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IMPACTS OF LAND-USE CHANGE ON PEATLAND DEGRADATION: A REVIEW

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Abstract

This paper presents a topical overview of peatland degradation as a result of land-use change by reviewing previous studies and looking for the converging results of interest so as to proffer possible solutions to this menace. As a result of rising awareness of climate change and its negative influence on our environment, many studies are being tailored towards the main drivers of climate change and the contributions of both human and natural activities towards the effects of climate change on our environments. Lots of commendable results have been achieved so far, and the major sources of these drivers of climate change have been discovered which have now limited the studies to particular areas of research. Peatlands, mostly found to be carbon stores, have been discovered to store very large amount of other major nutrients apart from carbon which, if not maintained within the peatland, could have serious and negative influence on our environment if allowed to escape to the atmosphere. The escape of these major nutrients like carbon dioxide, CO_2, and nitrous oxide, N_2O locked up within these peatlands as a result of land-use change has seriously degraded these peatlands, thereby making them becoming more of carbon sources than carbon stores which in turn aggravates the dangers of global warming. The review, therefore, tends to bridge the gap between the agricultural expansion which was caused by increase in oil palm demands that resulted to change in land use such as deforestation and the subsequent degradation of peatland and the associated food supply concerns.

Key Words: *Land-use, Peatland, Degradation, Soil carbon, Climate change*

Introduction

Land-use change and economic viability of a nation have been a major topic that has called for serious attention in the world over. In both developed and developing nations of the world, land use change has been a major factor on which the impacts of government policies are being evaluated. Most of the developing countries rely mainly on cultivating their lands for agricultural purposes, for example, where the higher percentage of population depends solely on farming. But the various uses the land is being subjected to determine how much benefit is derived from such a natural endowment. From

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agricultural production, recreation, urbanization, and so on, land has been put to various uses which in one way or the other determine its durability or productivity for food production. Land-use change in the other hand can thus be said to include conversion of land from one form of practice to another. Forested lands in many parts of the world have been converted to agricultural farms for the purpose of food production. And most of the swamp forests available in South-East Asia are being converted for agricultural purposes particularly for emerging oil palm cultivation. Land use/land cover change (LULCC), also has to do with human-caused changes that affect the biophysics, biogeochemistry, and biogeography of the terrestrial surface and its effect on the atmosphere. These changes effected on the lands have posed great dangers to the natural resources embedded in the soil mass and have also impacted negatively on the environmental safety. Land use change, which involves indiscriminate conversion of peat swamp forests for agricultural purposes, has also contributed negatively to the degradation of agricultural soil there by resulting into low productivity of such agricultural soil and with consequence of problem in food supply (DeFries and Rosenzweig, 2010). The study further noted the minor contribution from deforestation-related agricultural expansion to overall food production at global scales.

Definition of Land-Use Change

According to Efiong-Fuller, (2008), land-use is defined in terms of human activities like agriculture, forestry and building construction that change land surface processes which include biogeochemistry, hydrology and biodiversity. Furthermore scientists and land managers has defined land-use to include the social and economic purposes and contexts for and within which lands are managed (or unmanaged), such as subsistence versus commercial agriculture, rented and owned, or private and public land (Ellies, 2010). According to Meyer and Turner (1992) and Vitousek *et al*., (1997), in an attempt to satisfy mankind's immediate demands for natural resources land-use has immensely changed a vast proportion of the earth's land surface. Land could be referred to as the backbone of agricultural economies, and it has its own share of provision of substantial and social benefits. For the sole purpose of achieving a meaningful economic development and social progress, land-use change is inevitable.

Global Peatlands and Land Use Change

Peatland basins are found in many parts of the world, both in temperate and tropical regions (Katimon, 2005). Out of 400 million hectares (11% of the world area of peatland resources in the world), about 72 million hectares alone are found in the tropic (Hugo, 1980). From this figure, 23 million hectares are in the South-East Asia, and according to Mutalib *et al.,* (1992), about 24 million hectares (7% of the total land area) is located in Malaysia. It will be of interest to note that those areas where the oil palms are now grown in Malaysia were formerly tropical forests which have now been subjected to serious land use conversion to favour the emerging oil palm productions in the region. The boom recorded in the region in oil palm industries in the 70's led to the conversion of major swamp forests for agricultural purposes. According to Hooijer *et al.* (2010), in order to satisfy increase in global demand for oil palm products, peat swamp forests in SE Asia are being deforested, drained extensively and burned for conversion to large scale oil palm plantations. About 3.1 million hectares of peatlands all in Peninsular Malaysia, Borneo and Sumatra have been converted to plantations as at

2010 (Miettinen *et al*., 2012). And if this trend is not arrested and checked, 50 % of the available peatlands in Peninsular Malaysia will be further converted by the year 2020. Table 1 shows the extent of the peatlands that have been developed for agriculture in three regions available in Malaysia, which include the Peninsular Malaysia, Sarawak and Sabah.

