อิทธิพลของการปลูกยางพาราต่อความอุดมสมบูรณ์ของดิน และการปลดปล่อยแก๊สเรือนกระจก

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บทคัดย่อ

ยางพาราเป็นพืชที่ให้ผลผลิตระยะยาว ความอุดมสมบูรณ์ของดินในพื้นที่ปลูกลดลงตามอายุของยางพารา โดยเฉพาะจากการสูญเสียธาตุอาหารไปกับผลผลิต และ การเซาะกร่อนดิน การใส่ปุ๋ย ปลูกพืชตระกูลถั่วคลุมดิน หรือใช้ระบบปลูกพืชที่เหมาะสมช่วยคงความอุดมสมบูรณ์ของดินไว้ได้ การเปลี่ยนพื้นที่ป่ามาปลูกยางพาราทำให้ชนิดและปริมาณของสิ่งมีชีวิตหน้าดินเปลี่ยนไป แต่ก็สามารถปรับเข้าสู่สมดุลใหม่ การปลูกสร้างสวนยางพาราสามารถปลดปล่อยแก๊สเรือนกระจกสู่บรรยากาศเป็นอันมากหากต้องทำลายป่าธรรมชาติ แต่ในสภาพสวนยางการปลดปล่อยแก๊สดังกล่าวค่อนข้างน้อย และยังเป็นแหล่งกักเก็บคาร์บอนได้เป็นอย่างดี

คำสำคัญ : การปลูกยางพารา ความอุดมสมบูรณ์ของดิน สัตว์หน้าดิน การปลดปล่อยแก๊สเรือนกระจก

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Influence of Rubber Plantation on Soil Fertility and Greenhouse gas Emission

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Abstract

Rubber tree *(Hevea brasiliensis)* is such a long life harvesting plant. Soil fertility under rubber plantation was decreased along rubber stand age, especially from crop removal and soil erosion in sloping area. Fertilizer application, legume crop covering and the use of suitable cropping system can be maintained soil fertility. Conversion of natural forest to rubber plantation effect to the species and density of soil macrofouna, and, finally it can be adjust to the new equilibrium. Large amount of greenhouse gases emitted from deforestation for rubber plantation establishment. However, gasses emission from rubber plantation was slightly low. Moreover, rubber plantation can mitigate the global worming by carbon sequestration.

Keywords : Rubber plantation Soil fertility Soil macrofauna Greenhouse gas emission

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Introduction

Rubber tree *(Hevea brasiliensis)* is indigenous to South America and it was introduced to colonial Southeast Asia by the British in the late 1800s. It is now supplies approximately 98% of the world's natural rubber, mostly from well-run plantations in Asia, Africa and Ceylon. Today most rubber tree plantations are in South and Southeast Asia and some also in tropical West Africa (1). In Thailand the first rubber tree was brought from Malaysia and planted in Trang province in 1899. They were grown in combination with indigenous plants and others fruit trees, food plants and other species. A promotion policy which started in 1911 and was further strengthened in 1978 made rubber plantation spread in the southern, eastern and northeast regions of the country. These cause a change in the production pattern of rubber, giving rise to large scale monoculture plantations which have play important role in the environment and in people (2).

Rubber plantations have changed the landscape. They can be seen all over the south of Thailand, from the highland areas down to the low lying plains and since the largest government promotion project in 2004-2006 clone seedling have begun sprouting in almost every province of the country replacing short-term cash crops (2). To establish new rubber plantation, the forest or the former vegetations must be eliminated which generally by slush and burn leading to temporary fertile soil. However, CO_2 from burning made an increment of CO_2 in the atmosphere. High temperature from burning can kill many soil born organisms. However, the new equilibrium are developed along the rubber life cycle. In addition, some rubber plantations in the south were located on 40-60 degree slopes, which result in soil erosion especially in the first stage of its growing that the canopies have not yet covered the space.

Rubber tree is such a deciduous and a long period of harvesting plant. Large amount of litters fall annually and accumulate in the floor becoming abundance feed of both flora and fauna which their habitats in the soil. Under rubber canopy, there are some shading plants that survive and make a diversity of plant. It seems like rubber plantation area showing the characteristic similar to natural forest compare to another monoculture crop. Whereas, some evident still inform and worn about the negative effect spreading of rubber plantation especially in Asia. This paper reviewed the effect of rubber plantation on the soil fertility, soil macrofauna and situation of greenhouse gas that might be derived from rubber plantation or relating activity of rubber cultivation both on positive and negative aspect.

