ECOSYSTEM WATER STORAGES OF CONSERVATION AND UTILIZATION COMMUNITY FORESTS OF KAREN TRIBE, CHIANG MAI, NORTHERN THAILAND

Taparat Seeloy-ounkeaw[1,*], Soontorn Khamyong[2], Niwat Anongrak [3]

[1] Department of Plant Science and Natural Resources, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand
[2] Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand
[3] Graduate School, Chiang Mai University, Chiang Mai 50200, Thailand
*e-mail: tprsee@hotmail.com

Abstract

The community forest of Karen people at Nong Tao village, Mae Wang district, Chiang Mai province, northern Thailand has been divided into two purposes; conservation (CF) and utilization (UF) forests. By a method of plant community analysis, 50, 40 x 40 m sampling plots were arranged in each forest using a stratified random sampling in areas between 1,000-1,800 m altitude. Stem girth at 1.3 m above ground and height of all tree species with $\geq$1.5 m height were measured. Totally 244 tree species (166 genus, 73 families) in CF and 132 species (93 genus, 51 families) in UF were found. The family of Fagaceae had the highest species richness (22 species). *Pinus kesiya* was the most dominant tree species in both forests. Other dominant trees in CF were *Schima wallichii* and oaks whereas those in UF were mainly *Quercus brandisiana.* Species diversity by Shannon-Wiener Index (SWI) was higher in CF (6.19) and lower in UF (4.16). CF had somewhat better forest condition than UF with mean indices of 54.45 and 50.16, respectively. Forest biomass was high in CF (252.36 $Mg.ha^{-1}$) and lower for UF (139.74 $Mg.ha^{-1}$). These biomass contained water amounts of 112.38 and 59.30 $m^3.ha^{-1}$, respectively. Maximum water storage within 2-m soil profiles of CF and UF were 6,100.30 and 6,565.10 $m^3.ha^{-1}$ whereas water storage on 1st August 2012 were 4,506.18 and 5,204.03 $m^3.ha^{-1}$, respectively. (78.41 and 73.18% of maximum storages). The two community forests (880 ha) could store water within 1-m soil profiles as 1,990,267.20 $m^3.ha^{-1}$ (1,360,032 and 630,235.20 $m^3.ha^{-1}$ in CF and UF). Within 2-m soil profiles, the water storage in community forest was increased to 4,219,077.60 $m^3.ha^{-1}$ (2,955,878.40 and 1,263,199.20 $m^3.ha^{-1}$ in CF and UF). Differences in original plant communities, forest utilization, and forest condition between CF and UF resulted in different ecosystem water storages of these two community forests. The water supply from the community forest is greatly beneficial to villager livelihood and lower land communities.

Keywords: community forest, montane forest, forest biomass, water storage, Karen tribe

Introduction

One of important functional roles of forest ecosystem is the hydrologic cycle. Input of water into the ecosystem through precipitation especially rainfall provides more water than the vegetation can use or soils can store. The excess water contributes to stream flow, which provides for irrigation and urban needs, far from the source of precipitation. Forest vegetation is a major factor in the hydrologic cycle. Before rainfall reaches the soil, water is intercepted and evaporated from the surface of vegetation and the litter layer. The rate at which water infiltrates into the soil, runs off surface, or percolates through to the water table is affected by the density and depth of roots and organic residue incorporated into the soil. The hydrologic cycle though forest ecosystem in details has been described by many scientists (Landberg and Gower, 1997; Waring and Running, 1998; Kimmins, 2004; Chang, 2006).

Most literatures focused on inputs of precipitation into forest ecosystem, and movement of water through many processes particularly interception-evaporation by forest canopy, throughfall, stemflow, uptake by roots transpiration, water flow through vegetation, evaporation from soil, infiltration into soil, drainage and runoff, stream flow, etc.