In the United Kingdom, for the purpose of agricultural expansion, vast areas of peatland were drained for agriculture and forestry, often with limited economic gain, but with considerable impact on the functioning of the peatland. This means that over 80% of UK peatlands have been affected in some way by drainage, fire, grazing or commercial extraction (Smith, 1970). During the 18th century, China intensified its agricultural practice by replacing shifting cultivation with commercial cropping in the hills. As a result of this land use change, land clearance on slopes resulted into erosion and frequent landslides, and flash floods (Peilke, *et al*., 2011), which as a consequence of degraded the farm land. Differing perceptions of the impacts on hydrological functions of tropical forest clearance and conversion to other land uses have given rise to growing and often heated debate about directions of public environmental policy in Southeast Asia

One of the major direct environmental impacts of development is the degradation of water resources and water quality (USEPA, 2001) and loss of carbon stored within the peatlands to the atmosphere (Hooijer*et al*., 2006). According to Bruijnzeel (2004), conversion of agricultural, forest, grass, and wetlands to urban areas usually give rise to growing and often heated debate about directions of public environmental policy in Southeast Asia. Andersen (1970) and Moscrip and Montgomery (1997) put it that land-use alteration is typically reflected in increase in the volume and rate of surface runoff and decreases in groundwater recharge and base flow. This, according to Field *et al*. (1982) and Hall (1984), eventually lead to larger and more frequent incidents of local flooding, reduced residential and municipal water supplies, and decreased base flow into stream channels during dry weather (Harbor, 1994).

Classification of Tropical Peatlands

Peatlands may be classified as ombrotrophic and minerotrophic based on the ways they receive inputs of water. In the first case, ombrotrophic peatland is the one that relies almost entirely on precipitation for inputs of water, nutrient, and minerals, while minerotrophic peatlands are hydrologically connected with surrounding starta, which means they derive nutrients and water from both precipitation and connecting strata. The latter have greater nutrients content than the former because of connectivity between minerotrohic peatland and underlying strata. Bragg and Tallis, (2001) reported that ombrotrophic peatlands have a high water content because of their location in areas with high precipitation rates. They are generally referred to as bogs with pH < 4 and unlike minerotrophic peats which are known as fens with pH ranging from 4.0 to 6.0 (acidic to slightly acidic).

Peatland as Carbon Sink

According to Lo and Parish (2013), peatlands in their natural state act as the most efficient carbon stores of all terrestrial ecosystems. Parish *et al*., (2008) also reported that peatlands in the tropical zone store 10 times more carbon per hectare than adjacent ecosystems on mineral soil. This, in essence, means large amount of carbon is found in the organic soil compared to what is obtainable in the mineral soil. South-East Asia alone stored about 68.5 Gt (billion tonnes) of soil carbon, which represents 77

% of tropical peat carbon and is equivalent to 14 % of global peat carbon (Page *et al*., 2011). Carbon in the soil plays a major role in regulating climate, water supplies and biodiversity, and therefore in providing the ecosystem services that are essential to human well-being (Victoria *et al*., 2012). Victoria *et al.,* (2012) further stated that it has become expedient to manage the soil so as to obtain multiple economic, societal and environmental benefits. And in order to achieve this, the policies that will maintain and enhance the soil organic carbon must be put in place. According to Batjes (1996) the global soil carbon store is approximately 2200 Gt (billion tonnes) and accounts for about 80% of total carbon in the terrestrial biosphere. Lal (2004) stated that two-thirds of it is in the form of organic matter, and three times the amount of carbon held in the atmosphere. However, with all these nutrients in the peatland, peatlands have been found to be vulnerable as far as carbon loss is concerned. Degradation of forest in form of burning of fossil fuels, clearing of forests for agricultural purposes and some other land use management practices have been solely responsible for this great loss. Because of carbon loss alone, one-quarter of the global land area has suffered a decline in productivity and in the ability to provide ecosystem services (Bai *et al*., 2008). Houghton, (1995) had earlier reported the loss of around 60 % of the carbon in the world's soils had been lost to land use in 19^{th} century. In addition to other factors responsible for the carbon loss are soil erosion (Montgomery, 2007) and peat land drainage (Joosten, 2009).The values placed on soils and its uses are mainly agricultural. Though soils are also of basic importance to the provision of many other ecosystem services, the major determinants of all the values and services mentioned are the amount and dynamics of carbon present in the soil.