Soil fertility under rubber plantation

Rubber tree is a long life deciduous and a high nutrient consumption plant. Tapping period is about 13-18 years (3) depending on the quality of tapping and fertilizer application for nutrient element compensation that are currently removed by latex harvesting. Investigation of nutrient cycle and soil fertility under rubber plantation in Hainan Island, China from 1954-1995 revealed that the output of N, K and Mg were more than their input in rubber plantation ecosystem. For 30-year rubber plantation the deficits of K, N and Mg per year were 23.41, 13.07 and 4.07 kg hm^{-2}, respectively.

Soil fertility decreases with increase of stand age of rubber plantation. Available P, available K, total N and organic matter decreased 48.2 %, 54.1% 56.7 % and 64.1 %, respectively. Total amount of nutrient cycle was also estimated. It showed that if the complete return of litters was considered without fertilizer addition, the consumption period for the main nutrient elements of rubber plantation was in the order P>N>K>Mg (4). Whereas, Karthikakuttyamma et al. (5) revealed that soil under rubber plantation showed an increase in P level, because of phosphate fertilizer residue. Though, soil under rubber plantation maintained high range of organic carbon, significant reduction occurs with replanting in organic carbon compare to soils from virgin forests. Total N, K, Ca and Mg are also comparatively low in rubber planting soil.

Growing cover crop in rubber plantation can retain soil moisture and protect soil erosion. Moreover, it can supply nutrient elements to the soil especially covering by legume plant. It was found that 32.6-56.5, 13.6-21.0, 2.9-4.3 and 2.4-4.3 kg ha^{-1} of N, K, P and Mg returned to the soil along 5 years of legume covering whereas only 3.8-10.4, 5.0-13.8, 1.3-2.6 and 1.4-2.4 kg ha^{-1} of their elements returned to the soil from grass covering (6). Rubber intercropping with another crop is the alternative pattern of land use. In China, rubber tree are intercropped with food crop such as sweet potatoes, maize, cassava, peanuts; economic plant like coffee, pepper, sugar cane, lemon grass, sisal hemp; fruit such as bananas and pineapple and many kinds of medicinal plants. Such crops or combinations of them are grown under rubber trees for effective land use (7).

Effect of rubber plantation and tea-rubber intercropping system on soil organic carbon pool were evaluated by recording change of soil organic carbon in an age sequence of 12, 20, 26 and 40 years old plantation. It was found that total organic carbon increased remarkably in tea-rubber intercropping tea-row soil but remained low in the rubber plantations and tea-rubber intercropping rubber-row soils at 40-year stand. In rubber plantation, total soil organic carbon did not change between stand age of 12 and 20 years, however it decreased at the 26-year stand. Whereas labile organic carbon increased in surface soils (0-10 cm.) with aging of rubber plantation and tea-rubber intercropping stands (8). In addition, rubber-tea intercropping decreased the vigorous of soil erosion compare to rubber monoculture and shifting cultivation which it showed 2,241, 2,694 and 48, 897 kg ha^{-1} yr^{-1} of soil erosion from rubber/tea system, rubber monoculture and shifting cultivation. (9).

Table 1 Density and biomass (mean ± SE, ind m^{-2} and g m^{-2}) of macroinvertebrates in the five plots. (11)