Witawassutikun and others (2011) reported that amounts of annual rainfall and streamflow of various forest types in Chiang Mai province were greatly different. The abundant montane forest received annual rainfall of 2,142.0 mm and had the high streamflow of 1,382.8 mm (64.56%). The disturbed montane forest obtained annual rainfall of 2,127.4 mm and had the lower stream flow, 415.99 mm (19.55%). The annual rainfall in mixed deciduous forest was 1,660.5 mm with the streamflow as 479.61 mm (28.88%) while the dry dipterocarp forest with annual rainfall of 1,734.3 mm had the streamflow of 124.45 mm (7.18%). The differences between annual rainfall and streamflow in these forests were 759.20; 1,711.41; 1,180.89 and 1,609.85 mm, respectively. These amounts were stored in forest biomass and soil, and losses through transpiration and evaporation.

Very few data concerned about the potentials of water storage in forest biomass and soil system of different forests. Nowadays, flooding and drought are considered as critical problems in Thailand. Forest conservation through protection of remained natural forests and reforestation in disturbed forest land is thus very important. The research on water storage in good natural forest, disturbed forest and plantation forests will provide basic information for forest management to reduce these problems.

The research objective was to assess the potential amounts of water storage in ecosystems of two community forests, conservation (CF) and utilization (UF) forests, of Karen tribe at Nong Tao village, Mae Wang district, Chiang Mai province in Northern Thailand. This research reported only the water storage in August, rainy season. The seasonal changes were not given here.

Materials and Methods

Forest vegetation survey: The field survey in CF and UF was carried out by a method of plant community analysis. Totally 100, 40x40 m plots were used (50 plots for each forest). The plots were arranged by a stratified random sampling. Each plot was divided into 16, 10 x 10m subplots. Data collection included stem girth at breast height (gbh, 1.3m above ground), tree height and crown width of tree species with $\geq$1.5m height. Ecological parameters were calculated (Krebs, 1985). All plots were located using GPS unit.

Biomass estimation: The biomass amounts of forests are calculated by allometric equations of Tsutsumi and others (1983).

$$W_S \text{ (stem)} = 0.0509\,(D^2H)^{0.919}$$
$$W_B \text{ (branch)} = 0.00893\,(D^2H)^{0.977}$$
$$W_L \text{ (leaf)} = 0.0140\,(D^2H)^{0.669}$$
$$W_R \text{ (root)} = 0.0313\,(D^2H)^{0.805}$$

where, W = biomass (kg)
D = diameter (cm)
H = height (m)

Shannon-Wiener Index (SWI) : The species diversity index of forest is calculated from Shannon-Wiener equation.

$$H = -\sum_{i=1}^{S} (pi)\,(\log_2 pi)$$

where H = index of species diversity
S = total number of species
p_i = relative individuals of species *i* to total individuals of all species

Forest Condition Index (FCI): FCI was calculated for 100, 40 x 40 m sampling plots according to following equation (Seeloy-ounkeaw, 2011). Stem girth class was divided every 25 cm interval. The larger number of bigger trees resulted in the higher FCI value.

$$FCI = \sum n_1.10^{-3}+n_2.10^{-2}+n_3.10^{-1}+(n_4+n_5\ldots n_n).1$$

where n_1 = number of individual having gbh <25 cm
n_2 = number of individual having gbh 25-50 cm
n_3 = number of individual having gbh 50-75 cm
n_4 = number of individual having gbh 75-100 cm
n_5 = number of individual having gbh 100-125 cm
n_n = number of individual having gbh [25(n-1) – 25n] cm

Water storages in forest biomass : Fresh leaf, branch, stem and root samples of dominant tree species were taken one time in rainy season, August. For each species, the samples were collected from five individuals of different sizes, small to big trees. They were oven-dried at 75 ^{o}C until constant weight, and later determined for moisture contents. Biomass water storage of each dominant tree were then calculated. The mean water contents were used for calculating water storages of other tree species in the two forests.