Apart from the release of carbon dioxide due to peat oxidation, peatlands have also been known to release greenhouse gases GHGs like N_2O, CH_4 and CO_2 into the atmosphere due to accelerated decomposition as a result of land-use change or unsustainable land management practices (Lal, 2010).

Peatland Carbon Loss, Greenhouse Gas Emissions and Climate Change

The topic of soil organic carbon loss cannot be exhausted without the mention of its associated impacts on climate change. Climate change has been described as occurring as a result of the accumulation of greenhouse gases emitted from soil surface in the atmosphere arising from fossil fuels combustion (Haines, 2006). Lal (2004) reported that since 1750, the rise in the atmospheric concentration of carbon dioxide by 31 % has been largely due to fossil fuel combustion, vegetation burning on peatland (Figure 1), and change in land-use such as deforestation, excessive farming practices. This atmospheric concentration of carbon dioxide has increased from 280 ppmv in 1750 to 367 ppmv in 1999 and with current increase rate of 1.5 ppmv/year or 3.3 Pg C/year (1 Pg = Petagram = billiontonn) (IPCC, 2001). Thus, the links between the loss in soil organic carbon, with some other elements locked up in the soil and atmospheric concentration of CO_2 must be established. Conversion of peat swamp forests to oil palm plantation involves deforestation which if carried out leads to significant release of stored soil carbon, either in gaseous form as CO2 or liquid form as dissolved organic carbon, DOC. In other words deforestation and forest degradation, through burning of forest biomass, contributes to emission of GHGs from the peatlands to the atmosphere (Fearnside, 1997).

IIPC, (2001) also stressed that nitrous oxide (N_2O) is increasing at a rate of 0.8ppbv/year. According to Lal (2004), this anthropogenic enrichment of greenhouse gasses (GHGs) in the atmosphere has resulted into an increase in the mean global surface temperature of 0.6^oC. Hence, establishing the links between these GHGs and soil carbon content is a necessity. Peat land has been described as carbon/sink (Sabiham *et al*., 2012), and organic soil that contain about 65% of organic matter, they then become potential sources of carbon release to the atmosphere following land use activities such as deforestation (Figure 3), and some other practices highlighted above (Van der Gon and Neue, 1995).

Biodiversity Loss Due to Peatland Degradation

Central Asia is an area which is very rich in biodiversity: it is a source of many of Asian domestic plants; it contains many local species and has been selected as one of the globally important eco-region of the World Wildlife Fund (Brooks *et al*., 2006). Most of these fauna and flora have been known to thrive in this area due to good habitat suitable for their existence like fertile soil, rainforest and conducive eco-system. According to Spitzer and Danks (2006), peatland possesses large qualities or characteristics that favour the existence of different species of animals and plants. He further stated that peatlands are abundant in the boreal zones of Europe, Asia, and North America, where there are favourable climate and relative high precipitation. Parish and Looi, (1999) revealed that clearing of peatlands as a result of agricultural development results in a loss of biodiversity and a loss of habitat for some indigenous flora and fauna. There is high level of presence of flora and fauna prior to the invasion of peatlands for logging purposes for expansion of oil palm plantation. Some environmental groups claim that the tropical peatlands have a large variety of fauna and flora endemic to these areas (Figure 4), but the total destruction of the swamp forest has caused a lot of damages to the ecosystem of the forest and therefore the biodiversity is gone!

Preventing Peatland Carbon Loss and Further Peatland Degradation

Various human activities on peatland like deforestation in readiness for cultivation purposes, indiscriminate waste disposal on these soils, burning of fossil fuels and so on, have contributed in degrading the soil the more by exposing the nutrients locked up within the soil to the atmosphere, and has also contributed in polluting the water resources, (both surface and groundwater). Since about 65 % of the organic matter in the soil is carbon, there is need to safeguard this important nutrient from escaping into the atmosphere. All efforts must be put in place to ensure that the disturbed and degraded peatlands are protected from further emissions by making sure that peatlands remain wet, a condition which allows the accumulation and storage of carbon for peatland restoration. In as much the peatlands remain wet at all time, further emission of GHGs would be totally impossible and this would favour the restoration of peatland. According to Parish *et al*. 2008, the restoration of peatland remains the most effective way of reducing GHGs emission from degraded peatland and preventing climate change. Peatland conversion should also be discouraged. It is very important the peatlands are safe and protected from future conversion to ensure that biodiversity and other ecosystem services are well protected.

