Understanding Material Cycling Related to Human Activities in Tropical Areas — Changes in Quality of Water, Air, and Soil with Land Use Change —

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Currently, there are many environmental problems occurring at a global level with many directly related to human activities and their subsequent impacts on nature. In particular, rapid environmental changes are affecting tropical areas through rainforest deforestation, peat land degradation, and the pollution of both ground and surface water. These issues have occurred partly due to an increase in the human population, and its demands for timber, land and water resources.

In order to make sense of the scale of environmental changes and problems taking place at a global scale, it is essential to know how the changes in environmental conditions in tropical areas function at a macro and micro scale of material cycling[1] (Figure 1). Despite uncertainties in knowing the real amount of biomass that exists in different regions of the world, tropical forests have been found to account for up to 35% of global gross primary production (Melillo et al., 1993; Dixon et al., 1994). Thus, the uptake of atmospheric carbon dioxide (CO_2) by plant photosynthesis- with its high productivity - accounts for about 57% of global plant biomass. As such, we shouldn't underestimate the great impact tropical rainforests, including peat land forests, have on the global climate in the sense that they regulate the flow of many kinds of important elements such as carbon and nitrogen. Here, peat land forests are tropical moist forests where waterlogged soils prevent the decomposition of dead wood and leaves. Over the years, this creates a thick layer of acidic peat. According to one recent report, tropical peat land area is 441,025km^2 (~11% of global peat land area) of which 247,778km^2 (56%) is in Southeast Asia (Page et al., 2011). They revealed a large peat land carbon pool in Southeast Asia of 68.5 Gt (giga tonnes) equal to 77% of the whole tropical peat carbon pool. This is 11–14% of the total global peat carbon pool. In particular, Indonesia has the largest share of tropical peat carbon (57.4 Gt, 65%). As such, peat land forests in Southeast Asia are considered to be one of the most important parts of larger ecosystems due to the huge amount of carbon stock and biodiversity they contain. Yet, recent rapid and intensive deforestation to procure timber and land for commercial plants or crops (Oil palm or rubber plantations) with social and economic pressure (Koh et al., 2009) have induced fundamental changes in the material cycling. In regards to these changes, our knowledge of both natural and human-impacted environments in tropical areas is still very limited due to access difficulties and the inability to continuously monitor them. In this essay, I report on the field research that my present research group has conducted and the different environmental conditions we encounter.

Our group is presently conducting research on Sumatra Island, Indonesia where we focus on changes in material cycling in the peatland ecosystem. Our research area includes both natural and degraded (after changing land use) sites. Most parts of natural peatland forest have been converted into oil palm or rubber plantations through their felling and forest fires. In our present field site, natural forest is also preserved in forest reserve areas, and this has permitted us to simultaneously observe both natural and human-impacted environmental conditions and compare the sequential changes in material cycling in tandem with environmental change.

To correctly understand material cycling in peatland forests, especially in carbon and nitrogen cycling, many kinds of simultaneous observations need to be carried out. If it is the carbon cycle[2], we conduct 1) soil sampling to understand the carbon storage in soil, 2) ground and river water sampling, rainfall monitoring and water table monitoring to understand changes in water quality and quantity which determine the amount of carbon flow in water, 3) the measurement of CO_2 and methane[3] (CH_4) emission rates from soil surface to the atmosphere, and also 4) wood or soil decomposers[4] (such as termites and ants) activities to know how much carbon flows in the whole ecosystem. At the same time, we also have to measure nutrients in soil, water, and woods to understand nitrogen cycling[5] and other elements. This is because nutrient conditions also affect carbon cycling through controlling microbial metabolic activities. Sometimes, specific tools for measurement are necessary such as isotope analysis which gives us information on the history or degree of biogeochemical reactions. The collection of these data allows us to consider when, how, and what reactions occur in the observation site. Ultimately, this permits us to understand some parts of the whole ecosystem.