Water storages in soils : Three soil pits, 1.5 x 2 x 2 m in size, were made in each plot for vegetation survey of a community forest, and the total of six soil pits were obtained. In each soil pit, soil samples were collected using a 100 cm corer from 13 layers at the depths of 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80, 80-100, 100-120, 120-140, 140-160, 160-180 and 180-200 cm with three replications. The samples were determined for soil mass, maximum water holding capacity and field moisture contents in laboratory.

Results

1. Plant diversity and forest condition

Figure 1 and **2** show variations of species diversity and tree densities in CF and UF with altitude gradient between 1,000-1,800 m msl. Species richness of tree and woody climber species in CF was high as 244 species (166 genera and 78 families) with average density of 1,963 trees/ha. The highest species richness was Fagaceae family (21 species), and the dominant trees were mainly *Pinus kesiya* and *Schima wallichii*. had the highest frequency whereas *P. kesiya* had the highest dominance and ecological importance. Species diversity index (SWI) and forest condition index (FCI) of this forest were 6.19 and 54.45, respectively. There were 191 species of seedlings and ground-covered species. In UF, 132 species (93 genera and 51 families) of tree and woody climber species were found with density of 2,425 trees/ha. The family of Fagaceae had the highest species richness, 16 species. *P. kesiya* was the most dominant tree. The tree species of 100% frequency were *Quercus brandisiana, Tristaniopsis burmanica, Wendlandia tinctoria, Anneslea fragrans,* and *Gluta usitata*. *Tristaniopsis burmanica* had the highest density (462.12 trees/ha). SWI and FCI in this forest were calculated as 4.16, and 50.16. There were 114 species of seedlings and ground-covered species and seedlings. Details were described by Seeloy-ounkeaw (2011).

2. Forest biomass and water storage

Table 1 shows water content in various organs of thirteen dominant tree species in community forests. In stem, *S. Wallichii* had the highest content 53.14%, whereas *Q. brandisiana* had the lowest content 29.45%. In branch, *Aporosa villosa* had the highest content 54.06%, whereas *Q. brandisiana* had the lowest content 39.90%. In leaf, *Aporosa villosa* had the highest content 62.32%, whereas *Lithocarpus* sp. had the lowest content 31.02%. In root, *A. villosa* had the highest content 48.22%, whereas *Vaccinium sprengelii* had the lowest content 17.32%. The mean contents in stem, branch, leaf and root of these species were 43.06, 47.17, 48.77 and 35.17%, respectively.

Amounts of forest biomass in CF and UF were 252.37 and 139.75 $Mg.ha^{-1}$ (Table 2), respectively. In CF, biomass water storage was calculated as 112.38 $m^3.ha^{-1}$ separated into stem, branch, leaf and root (73.24, 24.72, 1.91 and 12.52 $m^3.ha^{-1}$). Using 50 plots, the water storage varied between 7.33-38.58 m^3/plot. *P. kesiya* could storage the highest water amount, followed by *S. wallichii*, *Castanopsis diversifolia*, *C. acuminatissima,* and *Lithocarpus thomsonii*. In UF, the water amount was lower, 59.31 $m^3.ha^{-1}$ included stem, branch, leaf and root (37.63, 12.65, 1.39 and 7.65 $m^3.ha^{-1}$). Using 50 plot, the water storage varied between 4.69-17.49 m^3/plot. *P. kesiya* had the highest water storage, followed by *Q.brandisiana*, *C. acuminatissima*, *T. burmanica,* and *G.usitata*. The average water storage in CF was 17.98 m^3/plot (112.38 $m^3.ha^{-1}$) whereas UF had the lower amount, 9.49 m^3/plot (59.30 $m^3.ha^{-1}$). Details were described by Seeloy-ounkeaw (2011).