macroinvertebrates	Forest	Hevea 5	Hevea 10	Hevea 20	Hevea 30
Earthworms	171.2 ± 22.4	339.2 ± 61.1	489.6 ± 54.9	150.4 ± 18.3	97.6 ± 7.7
	52.3 ± 31.9	27.7 ± 6.9	52.0 ± 19.8	59.5 ± 23.7	9.2 ± 6.2
Termites	4920 ± 1107	21011 ± 7633	2080 ± 586	1334 ± 676	1976 ± 701
	10.9 ± 3.3	45.3 ± 15.1	3.3 ± 1.1	3.5 ± 3.2	2.7 ± 1.3
Ants	100.8 ± 44.6	374.2 ± 241.9	27.2 ± 9.1	24.0 ± 11.9	28.8 ± 14.6
	0.48 ± 0.33	2.44 ± 1.63	0.33 ± 0.22	0.18 ± 0.10	0.13 ± 0.08
Coleoptera	88.0 ± 32.2	41.6 ± 4.5	28.8 ± 7.0	83.2 ± 15.0	164.4 ± 39.4
	3.71 ± 3.31	0.20 ± 0.07	0.57 ± 0.38	1.08 ± 0.52	2.13 ± 0.61
Dermaptera	27.2 ± 9.8	20.8 ± 11.3	6.4 ± 4.5	6.4 ± 5.2	16.0 ± 10.1
	0.05 ± 0.02	0.03 ± 0.02	0.01 ± 0.01	0.15 ± 0.15	0.10 ± 0.08
Arachnida	41.6 ± 9.8	22.4 ± 7.2	16.0 ± 5.6	17.6 ± 7.3	40.0 ± 9.2
	1.08 ± 0.76	0.38 ± 0.21	0.30 ± 0.17	0.17 ± 0.08	1.15 ± 0.46
Chilopoda	81.6 ± 22.1	20.8 ± 7.1	19.2 ± 6.6	70.4 ± 17.3	24.0 ± 5.8
	1.23 ± 0.95	0.15 ± 0.07	0.23 ± 0.07	0.23 ± 0.07	0.12 ± 0.05
Diplopoda	142.4 ± 37.4	121.6 ± 30.7	35.2 ± 14.0	38.4 ± 7.2	51.2 ± 10.3
	3.00 ± 1.33	1.44 ± 0.28	6.81 ± 3.32	7.69 ± 6.72	1.59 ± 0.63
Isopoda	33.6 ± 9.2	6.4 ± 3.79	1.6 ± 1.7	27.2 ± 9.1	28.8 ± 10.0
	0.98 ± 0.81	0.37 ± 0.29	0.01 ± 0.01	0.79 ± 0.46	0.27 ± 0.19
Mollusca	22.4 ± 6.7	14.4 ± 6.9	9.6 ± 3.7	8.0 ± 3.8	4.8 ± 2.6
	0.33 ± 0.10	0.57 ± 0.22	0.30 ± 0.14	0.40 ± 0.27	0.14 ± 0.10
Other	118.4 ± 34.6	436.8 ± 139.1	755.2 ± 190.9	59.2 ± 15.1	169.6 ± 37.8
	0.22 ± 0.08	5.48 ± 5.21	1.16 ± 0.25	0.43 ± 0.18	0.43 ± 0.16
Total	5747 ± 1143	22414 ± 7522	3469 ± 5293	1819 ± 693	2602 ± 694
	74.24 ± 31.24	64.10 ± 16.37	65.00 ± 19.	74.09 ± 23.49	17.87 ± 6.82

Soil macrofauna diversity under rubber plantation

In the humid tropic soil, macrofauna such as earthworm, termite and ant etc. are known to be an important determinant of organic matter dynamic and nutrient cycle. The abundance and composition of their communities can be used as indicators of fertility status of soil (10). Deforestation and the pattern changing to cultivation area affect to macrofauna both species and their population. Bioactivity of soil under rubber plantation in the southern forest belt of Ivory cost was investigated and also compared to the secondary forest. It was revealed that the secondary forest had high population of soil invertebrates (5,750 no m^{-2}) dominated by termites (4,900 no m^{-2}). Biomass was also high (74 g m^{-2}) because of the large abundance of large litter-feeding earthworm. After 5 years of Hevea cultivation, macroinvertebrate density was 4 times greater than in the original forest mainly due to large increase of wood feeding termites. Earthworm communities were also modified; the abundance of large litter-feeders had decreased whereas small endogeics were more numerous. Biomass of ants was also greater in youngest plantation than in original forest (Table 2) (11)

Rubber tree is a deciduous plant which litter fall during summer season, and annual litter addition to plantation floor amounting to 7 ton ha^{-1} (12). The litter is not generally removed but persists on the plantation floor through a large part of the year and shows very slow rate decomposition due to high lignin content. Some phenolic compounds are known to be present in the rubber plant material (10). Earthworm account for the highest biomass among tropical soil macrofauna which play the role of decomposition, building and maintenance of soil structure (13).

