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Comparative Carbon Footprint and Ecological Footprint of Loss and Gain of Forest and Agriculture Area due to Large-Scale Water Development Project

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Abstract

Quantitative evaluation of environmental loss and gain of forest and agriculture area were analyzed from the large-scale water development project in Thailand, The Increasing Volume of Water of Mae Kuang Project. It was found that after the project was completed, forest land will be increased and remove carbon dioxide in the atmosphere for about 7,106 tCO_2e. Ecological footprints in forest areas found footprints in the uptake of carbon dioxide from the reforestation areas have increased for about 1,476 ha_G. Agriculture land will be increased and remove carbon dioxide in the atmosphere for about 42,087 tCO_2e. Ecological footprints in the uptake of carbon dioxide from the agriculture areas have increased for about 2,834 ha_G. In terms of ecological footprints, about 4 and 11.27 times better use of land due to more forest area and better irrigation. From this study, it was found that footprints in forest and agriculture areas have a more positive impact than a negative impact. If construction is completed with better water management and able to deliver water to irrigation areas which helps increase the chances of absorbing more carbon dioxide from plants that can be cultivated throughout the year.

Keywords : water development project; carbon footprint; ecological footprint; Thailand

Introduction

Large-scale water development project in Thailand is required by law to conduct the environmental impact assessment (EIA) on the project prior to the approval of the project construction. According to Office of Natural Resources and Environmental Policy and Planning (ONEP) [1], large-scale water development project is defined as dam or reservoir with more than 100 million cubic meter of water or area contain more than 15 square kilometer of water or project with irrigated area of more than 80,000 rai (128 square kilometer when 1 rai equals 1600 square meter). Normally the project owner is required to conduct the environmental impact assessment (EIA) by following templates guided by ONEP with 4 main environmental impacts to be studied; impact on physical resources, biological resources, human use value and quality of life value. The Increasing Water Volume in Mae Kuang Udom Tara Project was being developed under the Royal Irrigation Department. Prior to the project construction, the EIA was conducted and report was published in 2009 with 4 main environmental impacts [2].

For the environmental impacts on physical value, one of the studies is the loss of natural forest and local agricultural plantation to be replaced with the project area (offices and other activities related of the project). This impact evaluation is in the form of monetary value of wood mass loss from tree cutting, the EIA however, did not quantitatively evaluate ecological loss due to the project. Also, the EIA report estimated the increasing irrigated area downstream of the project due to more water accessibility and again, did not quantify positive environmental impact to the irrigated area. These conventional impact study can be further evaluated and presented in the more up to date parameters of ecological and carbon footprints.

In this study, the environmental loss and gain from the large-scale water development project were being quantified in terms of ecological footprint (area base) and mass of carbon dioxide equivalent (kgCO_2e or tonCO_2e) or carbon footprint. This evaluation is to present another angle of environmental impact presentation of the large-scale project towards sustainability development goal.

Materials and Methods

Case study: Increasing Water Volume of Mae Kuang Udom Tara Project

From [2], the project of increasing water volume was being constructed by deviate 113 million cubic meter of water per year from Mae Tang river into Mae Ngat reservoir and then, 160 from Mae Ngat million cubic meter of water per year to Mae Kuang reservoir, as shown in Figure 1. Water from Mae Kuang reservoir was then flow into Mae Ping river, the main river in Northern Thailand. The project was expected 160 million cubic meters of water at Mae Kuang reservoir and improve water stability downstream within the area and then improve water management within northern Mae Ping river basin. The increasing of irrigation area was shown in Figure 2.