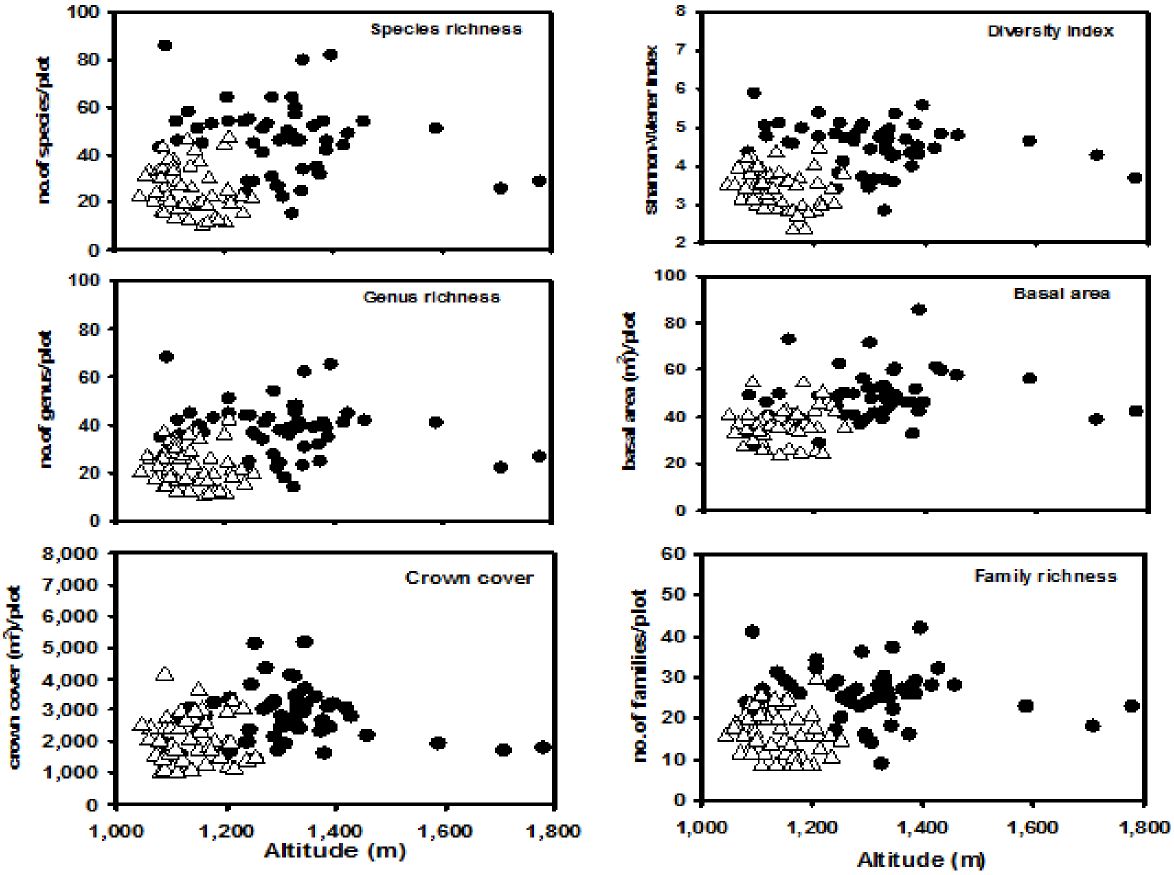

Figure 1 Variations with altitude gradient of species richness, genus richness, family richness, species diversity indices, stem basal area and crown cover of tree species in CF and UF

