# A Guideline for Forest Development to Promote Mini-Hydropower: a Case Study in 4 Community Forests in Lampang Province

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*Abstract* - **Healthy community forests can benefit the society by releasing water mass for small scale hydropower plants. This study has an objective to obtain a guideline for accelerating development of community forests that ideally can serve hydropower all year long like natural ones. From surveying 4 community forests in Lampang Province, the current rehabilitation programs were inefficient in providing water resources for hydropower. Thus this study developed a "Water-drawing trees' roots" model. The model proposes planting more evergreen trees to help protect and conserve moisture in the forest in order to enhancing surface run-off. The "Water-drawing trees' roots" is expected to support the country's AEDP2015 plan in using alternative energy instead of fossil fuel.**

*Keywords* - **Water-Drawing Trees' Roots, Forest Rehabilitation, Community Forest, Evergreen Trees, Alternative Energy**

## I. INTRODUCTION

Global warming refers to the condition that the earth's average air temperature gets higher. This happens because earth cannot emit heat energy out to the space because its atmosphere is covered by greenhouse gases such as carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbon, etc. Hence, heat is accumulated on the earth and affects its ecosystems. Global warming is recognized as one of the seven calamities threatening the human race [1]. In Thailand, it is predicted that water deficits will take place in Central Plain Basin in 2015-2039 [2].

Combustion of all carbon-containing matters can directly lead to an increase of greenhouse gases, especially carbon dioxide ($CO_2$). Prior to the industrial revolution, the earth's atmosphere contained $CO_2$ for 280 ppm., which has increased to 380 ppm. at present [3]. It is predicted that $CO_2$ in the atmosphere will be as high as 650 ppm. in 2030 [4]. To decrease green house gases, affordable and clean energy scheme is one of the UN's 17 targets set for Sustainable Development Goals for the next decade [5].

Fossil fuel is important energy of Thailand. In 2013, it imported for 56,978,000 tons of fossil fuel [6]. Fossil fuel thus becomes a major source of $CO_2$ emission that raises Thailand's influence on global warming.

Realizing the financial and economic losses due to fossil fuel imports, the government endorsed a policy to promote alternative energy use since 1989. The Ministry of Energy [7] established the Alternative Energy

Development Plan (AEDP2015) for 2015-2036. The Plan sets a goal to increase power generation from small scale hydropower from 142.01 MW in 2014 to 376.00 MW in 2036, or 165% increase.

Department of Alternative Energy Development and Efficiency has installed a hydro generator in Mae Mon Basin in an area of 20,412 rai (= 32.66 $km^2$) of Chae Son National Park, Lampang. Power was generated for 40kW throughout the year [8]. Thus forest is an important energy source of the country.

Community forests are managed by a community process in order to achieve sustainable benefits for the community [9]. Currently Thailand has 9,585 community forests, covering 4,244,033 rai [10]. Therefore, community forests are a promising alternative source of alternative energy for generating electricity at a small scale for community use.

### *A. Objective*

To obtain a guideline in developing community forests with potential for small scale hydropower for community use.

### *B. Study Area*

1. Sam Kha Community Forest, Hua Suea Sub-district, Mae Tha District, Lampang; with 12,000 rai; established in since 2002. Department of Alternative Energy Development and Efficiency also installed a 20-kW hydro generator in the area which can produce electricity for only 4-8 months per year.

2. Sa Sob Hok Community Forest, Ban Sa Sub-district, Chae Hom District, Lampang; with 2,100 rai; established in 2007.

3. Rai Sila Thong Community Forest, Phi Chai Sub-district, Muang District, Lampang; 1,200 rai; established in 2009.

4. Ton Tong Community Forest, Phi Chai Sub-district, Muang District, Lampang; 1,500 rai; established in 2010.

## II. RESEARCH METHODOLOGY

This study compares characteristics of the community forests with natural ones. Data of trees (GBH larger than 16 cm [11]) in 4 community forests were collected quantitatively with the Point-Centered Quarter Method [12] in the following procedures.

1. A thalweg of creeks surrounded by mixed deciduous or dry dipterocarp forests was selected and designed as a baseline. Sampling lines perpendicular to baselines were fixed at every 100 meters of thalwegs.