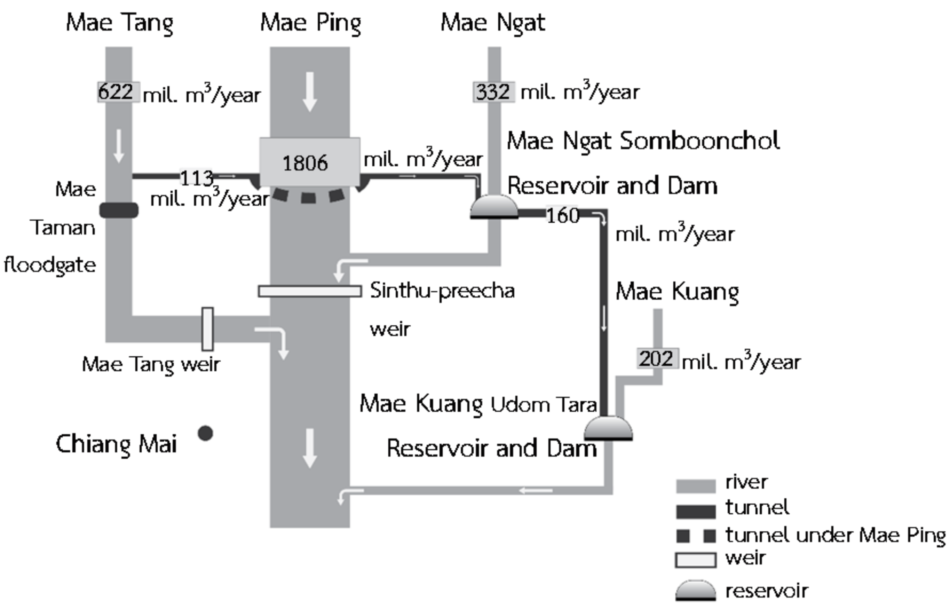

Figure 1 Schematic diagram of the Increasing Volume Water of Mae Kuang Reservoir Project (Adapted from the project's EIA report [2])

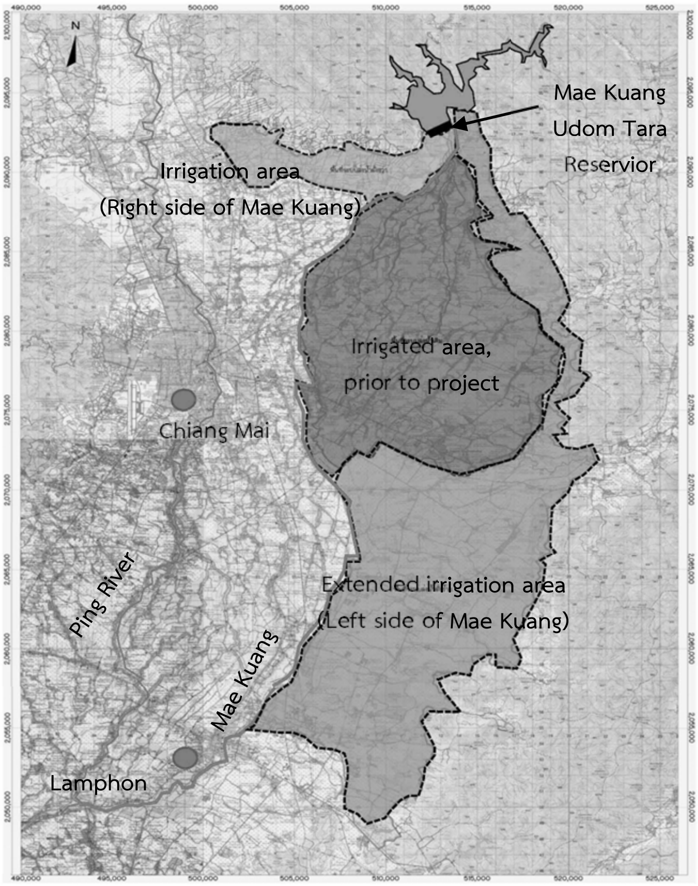

Figure 2 Increasing irrigation area after the project completion (Adapted from [3])

Calculation of greenhouse gas emission and removal

The assumption in this study was that when designated forest area is cleared for any anthropogenic project, potential use of atmospheric CO_2 due to plant photosynthesis in that area is demolished. Wise versa, after the project construction and the reforest planting program for more trees under the EIA agreement is succeeded, potential removal of atmospheric CO_2 occurs due to photosynthesis. Another point is that CO_2 uptake increases in irrigation area due to more accessibility of water from the large-scale water project.

The greenhouse gas emission due to the loss and gain of forest area was estimated based on carbon footprint calculation; footprint equals to activity data multiplied by emission factor. The emission factor used in this study was based on Guyana's Forest Carbon Monitoring System [4]. Based on [4], the emission factor applied to this study was of deforestation with change to infrastructure (high potential for change); 1,042.0 $tCO_2e\ ha^{-1}$ and to agriculture area of 1,141.9 $tCO_2e\ ha^{-1}$. The forest replanting program causing increasing in forest area, which increase the atmospheric CO_2 removal and the removal factor is 0.95 tCO_2/rai/yr for forest with local trees (slow growing) [5]. The large-scale water development project also increased the irrigation area downstream and this also caused better atmospheric CO_2 removal due to more effective plantation, compared to the 'before project' time frame. Atmospheric CO_2 removal was estimated with same removal factor.

