricultural commodity productionsystems. *Conservation Biology*. 18:17–37.

Dong, Y.H., Wang, H., An, Q., Ruiz, X., Fasola, M. & Zhang, Y.M. (2004). Residues of organochlorinated pesticides in eggs of water birds from Tai Lake in China. *Environmental Geochemistry and Health*. 26: 259-268.

Dormann, C.F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., Marquéz, J.R.G., Gruber, B., Lafourcade, B., Leitão, P.J., Münkemüller, T., McClean, C., Osborne, P.E., Reineking, B., Schröder, B., Skidmore, A.K., Zurell, D., Lautenbach, S. (2013). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography*. 36:27–46.

Edwards, D.P., Hodgson, J.A., Hamer, K.C., Mitchell, S.L., Ahmad, A.H., Cornell, S.J. & Wilcove, D.S. (2010). Wildlife-friendly oil palm plantations fail to protect biodiversity effectively. Conservation Letters. 3:236–242.

Elphick, C.S. & Oring, L.W. (1998). Winter management of Californian rice fields for waterbirds. *Journal of Applied Ecology*. 35: 95–108.

Fasola, M. & Ruiz, X. (1996). The value of rice fields as substitutes for natural wetlands for waterbirds in the Mediterranean Region. *Colonial Waterbirds* .19: 122-128.

Giri, C., Zhu, Z., Tieszen, L.L., Singh, A., Gillette, S., Kelmelis, J.A. (2008). Mangrove forest distributions and dynamics (1975–2005) of the tsunami-affected region of Asia. *Journal of Biogeography*. 35, 519–528.

Henkel, L.A. (2006). Effect of water clarity on the distribution of marine birds in nearshore waters of Monterey Bay, California. *Journal of Field Ornithology*. 77, 151–156.

Jeyarajasingam, A. (2012). A Field Guide to the Birds of West Malaysia and Singapore. Oxford University Press, UK.

Keddy, P.A. (2010). Wetland Ecology: Principles and Conservation. Cambridge University Press, United Kingdom.

King, S., Elphick, C.S., Guadagnin, D., Taft, O. & Amano, T. (2010). Effects of landscape features on waterbird use of rice fields. *Waterbirds*. 33: 151-159.

Koh L.P., Wilcove D.S. (2008). Is oil palm agriculture really destroying tropical biodiversity? Conservation Letters. 1: 60-64.

Koh, L.P. 2008. Can oil palm plantations be made more hospitable for forest butterflies and birds? *Journal of Applied Ecology*. 45:1002–1009.

Koh, L.P., Miettinen, J., Liew, S.C. & Ghazoul, J. (2011). Remotely sensed evidence of tropical peatland conversion to oil palm. PNAS 108, 5127-5132.

Krebs, J.R. et al. (1999). The second silent spring? Nature, 400: 611–612.

Lantz, S.M., Gawlik, D.E. & Cook, M.I. (2011). The effects of water depth and emergent vegetation on foragingsuccess and habitat selection of wading birds in the Everglades. *Waterbirds*. 34:439-447.

Ma, Z., Cai, Y., Li, B. & Chen, J. (2010). Managing Wetland Habitats for Waterbirds: An International Perspective. Wetlands. 30: 15-27.

Mohd Roslan, M.N., Mohd Haniff, H., Ahmad Tarmizi, M., Ahmad Kushairi, D., & May, C.Y. (2013). Water for oil palm: water management. Planter. 89, 171-177.

Naigaga, I. Kaiser, H., Muller, W.J., Ojok, L., Mbabazi, D., Magezi, G. & Muhumuza, E. (2011). Fish as bioindicators in aquatic environmental pollution assessment: A case study in Lake Victoria wetlands, Uganda. Physics and Chemistry of the Earth, Parts A/B/C 36, 918–928.

Noske, R.A. 1995. The ecology of mangrove forest birds in Peninsular Malaysia. Ibis. 137: 250–263.

Nyström, K.G.K.& Pehrsson O. (1988). Salinity as a constraint affecting food and habitat choice of mussel-feeding diving ducks. Ibis 130, 94–110.

Ogunkunle, A.O. (1993). Soil in land suitability evaluation: an example with oil palm in Nigeria. *Soil Use and Management*. 9, 35–39.

Ormerod, S.J. & Tyler, S.J. (1993). Birds as indicators of changes in water quality. In Birds as Monitors of Environmental Change Paperback, edited by Furness R. & Greenwood, J.J.D. Chapman & Hall, UK.

Paillisson, J. M., Reeber, S., Marion, L. (2002). Bird assemblages as bio-indicators of water regime management and hunting disturbance in natural wet grasslands. *Biological Conservation*. 106: 115–127.

Parsons, K.C., Mineau, P. & Renfrew, R.B. (2010). Effects of pesticide use in rice fields on birds. *Waterbirds*. 33: 193-218.