● = CF **△ = UF**

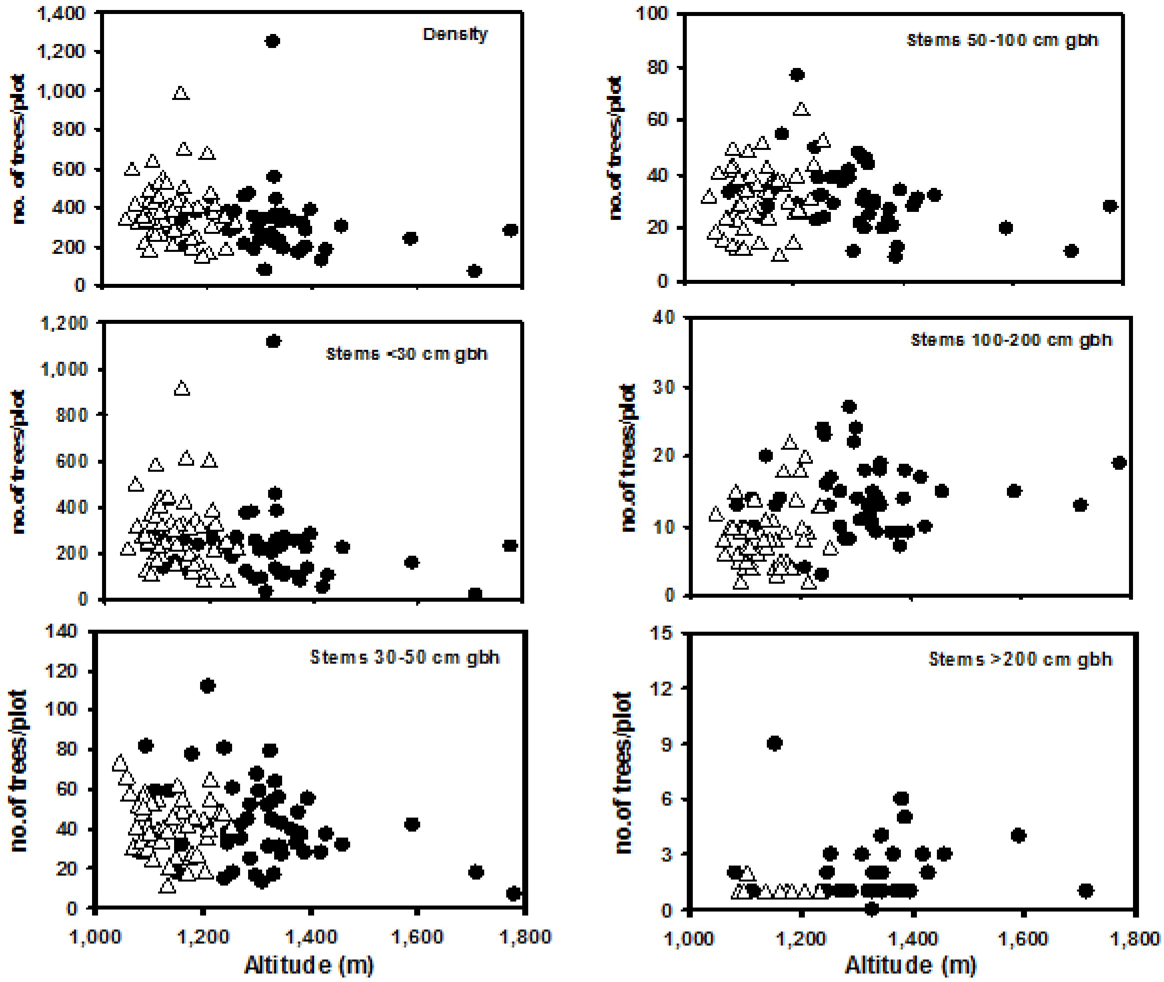

Figure 2 Variations with altitude gradient of tree densities with different stem girth classes of tree species in CF and UF ● = CF △ = UF

Table 1 Mean water contents in various organs of dominant tree species

Dominant tree species	Water contents (%)			
	Stem	**Branch**	**Leaf**	**Root**
1. *Anneslea fragrans*	46.17	48.83	55.57	25.22
2. *Aporosa villosa*	45.55	54.06	62.32	48.22
3. *Castanopsis acuminatissima*	39.79	41.98	37.92	34.43
4. *Castanopsis diversifolia*	37.69	43.95	44.54	38.10
5. *Lithocarpus thomsonii*	44.52	45.17	31.02	40.59
6. *Phyllanthus emblica*	46.57	49.71	52.66	34.00
7. *Pinus kesiya*	49.03	51.67	61.31	45.34
8. *Quercus brandisiana*	29.45	39.90	42.81	32.27
9. *Schima wallichii*	53.14	48.47	41.19	37.63
10. *Ternstroemia gymnanthera*	42.67	49.83	52.95	29.66
11. *Tristaniopsis burmanica*	43.24	49.00	48.83	35.64
12. *Vaccinium sprengelii*	37.31	40.67	51.63	17.32
13. *Wendlandia tinctoria*	44.66	50.00	51.22	38.75
Average	**43.06±5.97**	**47.17±4.41**	**48.77±9.03**	**35.17±8.11**