Calculation for ecological footprint

For the concept of ecological footprint of losing forest area for the anthropogenic project, ecological footprint (EF), in area unit was calculated based on conventional calculation of EF from [6] and modification of 35% carbon sequestration from ocean, ecological footprint based on global agricultural ecological zone (EF-GAEZ) from [7] as,

$$EF_{forest} = \frac{CF_{forest} \times (1 - F_{CO_2})}{S_{CO_2 - Nation}} \times YF_f \times EQF_f$$

When *EF* is ecological footprint [in global hectare, ha_G], CF_{forest} is greenhouse gas based on land use change [tCO_2e], FCO_2 is CO_2 adsorption rate of reservoir, 35%, $SCO_{2\text{-}Nation}$ is greenhouse gas sink in forest, in Thailand [tCO_2/ha], YF_f is yield factor of forest, in this case $SCO_{2\text{-}Nation}$/ $SCO_{2\text{-}world}$. *EQF* is equivalent factor [ha_G/ha]. Equivalent factor of the forest, EQF_f is based on [8] and for forest, EQF_f is 1.26 and agricultural area, *EQF* is 2.51.

Sequestration rate of forest in Thailand

The $SCO_{2\text{-}Nation}$ in this study was from [9] after [10]. The carbon sequestration of semi-evergreen forest, 14.1% of the forest in Thailand, was 7.53 tCO_2e/ha/yr while 3.51 tCO_2e/ha/yr from mixed-deciduous forest, 53.9% of the forest in Thailand was reported. The average of 4.34 tCO_2e/ha/yr was then used as $SCO_{2\text{-}Nation}$.

Sequestration rate of world forest

Based on [7], the world sequestration rate from 26 forest biomes around the world and was reported 0.95 metric tonnes of carbon per hectare per year. The data was then converted to be 0.95x44/12 equals to 3.48 tCO_2e/ha/yr.

Yield Factor for agricultural area

For agricultural area loss from this project, they were mostly fruit plantation for longan and mango. From FAOSTAT [11], primary fruit data for Thailand was 9.06 t/ha and 1.32 t/ha for world average (on year 2017). Yield factor for agricultural area in this study was 9.06/1.32 equals 0.68. Based on the estimation in the project's EIA report, increasing area for plantation of rice, soybean, potatoes, garlic and vegetable were reported. The yield factors were then calculated differently for each types of plants using 2017 FOASTAT data.

Results and Discussion

Based on the EIA report [2], area loss and gain due to project development were presented in Table 1. Since the project was mostly for construction of tunnel to deviate water from Mae Tang river to reservoirs, less forest land was used compared to other water development projects. The total area loss was 601,800 square meters. Irrigation area gain from this project was about 94,510,000 m^2 and 1,280,000 m^2 for foresting. When carbon footprint was calculated correction factor was used for 85% survival rate for foresting (normal practice, [12]) and 75% irrigation area was used for more realistic atmospheric CO_2 removal mechanism.

Figure 3 shows the estimation of carbon footprint from area loss and gain due to the project development. For forest, loss of potential atmopheric CO_2 removal of 2,104 tCO_2e due cut of forest plants. However, since forest rehabilitation project was established and maintained for at least 11 years following the project, 7,106 tCO_2e was calculated to be removed from atmosphere due to new area of forest at Mae Tang national forest and at Mae Taman floodgate area. For the agricultural area loss due to the project, 4,305 tCO_2e emitted to atmosphere. However, after project completion, 42,087 tCO_2e of etmospheric CO_2 will be potentially removed due to increasing irrigation area.

Another way to present this information was by calculating ecological footprint of the project in the unit of global hectare, as shown in Figure 4. By using carbon footprint presented in Figure 3, ecological footprint due to lossing land both forest and agricultureal area were 496 ha_G and 276 ha_G, reprectively. However, the forest rehabilitation and increasing irrigation area improve the ecological footprint for 1,972 ha_G and 3,110 ha_G, respectively.

From Figure 3 and 4, this study proposed another environmental impact presentation by showing values of forest and agricultural area loss and gain, not only for their monetary value but for improvement of environmental condition in the form of carbon footprint and ecological footprint.