Peh, K.S.H., Sodhi, N.S., de Jong, J., Sekercioglu, C.H., Yap, C.A.M. & Lim, S.L.H. (2006). Conservation value of degraded habitats for forest birds in southern Peninsular Malaysia. Diversity and Distributions. 12: 572–581.

Posa, M.R.C., Wijedasa, L.S., Richard T. Corlett, R.T. (2011). Biodiversity and Conservation of Tropical Peat Swamp Forests. *BioScience*. 61: 49-57.

Robson, C. (2011). *Field Guide to the Birds of South-East Asia*.New Holland, Australia.

Savilaakso, S., Garcia, C., Garcia-Ulloa, J., Ghazoul, J., Groom, M., Guariguata, M.R., Laumonier, Y., Nasi, R., Petrokofsky, G., Snaddon, J., Zrust, M. (2014). Systematic review of effects on biodiversity from oil palm production.Environmental Evidence 3, 4.

Sayer, J., Ghazoul, J., Nelson, P. & Boedhihartono, A.K. (2012). Oil palm expansion transforms tropical landscapes and livelihoods. *Global Food Security.* 1: 114–119.

Schall, R., (1991). Estimation in generalized linear-models with random effects. *Biometrika*. 78:719–727.

Sebastián-González, E., Sánchez-Zapata, J.A. & Botella, F. (2010). Agricultural ponds as alternative habitat for waterbirds: spatial and temporal patterns of abundance and management strategies. *European Journal of Wildlife Research.* 56:11-20.

Silva, D. de paiva,Marco, P.D. & Resende, D.C. (2010). Adult odonate abundance and community assemblage measures as indicators of stream ecological integrity: A case study. Ecological Indicators 10, 744–752.

Smith, B.G. (1989). The effects of soil water and atmospheric vapour pressure deficit on stomatal behaviour and photosynthesis in the oil palm. *Journal of Experimental Botany*. 40: 6647-651.

Therriault, T.W. & Kolasa., J. (1999). Physical determinants of richness, diversity, evenness andabundance in natural aquatic microcosms. Hydrobiologia. 412, 123–130.

Thiere, G., Milenkovski, S., Lindgren, Per-E., Sahlén, G., Berglund, O. & Weisner, S.E.B. (2009). Wetland creation in agricultural landscapes: Biodiversity benefits on local and regional scales. *Biological Conservation*. 142: 964–973.

Tourenq, C., Sadoula, N., Beck, N., Mesléard, F. & Martin, J-L. (2003). Effects of cropping practices on the use of rice fields by waterbirds in the Camargue, France. *Agriculture, Ecosystems & Environment*. 95: 543–549.

Turner, E. C., Snaddon, J. L., Fayle, T. M. & Foster, W. A. (2008). Oil palm research in context: identifying the need for biodiversity assessment. Plos One 3, e1572

Turner E.C., Snaddon J.L., Ewers R.M., Fayle T.M. & Foster W.A. (2011). The impact of oil palm expansion on environmental change: putting conservation research in context. Book chapter in Environmental Impact of Biofuels, InTech open access publisher (http://www.intechweb.org/), Edited by Marco Aurélio dos Santos Bernardes, ISBN 978-953-307-479-5.

Valiela, I.,Bowen, J.L. & York, J.K.(2001). Mangrove forests: One of the world's threatened major tropical environments. *BioScience.* 51: 807–815.

Whelan, C.J., Wenny, D.G. & Marquis, R.J. (2008). Ecosystem services provided by birds. Annals of the New York Academy of Sciences 1134, 25–60.

Williams, P., Whitfield, M., Biggs, J., Bray, S., Fox, G., Nicolet, P. & Sear, D. (2004). Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England. *Biological Conservation*. 115: 329–341.

Wollheim, W.M. & Lovvorn, J.R. (1995). Salinity effects on macroinvertebrate assemblages and waterbird food webs in shallow lakes of the Wyoming High Plains. *Hydrobiologia*. 310:207-233.

Wright, H. L., Lake, I. R., & Dolman, P. M. (2012). Agriculture—a key element for conservation in the developing world. Conservation Letters 5, 11-19.

Wyman, R.L. (1988). Soil Acidity and Moisture and the Distribution of Amphibians in Five Forests of Southcentral New York. Copeia 1988, 394-399.

Ye, S., Li, Z., Lek-Ang, S., Feng, G., Lel, S., Cao, W., (2006). Community structure of smallfishes in a shallow macrophytic lake (Niushan Lake) along the middle reach ofthe Yangtze River, China. Aquat. Living Resour. 19, 349–359.

Zedler, J.B. & Kercher, S. (2005). Wetland resources: Status, Trends, Ecosystem Services, and Restorability. Annu. Rev. Environ. *Resour*. 30, 39–74.