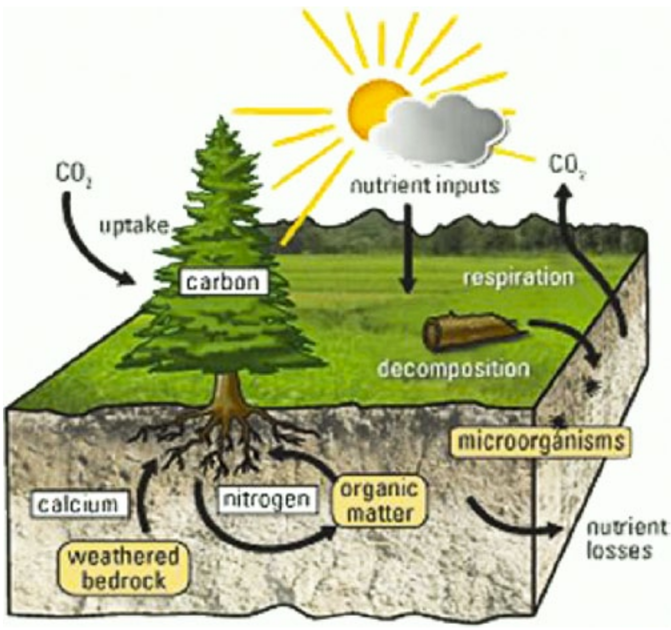

Fig. 1: Simple diagram of carbon and nitrogen cycling among the soil, vegetation, and atmosphere. This illustrates how these nutrients are cycled within the system. Source: Beldin, S.I., and Perakis (2009)

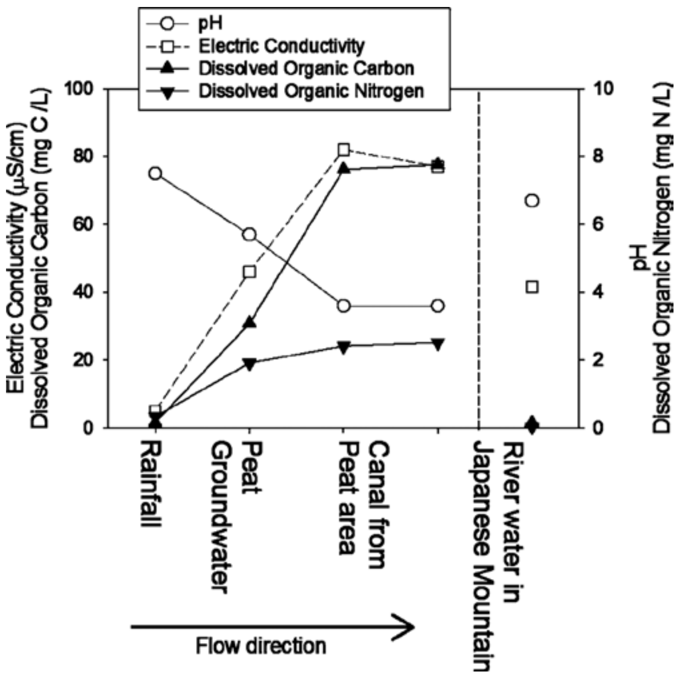

Fig. 2: Results of chemical components in sampled water in the peatland site in Sumatra, Indonesia. Arrows indicate the water flow direction. Same data of Japanese mountainous river site is also shown for comparison.

Our present research group consists of researchers from various backgrounds: hydrology, biogeochemistry, biology, and ecology. Our research targets also include various components and not only the analysis of one of their elements. As such, we deal with soil, water, air, tree, and insects: all important features of the ecosystems. And at a larger macro scale, we also must deal with microclimate information and geological information (see Kozan Osamu's article in this issue of the CSEAS newsletter). The important thing that must be kept in mind, is that all the elements and their functions relate to each other in a highly complex fashion. Land use change leads to changes in the chemical and physical properties of soil. When this occurs, gas (carbon and nitrogen emissions from soil to atmosphere), water movement, and water quality below the ground can be significantly affected. Insects such as termites, also play an important role in both carbon and nutrient cycling as wood or soil decomposers (see Kok-Boon 2012, 17-18). What this suggests to us is the necessity for careful observation of the whole ecosystem across its many interacting levels. Of course this is no easy feat, but our group is trying to do this through the multidisciplinary researcher base that exists at the Center for Southeast Asian Studies and the other institutions. We always welcome new researchers who are specialists of other disciplines to help us enrich our approach to our own field of research.

