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Title：Forest carbon market; a possibility to improve income for forest protectors

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Abstract

Net Ecosystem Production (NEP), carbon sequestration or carbon accumulation is a fundamental property of ecosystems. It was originally defined as the difference between the amount of organic carbon fixed by photosynthesis in an ecosystem and total ecosystem respiration. Based on this definition (Fig. 1), NEP represents the organic carbon available for storage within the system. In other ways, NEP is known as the rate of carbon accumulation in forest ecosystem.

Study was conducted in a tropical evergreen broadleaved forests, Northwest Vietnam at 21°23'N and 103°38'E.

The NEP or rate of carbon accumulation in a forest ecosystem is estimated as NEP = ΔM + ΔCr + Lf + Fp – Rs, where ΔM is aboveground biomass increment, ΔCr is coarse root increment, Lf is aboveground litterfall, Fp is fine root production, and Rs is heterotrophic respiration (soil respiration).

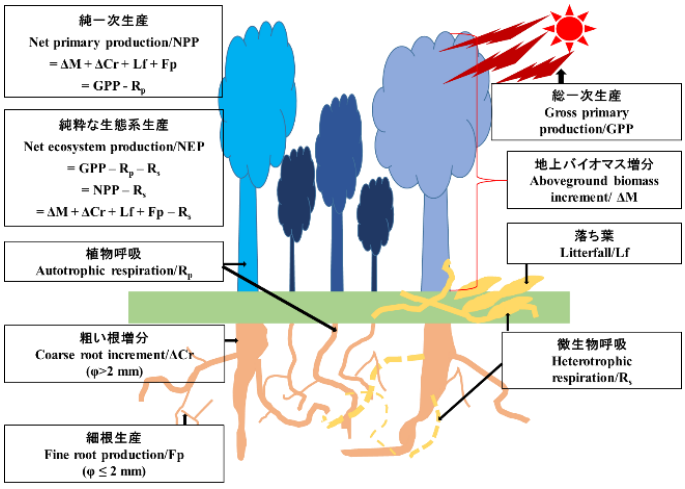

Figure 1. Net Ecosystem Production estimation

The results indicate one hectare of secondary broadleaved forest in Vietnam can accumulate 6.6 Mg C y^{-1}, more than twice that of old-growth forest at 2.6 Mg C y^{-1}. The NEP of evergreen broadleaved in Vietnam is much higher than some other forests around the world (Table 1).

The international carbon market was developed under the Kyoto Protocol, and today carbon pricing initiatives are proposed, continuously, at regional and national levels, especially in developing countries. This alone underlines the strong endorsement that carbon pricing still receives attention well compared to other policy instruments to reduce greenhouse gas emissions. Like any other products, the carbon price fluctuates year by year, region by region, and country by country; it is higher in Europe and developed countries such as Japan, Australia than many other parts of the world.

The carbon price is implemented in the form of carbon taxes to CO_2 emitters. On the other hand, CO_2 emitters can buy carbon certificates from CO_2 absorbers such as forest owners and/or protectors to ensure that they pay for the same amount of CO_2 they emitted to the atmosphere. It is obvious that to gain carbon certificate, forest owners and/or protectors must approve how much carbon is now

stored and will be accumulated in their own forests. Identifying carbon prices is not easy work. It must be based on the economic status and conditions of each country. For sustainable natural forest management, the rule of thumb is that forest carbon pricing must ensure the minimal daily life of protectors. An example is that to successfully protect forests in Sabah Borneo Island, Malaysia, the carbon price is set as US$28 per ton of carbon for primary forest and it is even higher at US$47 per ton of carbon for a mixed forest of timber and palm.

In Vietnam, carbon price should be identified locally based on economic and natural status other than using one flat rate for the whole country. This ensures that payment for carbon must minimally sustain the livelihood of local people. For example, in the northwest region of Vietnam local people sustain their life through paddy rice and shifting cultivation, leading to low requirements for daily life. In the Central Highland region growing coffee brings much higher income for local people. If the same rate is paid to local people, who living in Central Highland cannot sustain their life this can lead to illegally logging forests: unsustainable forest management. For example, a six-person household in northwest region participates in protecting 10 ha of secondary natural forests, equaling to 65 tons carbon accumulated in their forests per year (Table 1). To minimally sustainable their life, it requires 1.080 kg of rice (15 kg rice per person per month), equaling to US$648 (0.6 US$/1 kg rice). Then, the carbon price must be 10 US$/ton carbon. Current payment for forest protection in Vietnam is US$10 ha/year without considering carbon accumulation. Therefore, US$55 ha/year more should be paid to forest protectors and this should come from CO_2 emitters through forest carbon certificate. Local people can get forest carbon certificate from responsible authorities and sell it to CO_2 emitters.

Table 1. Net ecosystem production of different forests around the world

Forest type	Study location	NEP (Mg C ha^{-1} y^{-1})	Measuring period	Sources
Evergreen old-growth broadleaved forest	21°23'N, 103°38'E; Vietnam	2.6	2014–2017	The present study
Evergreen secondary broadleaved forest		6.6		
A Japanese red pine (*Pinus densiflora*) stand	35°27'N, 138°46'E; Japan	2.9	1999–2008	[1]
A dry evergreen forest	14°30'N, 101°55'E; Thailand	0.7	2004	[2]
A young larch forest	62°13'N, 129°l0'E; Russia	2.4	1998–1999	[3]

[1] Ohtsuka T, Negishi M, Sugita K, Iimura Y, Hirota M (2013) Carbon cycling and sequestration in Japanese red pine (*Pinus densiflora*) forest on lava flow of Mt. Fuji. Ecological Research 28:855–867.

[2] Adachi M, Ito A, Ishida A, Kadir WR, Ladpala P, Yamagata Y (2011) Carbon budget of tropical forests in Southeast Asia and the effects of deforestation: an approach using a process-based model and field measurements. Biogeosciences 8:2635–2647.

[3] Sawamoto T, Hatano R, Shibuya M, Takahashi K, Isaev AP, Desyatkin RM, Maximov TC (2003) Changes in net ecosystem production associated with forest fire in Ihiga ecosystems, near Yakutsk, Russia. Soil Science and Plant Nutrition 49:93–501.