Conclusion

Impacts of land use change on peatland degradation have been reviewed. Peatland has been reported as very important source of major nutrients like carbon, and some GHGs which are better locked up in the soil mass as their escape to the atmosphere could trigger global warming. It has also been established that various human activities like conversion of swamp forests to plantation for agricultural purposes are responsible for the degradation of many of these peatlands. Desire to meet the global demand of oil palms was found to be responsible for major conversion of swamp forests in SE Asia to oil palm plantations. Trees were felled across the region which led to major and unprecedented deforestation in the region and subsequent release of GHGs from the peatland thereby triggering global warming. Other researchers attributed the release of these nutrients to the lowered water table which leads to shrinkage of the peats and subsequent degradation of peatlands and release of the embedded nutrients. The best possible ways of keeping the nutrients locked up in the peatlands were reported by many researchers as; avoiding new emissions from the peatlands by avoiding further land conversion; restoring degraded peatlands to enhance carbon sequestration; and improving management practices so as to reduce emissions from the restored peatlands. Government and relevant agencies should, as a matter of urgency, create more awareness on the need to stop further land conversion of swamp forest in favour agriculture, especially by the locals in the communities. Planting of trees should also be encouraged on the degraded peatlands. Cover crops and other peat-forming plants should be planted on the disturbed peatland for the purpose of restoring them. Adherence to the best management practices BMPs, as developed by the NGOs and government agencies in the oil palm industry should be enforced so as to limit the damages related to the peatland cultivation.

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Table 1. Extent of peatland developed for agriculture in Malaysia.

Region	Total Area of Peat (Ha)	Area Developed for Agriculture	
		Ha	%
Peninsular Malaysia	796,782	313,600	39.4
Sabah	200,600	NA	NA
Sarawak	1,765,547	554,775	30.8
MALAYSIA	2,762,929	868,375	70.2

Source: Abdul Jamil *et al.* (1989) and Melling, (1999)

Figure 1: Fossil fuel combustion and vegetation burning as another source of CO_2 emission from peatland

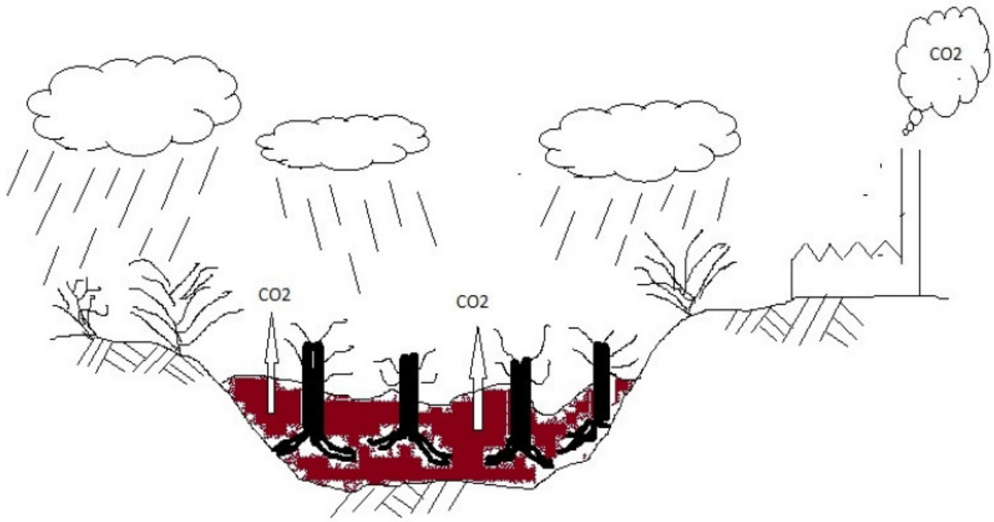

Figure 2: Drained peatland with dead vegetation emitting large amount of Carbon

Figure 3: Deforestation levels and Oil palm plantation adjacent to tropical forest

Figure 4: Different species of fauna found in the rainforest prior deforestation