Even though our research in Sumatra peat land is just beginning, we have started to observe some changes in chemical parameters in rain water, peat land ground water, and river water discharged from this peat land area as part of our preliminary study (Figure 2). In Figure 2, we also show the results of river water from non peat land forest sites in Japanese mountain sites for comparison. The increase in electric conductivity and dissolved organic matter along the flow direction indicates that much dissolved inorganic and organic matters is discharged from degraded peat land areas through manmade canals. The concentration of dissolved organic matter in canal water (77 mg C/L (carbon per liter) and 2.5 mg N/L (nitrogen per liter) is much higher than that of groundwater in this area (31 mg C/L and 1.9 mg N/L). This implies that an increase of discharge water stored below ground through the creation of artificial canals can enhance the carbon and nitrogen discharge in downstream areas. Now, we have set up our field survey equipment (a number of wells for water table level measurement and for water collection) in degraded peat sites and oil palm plantation sites (Picture 1a and 1b) and will make a new observation plot in natural forest sites to observe the difference in material cycling among the sites. Continuous monitoring will allow us to understand the mechanisms.

Although a large number of scientific papers have been published on material cycling in tropical areas, most of them restrict their focus to the natural phenomenon of their observed dataset. However, we frequently encounter data which cannot be explained only through natural phenomenon. Nowadays, there are few places free from the effects of human impacts, and, especially in fields that are located close to residential areas, there are many kinds of impacts that change local environments. For example, people fell trees, create ditches for

Pict. 1: Peatland after cutting down the forest and fires (a). Oil palms (b) or rubbers will be planted.

Pict. 2: Teaching a local student methods to prepare a river water sample.

lowering water, and sometimes start fires on peatlands. These impacts can heavily affect observable values and must be included in any analysis of datasets and discussions.

Our Center offers us a great advantage to consider human impacts as there are many social scientists based here who provide natural scientists useful and relevant information on local people's thinking, activities, and their living conditions. This information can usefully explain the unexplainable parts of our observation data. At the same time, we, as natural scientists, hope our scientific data can be useful information for social researchers and contribute to how they can potentially understand local communities and the environments they exist within. Numerical (either in terms of quality or quantity) data made up of many observational components from the natural environment can be strong tools to strengthen social scientists discussions and allow them to provide clearer statistical evidence. Doing so will allow for a synergy to take place across disciplines working in the same field.

In concluding on our research, and thinking in terms of international research exchange, I realize the importance for exchanging the research techniques and knowledge between local researchers in Southeast Asian countries. Such exchanges permit us to discover new evidence in the field, greatly in part due to their intimate knowledge of the field, and its natural character. Although my research in peatland forest is only just beginning, I hope our research project will be a collaborative one with many local researchers and produce new findings in the near future.

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Notes

[1] Material cycling refers to the transfer of organic and inorganic compounds. Natural ecosystems are basically constituted by producers (plants which produce organic matter), consumers (which utilize organic matter for energy), and decomposers (which convert the organic matter to inorganic matter). Materials in the environment are used repeatedly by these living organisms. This is known as material cycling.

[2] The biogeochemical cycle (material cycling with biological or geological or chemical or some of them) by which carbon is exchanged between the different spheres of the Earth.

[3] The second most significant greenhouse gas next to carbon dioxide. CH_4 is also produced and consumed biologically by soil microorganisms.

[4] Organisms that absorb nutrients by utilizing organic matters and then convert them into inorganic forms.

[5] The most abundant gases in the Earth's atmosphere. In the cycle, nitrogen is converted by soil bacteria to compounds which can be assimilated by plants. This incorporated nitrogen is then taken in by other organisms, subsequently released, acted on by bacteria, and made available again to the nonliving environment.