3. Water storages in soils

Maximum water holding capacities and field moisture contents within 2-m soil profiles as well as soil mass in CF and UF were investigated. It is found that the values varied along soil depth. The maximum water holding capacities within 1-m soil profiles under CF and UF were 3,002.0 and 3,370.60 $m^3.ha^{-1}$, respectively. Within 2-m soil profiles, the values were increased to 6,100.30 and 6,565.10 $m^3.ha^{-1}$.

On 1st August 2012, the water storages in 2-m soils under CF and UF were determined as 4,506.18 and 5,204.03 $m^3.ha^{-1}$, respectively. These amounts were calculated to 78.41 and 73.18% of the maximum amounts of water storages in two forest soils.

4. Water storages in forest ecosystems

The water storage in forest ecosystem involves mainly two compartments, forest biomass and soil system. It is found that the amounts of water stored in biomass of CF and UF were 112.38 (Table 3) and 59.30 $m^3.ha^{-1}$ (Table 2), respectively. This implies that biomass water storage in CF is about two times of UF.

The water storages in their soil profiles within 1-m depth on 1st August 2012 were in the order of 2,125.09 and 2,625.98 $m^3.ha^{-1}$. The total ecosystem storages in CF and UF were calculated as 2,237.47 and 2,685.28 $m^3.ha^{-1}$, respectively. The CF soil had the lower capacity of water storage. The storages in forest biomass were only 5.28 (in CF) and 2.25% (in UF) of the total amounts.

Within 2-m soil profiles, the water storages on 1st August 2012 were in 4,506.18 and 5,204.03 $m^3.ha^{-1}$, respectively, and the total storages were calculated to be 4,618.56 and 5,263.33 $m^3.ha^{-1}$. The water storages in biomass of these forests were 2.49 and 1.13% of the total. These figures indicate to the lower percentages of water storages in forest biomass compared to the soils.

Base on area approach, CF (640 ha) could store water in ecosystem as 1,360,032 $m^3.ha^{-1}$ whereas UF (240 ha) had 630,235.20 $m^3.ha^{-1}$ within 1-m soil profiles. The total ecosystem storage in these two community forests (880 ha) was 1,990,267.20 $m^3.ha^{-1}$. Within 2-m soil profiles, the larger amounts as 2,955,878.40 and 1,263,199.20 $m^3.ha^{-1}$ were stored in CF and UF, respectively, and the total ecosystem storage in these two community forests (880 ha) was high as 4,219,077.60 $m^3.ha^{-1}$.