Survey of earthworm species in rubber plantation of Tripura, India found at least 20 species of earthworms belonging to 10 genera and 10 families: Octochaetidae *(Eutyphoeus gigas, E. gammiei, E. comillahnus, E. assamensis, E.fastivas, Eutyphoeus* sp.1, *Dichogaster bolaui, D. affinis, Lenogaster chittagongensis, Octochaetona beatrix, Megascolecidae (Metaphire houlleti, Perionyx* sp.1 *Kanchuria sumerianus, Kanchuria* sp.1, *Kanchuria* sp.2), *Moniligastridae (Drawida nepalensis, Drawida sp.1, Dawida* sp.2), *Glossoscolecidae (Pontoscolex corethrurus) and Ocnerodrilidae (Gordiodrilus elegans).* Earthworms experienced mean soil temperature 25.9°C moisture 24.8 % pH 4.85 and organic matter 1.8 % mean value for density and biomass were 108.6 no. m^{-2} and 43.4 g m^{-2}. Among all the species, *Pontoscolex corethurus* show wide range of tolerance to edaphic factors (soil temperature 22-28 °C, moisture 8.7-51.0 % , pH 4.1-6.8, organic matter 0.67-8.46 %), thus it was dominant species of rubber plantation, representing 61.5 % biomass and 72 % density of total earthworm population. Rubber agroecosystem is largely dominated by endogenic species of earthworm (10).

Araujo et al.(14) also revealed that *Pontoscolex corethurus* was well adapt species and showed high activity in the soil. In this experiment, they added two tropical earthworm species, *Rhiodrilus contortus* and *P. corethrurus* in the soil incorporated with 3 kinds of leaf litter species (*Hevea bassiliensis, Carapa guianensis* and *Vismia* sp.) and measured the availability of mineral N, soil microbial biomass and decomposition rate of leaf litter in glasshouse experiment. It was found that earthworm density and biomass decreased at the end of experiment for the species *R. contortus*. The experimental unit which added P. corethrurus in leaf litter incorporated soil gave higher fecal material than those added *R. contortus* and the largest amount of cast produced in rubber leaf litter incorporation. The upper soil layer that present earthworm showed significant higher NO_3^- than those without earthworm. The soil with R. contortus showed NO_3^-, NH_4^+ and microbial biomass-N concentrations higher than soil with *P. corethrurus*. Treatment that added Rubber leaf litter showed the highest NO_3^-, NH_4^+ and microbial biomass-N concentrations.

Greenhouse gas from rubber plantation

Greenhouse gas which mainly derived from agricultural activity both on the cultivation areas and farmlands are CO_2, CH_4 and N_2O. Carbon dioxide emitted to the atmosphere from the decomposition of organic residue in aerobic condition, pollution gas from tractor or agricultural engine with drive by fossil fuels and from slush and burn land clearance for new planting or replanting (15,16). Methane (CH_4) release from organic decomposition on anaerobic condition that organic carbon is changed to CH_4 instead of CO_2. Whereas N_2O are accepted to increase with increase using of nitrogen fertilizers (17). In anaerobic condition which lack of oxygen, microorganism use NO_3^- for electron acceptor and N_2O was released to the atmosphere (18).

In many cases, changes in land use or land management result changes in CO_2, N_2O or CH_4 emissions beyond those associated with carbon sequestration. For example, a change from conventional tillage to no-till generally results in carbon sequestration, but it also reduces the use of agricultural field machinery, which subsequently reduces the use of fossil fuels and associated CO_2 emission. Nitrous oxide (N_2O) emission may also change with changes in soil management. Emissions of N_2O can be expressed in C-equivalent (C_{eq}) terms based on the global warming potential of N_2O that is compared to CO_2. It is estimated that 2.66 kg C_{eq} ha^{-1} is emitted per kilogram of applied synthetic nitrogen fertilizer (15)

