CHAPTER 5

Conclusions and Recommendations

The research objectives were to evaluate the biological production, carbon and nutrient accumulations in ecosystems of a series of *Pinus kesiya* plantations in highland watershed at Boakaew Watershed Management Station, Chiang Mai. The biological production of plantations included pine trees and succession tree species. The data were compared to adjacent fragmented forests. The ecosystem involved three nutrient compartments; tree biomass, forest floor and soil. The overall data imply to the roles of reforestation through pine plantation on carbon and nutrient storages, and further affect on reducing atmospheric CO_2 and global warming.

5.1 Tree Biomass in a Series of Pine Plantations and Fragmented Forests

(1) Biomass of Pine Trees and Succession Tree Species

Growths of pine trees in 21 age-class pine plantations of 14 to 34 years old including stem diameter and height growths were varied among plantations, and did not increase continuously with stand ages. Some factors especially site factors, and different densities of pine and succession trees were affected on the pine growths and production. Their mean height and stem diameter (dbh) in these stands were in ranges of 15.31-23.30 m and 24.24-35.37 cm, respectively. The annual height increment varied between 0.52-1.15 m/yr, whereas the annual dbh increment was 0.94-2.24 cm/yr.

As the same as pine growths, pine biomass in different age plantations did not increase continuously with stand ages. The values were 23.6 to 212.7 $Mg.ha^{-1}$. The majority of pine biomass was allocated in the stem component, followed by root, branch and leaf. The high fluctuation of pine biomass was observed among the pine plantations.

The number of succession tree species in 21 pine plantations varied between 16-69 tree species. Their biomass in pine plantations were varied from 8.1 to 94.1 $Mg.ha^{-1}$, and did not increase with stand ages. Their biomass contributed to 4.2-71.7% of total plantation biomass.

The total tree biomass in a series of 21 age-class pine plantations involved biomass of pine and succession broad-leaved trees. The amounts were varied between 70.5-248.2 $Mg.ha^{-1}$, and did not increase continuously with stand ages.

(2) Biomass of Fragmented Forests

Biomass of tree species in fifteen fragmented forests were different, 117.3 to 253.3 $Mg.ha^{-1}$ (201.1 $Mg.ha^{-1}$ in average). The average amounts allocated in stem, branch, leaf and root components were 130.0, 40.5, 3.3 and 27.3 $Mg.ha^{-1}$, respectively The biomass amounts were stored mainly in tree species of Fagaceae, Pinaceae and Theaceae families. Among 103 species, *Pinus kesiya* had the highest biomass amount, and followed by *C. acuminatissima*, *S. wallichii*, *C. diversifolia*, *Q. brandisiana*, *T. rufescens*, etc.

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5.2 Biomass Carbon and Nutrients in Pine Plantations and Fragmented Forests

(1) A Series of Pine Plantations

Stored carbon amounts in biomass of tree species in different age-class pine plantations were different, 46-140 $Mg.ha^{-1}$, separated to 12-106 $Mg.ha^{-1}$ in pine trees and 6-69 $Mg.ha^{-1}$ in succession trees. The amounts did not increase continuously with stand ages. Similar to other nutrients, differences in the stored nutrients were found: nitrogen; 370-965 $kg.ha^{-1}$ (pine: 55-490 $kg.ha^{-1}$ for pine, succession trees: 65-765 $kg.ha^{-1}$), phosphorus; 44-127 $kg.ha^{-1}$ (pine: 6-58 $kg.ha^{-1}$, other trees: 263-680 $kg.ha^{-1}$), potassium; 9-107 $kg.ha^{-1}$ (pine: 40-362 $kg.ha^{-1}$, other trees: 44-523 $kg.ha^{-1}$), calcium; 480-1,329 $kg.ha^{-1}$ (pine: 70-627 $kg.ha^{-1}$, other trees: 94-1,113 $kg.ha^{-1}$), and magnesium; 75-279 $kg.ha^{-1}$ (pine: 10-86 $kg.ha^{-1}$, other trees: 21-249 $kg.ha^{-1}$). The carbon and nutrients were stored mainly in tree species in the families of Fagaceae, Theaceae, Myrtaceae, Leguminosae, Euphorbiaceae, Rubiaceae and Lauraceae.