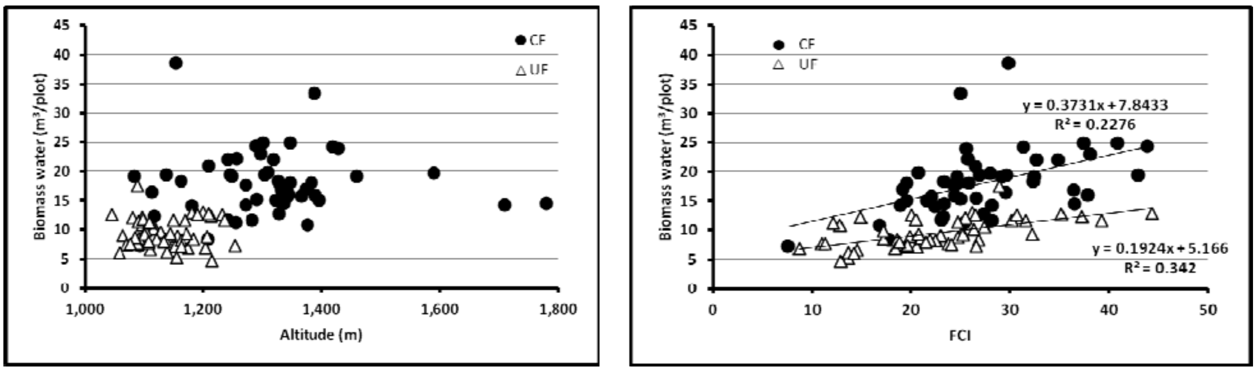

Figure 3 (Left) Variations of water storages in forest biomass using 50 sampling plots for each of CF and UF (Right) relationship between biomass water storage and forest condition indices

Table 2. Amounts of water storages in forest biomass in fifty sampling plots of CF and UF

No.	Biomass	Biomass water storages				
		stem	branch	leaf	root	total
Conservation forest (CF)						
mean (Mg/plot) Mean (Mg/ha)	40.38±11.60 252.37±72.50	11.72±3.68 73.24±23.00	3.95±1.36 24.72±8.50	0.30±0.07 1.91±0.43	2.00±0.54 12.52±3.37	17.98±5.60 112.38±35.00
%		65.17	21.99	1.70	11.14	100
Utilization forest (UF)						
mean (Mg/plot) Mean (Mg ha)	22.36±5.80 139.75±36.25	6.02±1.64 37.62±10.25	2.01±0.57 12.58±3.56	0.22±0.04 1.40±0.25	1.23±0.28 7.69±1.75	9.49±2.52 59.30±15.75
%		63.44	21.21	2.39	12.96	100

Table 3 Amounts of water storages in soils, forest biomass and ecosystems of CF and UF

Soil depth (cm)	Conservation forest (CF)				Utilization forest (UF)			
	soil mass (Mg/m^3)	Maximum water Holding (m^3/plot)	Water storage in August (m^3/plot)	(%)	soil mass (Mg/m^3)	Maximum water Holding (m^3/plot)	Water storage in August (m^3/plot)	(%)
0-5	1.03±0.34	22.45±10.8	17.61±7.9	78.41	0.63±0.18	24.00±7.3	17.56±7.9	73.18
5-10	1.19±0.08	21.55±9.9	17.20±6.9	79.81	0.70±0.17	26.44±2.0	19.60±4.9	74.13
10-20	1.29±0.06	49.73±21.5	37.30±15.3	75.01	0.83±0.19	52.11±8.2	39.30±8.9	75.41
20-30	1.27±0.10	45.78±12.2	34.06±8.2	74.39	0.84±0.12	52.96±2.9	39.23±3.6	74.08
30-40	1.36±0.07	47.70±15.7	31.72±11.6	66.50	0.85±0.16	56.01±7.9	43.48±8.5	77.62
40-60	1.35±0.07	96.62±9.6	63.64±12.5	65.87	0.92±0.16	112.07±21.2	88.10±19.3	78.61
60-80	1.37±0.13	95.96±16.5	69.82±8.2	72.76	1.07±0.05	109.25±32.5	86.10±23.8	78.81
80-100	1.40±0.10	100.53±25.3	68.67±8.3	68.30	1.14±0.11	106.44±22.7	86.79±20.7	81.53
100-120	1.45±0.11	100.67±9.6	70.69±5.1	70.22	1.19±0.10	106.56±23.0	87.83±23.0	82.43
120-140	1.45±0.10	96.70±1.3	71.38±9.2	73.82	1.19±0.15	105.91±20.7	86.34±17.1	81.52
140-160	1.43±0.05	98.10±10.4	78.49±6.5	80.02	1.29±0.06	100.76±13.0	80.47±12.0	79.87
160-180	1.43±0.04	98.32±16.7	78.68±9.6	80.03	1.30±0.10	102.30±10.5	82.15±15.7	80.31
180-200	1.36±0.03	101.95±18.7	81.72±15.7	80.16	1.40±0.11	95.60±5.2	75.69±13.1	79.18
Total (1m) (per plot) Total (2m) (per plot)		480.32±121.4 976.05±178.0	340.01±78.9 720.99±125.0	73.87 78.41		539.30±104.6 1,050.42±177.1	420.16±97.5 832.65±78.2	79.27 73.18
per ha (1m) per ha (2m)		3,002.00 6,100.31	2,125.09 4,506.18			3,370.60 6,565.10	2,625.98 5,204.03	
Biomass water storage (per ha)		112.38±5.60	112.38±5.60			59.30±15.75	59.30±15.75	
Ecosystem (1-m soil) (/ha) Ecosystem (2-m soil) (/ha)		3,114.38 6,212.69	2,237.47 4,618.56	71.84 74.34		3,429.90 6,624.40	2,685.28 5,263.33	78.29 79.45