Table 1 Area loss and gain from the Increasing Water Volume Project

Type	Area m^2
Loss to roads, construction area, tunnel portal and pumping station area	
Forest	210,400
Agriculture area (fruit plantation and corn)	391,400
Gain	
Forest: rehabilitation project at Mae Tang national forest and at Mae Taman floodgate area	1,280,000
Agriculture: increasing irrigated area downstream	94,510,000

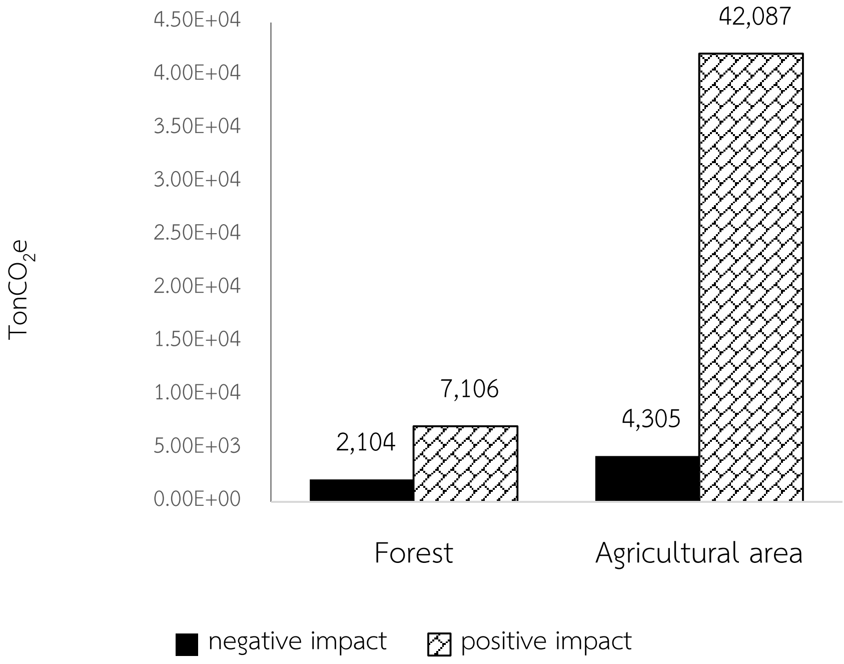

Figure 3 Carbon footprint from area loss and gain

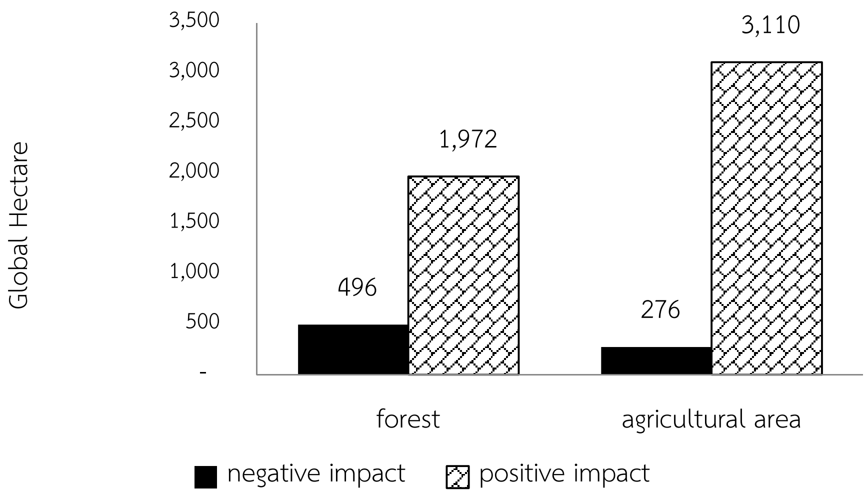

Figure 4 Ecological footprint in global hectare from area loss and gain

Conclusion

This study proposed another environmental impact presentation by showing values of forest and agricultural area loss and gain, not only for their monetary value but for improvement of environmental condition in the form of carbon footprint and ecological footprint. For carbon footprint, 3.38 times of CO_2e removal from the atmosphere in the area affected due to forest rehabilitation and 9.77 times of CO_2e removal from the atmosphere due to more effective agricuture because of better water accessibility and more irrigation area. In terms of ecological footprints, about 4 and 11.27 times better use of land due to more forest area and better irrigation.

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