Rubber plantation activity may produce greenhouse gas in several way such as from land clearing, production of raw material used in rubber plantation and greenhouse gas emission from plantation (3). Changing forest to rubber plantation, all the tree have to be cleared by cutting. The trunk of the big trees can be sent to a timber or wood industries, whereas debris or many small branches are burned and release CO_2 to the atmosphere. However, all farmers and plantation companies recognize that fire is the cheapest and easiest way of clearing vegetation for making space of a new crop and a tree. In summary, the benefit of fire are 1) provision of nutrient elements via ash 2) improvement of soil structure 3) elimination of field debris that making possible to work around in the plot 4) reduction in regrowth of weeds and 5) reduction in pest and disease problems (19). Land conversion from forests to rubber plantation emitted 6,097, 0 and 0.24 kg t^{-1} of CO_2, CH_4 and N_2O or 6,171 CO_2-eq of fresh latex. Production of material used in rubber plantation such as fertilizer, fuel for tillage and latex transportation emitted 118 CO_2-eq of fresh latex, and total greenhouse gas emitted from plantation was 85 CO_2-eq of fresh latex (Table 2). It also revealed that annual greenhouse gas emissions from forest replacing rubber plantations are about 6.4 CO_2-eq t^{-1} yr^{-1} of fresh latex, whereas only 0.2 CO_2-eq t^{-1} yr^{-1} from non-forest replacing land (3)

Carbon stock in the forest was range 150-254 Mg ha^{-1}, in rubber plantation was 97-116 Mg ha^{-1} and in oil palm plantation was 91 Mg ha^{-1}. Carbon dioxide flux decreased with decrease carbon stocks and plant species richness. Nitrous oxide (N_2O) flux in plantation area was higher than in natural forest because of nitrogen fertilizer application (16). Yashire et al. (20) measured N_2O fluxes in the 3 type of typical land uses in primary forest of Peninsular Malaysia, oil palm plantation and rubber plantation, and revealed that N_2O emission rate in primary forest was higher than in oil palm and rubber plantation and it had a clear seasonal change, with higher values during rainy season. Whereas those in oil palm plantation and rubber plantation had no seasonal change (19).

Rubber plantation, both growing as agroforest and monoculture contain carbon stock lower than natural forest. Carbon in above-ground biomass, below-ground biomass and soil in tropical forests are 235, 87 and 57 t ha^{-1}, whereas in rubber plantation these value are 103, 57 and 40 t ha^{-1} respectively (3).

Table 2 Greenhouse gas emissions from fresh latex production in rubber plantation (3)

Activity	Emission (kg t^{-1} of fresh latex)			
	CO_2	CH_4	N_2O	CO_2-eq
Land conversion from rubber plantation	6,097	0	0.24	6,171
Production of raw materials used in rubber plantation	35	<0.001	0.26	118
Emission from plantations	7.4	<0.001	0.25	85

Table 3 Sequestration of rubber within 30-year life period (4)

Plant components	C sequestration
Biomass of rubber tree (t hm^{-2})	90.5 (33.26 %)
Stem + main branch (t hm^{-2})	56.25
Secondary and tertiary branches (t hm^{-2})	16.13
Roots (t hm^{-2})	16.50
Fresh branch (t hm^{-2})	10.3
Leaves (t hm^{2})	1.50
Rubber produced (t hm^{-2})	24.02 (8.83 %)
Litter (t hm^{-2})	157.56 (57.91 %)
Total (t hm^{-2})	272.08 (100.00 %)
Mean (t $hm^{-2}a^{-1}$)	9.07

Rahaman (21) revealed that above ground biomass of rubber plantation were in the same range to humid tropical evergreen forest. It' s rages from 206.1 to 444.9 t ha^{-1} of dry weight in eleven years to thirty-three years rubber plantation. Whereas the biomass of untapped and thirty-three years rubber plantation was higher than in the forest. Change et al.(4) also estimated carbon sequestration and showed that total carbon sequestration of rubber within 30 year life period was 272.08 t hm^{-2} and large amount of carbon contain in the litter (Table 3). Therefore, rubber plantation can mitigate the global worming by carbon sequestration, especially establish new planting in abandon areas which avoid natural forest disturbance.

Discussion

Rubber tree is an economic plant and widely spread in Asia. In Thailand, plantation area expand to almost every province especially after rubber promotion policy were used. The plantation areas expand rapidly to the North-east and the North of the country. In addition, many abandon paddy rice fields in the South of Thailand have been replaced by rubber plantation because of the high price of rubber latex. Rear information about soil properties affect by changing the natural forest to rubber plantation in Thailand that should be investigated.