Conclusion

The management of community forest into CF and UF influenced on their potentials of ecosystem water storage. The large storages were occurred in the soil system of both forests, and only small proportions existed in forest biomass. The forest condition of CF was higher than UF, and resulted in two times of water storage in biomass. It is considered that the water storage in forest biomass is very important for energy balance of an forest ecosystem through many processes including heat absorption, water movement and cooling by evaporation-transpiration. The differences in original plant communities, forest utilization, and forest condition between CF and UF resulted in different ecosystem water storages. These two community forests continuously supply water to paddy field and the village.

Discussion

Management of community forest by Nong Tao (Karen) villagers in to conservation (CF) and utilization (UF) forests results in different forest conditions. They are the highland watershed forest, and classified as montane and pine-montane forest. The CF covers an area of about 640 ha and is used for head watershed. Tree cutting is not permitted according to village regulations. The selected tree cutting is allowed in UF which covers an area of 240 ha. Forest utilization in this forest results in degrading forest condition. Difference in forest conditions influences on functional roles of forest ecosystem particularly the hydrologic cycle. The most abundant montane forest locates at the summit of Mt. Inthanon, the highest mountain in Thailand (Khamyong and others, 2004).

The forest ecosystem can store water in two main compartments, forest biomass and soil system. In forest biomass, the water will be stored in different organs including stem, branch, leaf and root. The amounts of water storage can be varied among tree species, and even the same species the storages are different among tree sizes and ages. In soil, the water storage depends on texture and organic matter contents. In this study, the amounts of water stored in biomass of CF and UF were 112.38 (Table 3) and 59.30 $m^3.ha^{-1}$ (Table 2), respectively, that implies to the higher in CF than UF about two times.

The water storage in soil is varied with time, daily or monthly changes. It is high in rainy season and very low in dry season. In this study, the water storages in soil profiles within 1-m depth on 1st August 2012 in CF and UF were 73.87 and 79.27% of the maximum ecosystem storage. The storages in forest biomass were only 5.28 (in CF) and 2.25% (in UF) of the total amounts. Within 2-m soil profiles, the water storages in these forests were 78.41 and 73.18% of the maximum ecosystem storage. The storages in biomass were 2.49 (in CF) and 1.13% (in UF) of the total. The percentages of water storages in forest biomass were much lower than the soils. Literatures in Thailand about water storages in forest biomass are not available. Witawassutikun and others (2011) reported that water storages in forest soils are different among forest types. The montane (150 cm soil profile), moist evergreen (100 cm), dry evergreen (70 cm), mixed deciduous (60 cm) and dry dipterocarp (30 cm) forests can store the water amounts as 9,475.5; 4,782.0; 3,184.3; 2,611.8 and 1,441.5 $m^3.ha^{-1}$, respectively.

According to Waring and Runing (1998), an forest ecosystem is important for energy balance. The energy exchange between vegetation and the environment involves a number of processes. Water storages in plants and soil can absorb heat energy during daytime, and make cooling by evaporation and transpiration. The heat transfer by re-radiation, convection and wind remove the rest.

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