(2) Fragmented Forests

Carbon storages in biomass of tree species in five fragmented forests varied between 58-125 $Mg.ha^{-1}$. The storages of other nutrients were different: nitrogen; 643-1,384 $kg.ha^{-1}$, phosphorus; 90-195 $kg.ha^{-1}$, potassium; 440-948 $kg.ha^{-1}$, calcium; 935-1,883 $kg.ha^{-1}$, and magnesium; 210-451 $kg.ha^{-1}$. The large amounts of nutrients were accumulated in stem component, followed by roots, branch and leaf. The majority amounts were stored in *Pinus kesiya*, *Castanopsis acuminatissima*, *Schima wallichii*, *Castanopsis diversifolia* and *Quercus brandisiana*.

5.3 Stored Carbon-Nutrients in Forest Floor and Soils under Pine Plantations and Fragmented Forests

(1) A Series of Pine Plantations

Forest Floor:

The dry matters of forest floor in different age pine plantations varied between 4,122-8,379 $kg.ha^{-1}$. Stored carbon in organic layers varied between 1,668-3,151 $kg.ha^{-1}$, and mainly in pine needles. The amounts of nutrients were different: nitrogen; 28,955-69,893 $kg.ha^{-1}$, phosphorus; 224-461 $kg.ha^{-1}$, potassium; 2,123-7,733 $kg.ha^{-1}$, calcium; 2,321-5,695 $kg.ha^{-1}$, and magnesium; 425-947 $kg.ha^{-1}$.

Soils:

The amounts of soil organic matter within 160 cm depth under different age pine plantations varied between 138.65-306.30 $Mg.ha^{-1}$. The different amounts were found for carbon (80.43-276.46 $Mg.ha^{-1}$), nitrogen (10,145-18,935 $kg.ha^{-1}$), phosphorus (27.78-84.98 $kg.ha^{-1}$), potassium (4,828-6,021 $kg.ha^{-1}$), calcium (423-8,198 $kg.ha^{-1}$), magnesium (353-1,211 $kg.ha^{-1}$), and sodium (619-694 $kg.ha^{-1}$).

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(2) Fragmented Forests

Forest Floor:

The dry matters of forest floor in fragmented forests varied between 5,855-7,644 kg.ha^{-1}. The amounts were different for other nutrients: carbon; 2,151-2,726 kg.ha^{-1}, nitrogen; 42,571-69,386 kg.ha^{-1}, phosphorus; 298-408 kg.ha^{-1}, potassium; 3,676-9,055 kg.ha^{-1}, calcium; 3,642-5,837 kg.ha^{-1} and magnesium; 635-915 kg.ha^{-1}.

Soils:

The amounts of soil organic matter within 160 cm depth in five fragmented forests were varied between 164-477 Mg.ha^{-1}. The amounts were different for each nutrient: carbon; 95-276 Mg.ha^{-1}, nitrogen; 9,048-19,845 kg.ha^{-1}, phosphorus; 43-63 kg.ha^{-1}, potassium; 3,656-8,078 kg.ha^{-1}, calcium; 1,349-6,872 kg.ha^{-1}, magnesium; 587-2,121 kg.ha^{-1} and sodium; 392-461 kg.ha^{-1}.

5.4 Ecosystem Carbon-Nutrient Storages in Pine Plantations and Fragmented Forests

The ecosystem carbon stocks including in biomass, forest floor and soil compartments in five age-class pine plantations were different, but did not increase continuously with stand ages. The large amounts were stored in soils (40.7-77.5%), followed by plants (21.3-57.9%) and litterfall (0.7-1.3%). The complex cycling of carbon in plantation ecosystems involved exchanges among pine trees, succession tree species, forest floor and soils as well as animals and microbes.

In five fragmented forests, the large amounts were also stored in soils (41.2-72.5%), followed by plants (26.8-57.7%) and litterfall (0.7-1.2%). The ecosystem carbon stock of the most abundant fragmented forest was higher than pine plantations.

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