Rubber tree is such a long life plant which the harvesting period around 20-25 years. It consumes large amount of plant nutrient element because they currently loss by crop removal. The nutrient removal from rubber plantations is estimated to be 755, 833, 1,260 and 945 kg ha^{-1} of N, K, Ca and Mg respectively during replanting cycle (5). The result of investigation in Hainan, China showed that an input of N, K, Mg in the plantation areas were lower than the output (4). Thus enough fertilizer should be applied in rubber plantation along the harvesting period.

Change of natural forest or secondary forest to rubber plantation make risk of plant nutrient deficiency because nutrient cycle was interrupted. Moreover, clearing the land surface by slush and burn make soil surface susceptible loss by soil erosion especially in sloping land that can be seen in several places. It was found that soil loss from shifting cultivation and rubber monoculture were 48,897 and 2,694 kg ha-1yr^{-1}. Whereas only 63 kg $ha^{-1}yr^{-1}$ of soil lose from tropical rain forest (9). However, this problem can be mitigated by legume covering or inter-cropping. It was also found that soil loss under rubber-tea intercropping was 16.83 % lesser than in rubber monoculture (8). The advantage of Inter-row covering by legume is not only protect soil erosion but also increase plant nutrient especially N. Nitrogen fixation under legumes grown in association with rubber averaged 150 kg ha^{-1} yr^{-1} over a 5-year period, with maximum rates of nitrogen fixation being about 200 kg ha^{-1} yr^{-1} (22)

The important role of soil macrofauna is regulating the soil process such as decomposition of organic material and mineralization of nutrient. Species and density depend on abiotic environmental factors for example soil fertility, soil temperature, soil humidity and soil aeration which relate to microclimate condition; temperature, humidity and light condition (23). The investigation of macrofauna from the plantation of 5-year, 10-year, 20-year, and 30-year rubber tree found that density and biomass of macro invertebrate were high in 5-20 years old rubber tree and significant decrease in the 30-year old plantation. In the early stage of the succession, there were large population of xylophagous termites. Because, there are a lot of dead wood. After 10 years their abundant decreased and endogenic earthworms became abundant. In 30 year-old stand, the overall biomass of macro invertebrate dropped (11).

Earthworm is the most interested macrofauna, because they provide several benefits to the agriculture for example; help the decomposition of organic material, translocate plant nutrient element to the surface soil along its diet process and increase soil aeration by burrowing and cast producing. (13) *Pontoscolex corethrurus* was dominated earthworm found in many rubber plantations. Because it could be well adapted to the wide range of abiotic environmental factors (10). However, some evidences show that *Pontoscolex corethrurus* was not the best specie for mineralization, although it showed high activity (14).

Clearing tropical forests has a significant environmental impact, in particular on climate change. Carbon dioxide is by far the most important. Approximately 20 % of the world CO_2 emissions caused by deforestation.

Concentration of CO_2 are now 25 % higher than in pre-industrial times and are rising by 0.5 % each year (21). Recently, It was estimated that soil emission from humid tropical forest account for 20-50 % of all global sources of atmospheric N_2O (20). In Thailand growing rubber tree by replacing natural forest more occur in new planting area like the Northeast and the North regions. Whereas rubber plantation in the old area like the southern and the eastern region were replanting. Carbon in above-ground biomass, below-grown biomass and soil in tropical forest are 235, 87 and 57 t ha^{-1} respectively, whereas for rubber plantation these values are 103, 57 and 40 t ha^{-1} respectively. Thus, overall loss of carbon from above-ground biomass, below-ground and soil carbon were 132, 30 and 26 t ha^{-1} respectively (3).

Along 20-25 year of rubber tree growing in the large area that microclimate similar to the natural forest leading to the resemble of green house gas emission situation. In addition, there was evidence showed higher N_2O emitted from natural forest than from oil palm and rubber plantation, especially in rainy season (20). Moreover, rubber plantation can mitigate the global worming by carbon sequestration.

Thus, proper management in rubber plantation to maintain soil fertility and concern about food security should be considered. Greenhouse gas emission from rubber plantation are not serious situation, except conversion of natural forest to the plantation. In addition, large amount of carbon was stocked in the area.

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