2. Sampling points were located at 20 and 120 meters on sampling lines of both left and right banks.

3. At a sampling point specified in Item 2., 4 quarters were defined as, 0-90 degree was Quarter 1, 90-180$^o$ was Q2, 180-270$^o$ was Q3, and 270-360$^o$ was Q4.

4. For each quarter, data were collected with one tree, which was nearest to the point and has GBH over 16 cm. Data include GBH (at 130 cm), height from the base to the first branch, distance to the point were measured, and tree species identified.

5. Sampling sizes were determined large enough for comparisims when no new species of tree found.

### *A. Data Presentation*

Four parameters from each community forest i.e. tree density, basal area, wood volume, and proportion of evergreen trees were calculated according to [12] and compared with those of natural one.

## III. RESULTS AND ANALYSIS

According to data from the survey, the 4 community forests were found to have several characteristics that were significantly inferior to a natural forest like Mae Mon forest in terms of the potential in supplying water. These characteristics include average age of trees, basal area, wood volume, average GBH, and proportion of evergreen trees, as shown in

Table I. Currently, community forests were of roughly 23.71-46.94% of natural ones. However, average tree density in the 4 forests was found to be significantly higher than Mae Mon forest. It is plausible that the 4 community forests are in a recovering stage. They have been rehabilitated by means of reforestation after being deteriorated. On the other hand, Mae Mon forest has been developed continuously since the past until the present. Its trees were about 30 years of age on average.

Therefore, this study proposes an idea of enhancing efficiency of community forests in storing and releasing water. The solution is to add long-living evergreen tree species that have special properties namely: 1) being a large tree that can serve as a structure of the forest; 2) providing food and medicine that allow the community to utilize; and 3) being an edible plant of wild animals in order to attract them to the area to help spread the seeds afterwards. Mae Mon forest is considered as the model of ultimate development. This model of restoring humidity to the forests is to be accomplished with the “Water-drawing trees’ roots” strategy, which focuses on Solar Energy Maximizing (SEM) concept, as shown in Fig. 1. The model applies scientific principles to supplement local wisdom approaches in rehabilitating forests (such as building check dams for trapping sediments, planting additional trees, making firebreaks, etc.). This process will accelerate development of the forest in order to provide benefits to human beings faster. As a result, the original target in achieving a fully functional forest within theoretically100 years will be reduced to merely 30 years according to the average age of trees in Mae Mon forest, as appears in Table I.

**Table I.** Attributes of the studied community forests compared to those of Mae Mon Basin forest, from a report of the Protected Area Region Office 13, Lampang Branch [13]

| Community forest | Year of establishment | Area (rai) | Number of survey points | Number of tree species | Number of trees | Percent of | | Average age of trees (years) | Average girth at breast height (GBH) (cm) | Tree density (trees±SD) | Basal area (sq.m. per rai) | Wood volume (cubic meters per rai) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Deciduous trees | Evergreen trees | | | | | |
| Mae Mon | 2533 | 20,412 | - | 19 | 58 | 43.10 | 56.90 | 30 | 77.79 | 92.8 | 259.10 | 173.88 |
| Sam Kha | 2545 | 15,100 | 30 | 38 | 120 | 89.17 | 10.83 | 13 | 49.31±30.45 | 209.78±214.49 | 8.29±14.71 | 54.20±116.13 |
| Sa Sob Hok | 2550 | 470 | 13 | 23 | 52 | 84.62 | 15.38 | 17 | 60.36±24.63 | 277.69±247.93 | 7.57±7.49 | 54.50 ±65.72 |
| Rai Sila Thong | 2552 | 1,200 | 15 | 23 | 59 | 83.05 | 16.95 | 13 | 48.19±20.65 | 179.49±192.17 | 6.05±23.39 | 26.86 ±48.92 |
| Ton Tong | 2553 | 1,500 | 18 | 25 | 72 | 62.50 | 37.50 | 10 | 42.68±21.18 | 182.06±127.71 | 3.18±3.28 | 17.64 ±18.94 |

**Remark:** The average age of trees is calculated from a table of the Trees Bank Project of Bank for Agriculture and Agricultural Cooperatives [14]

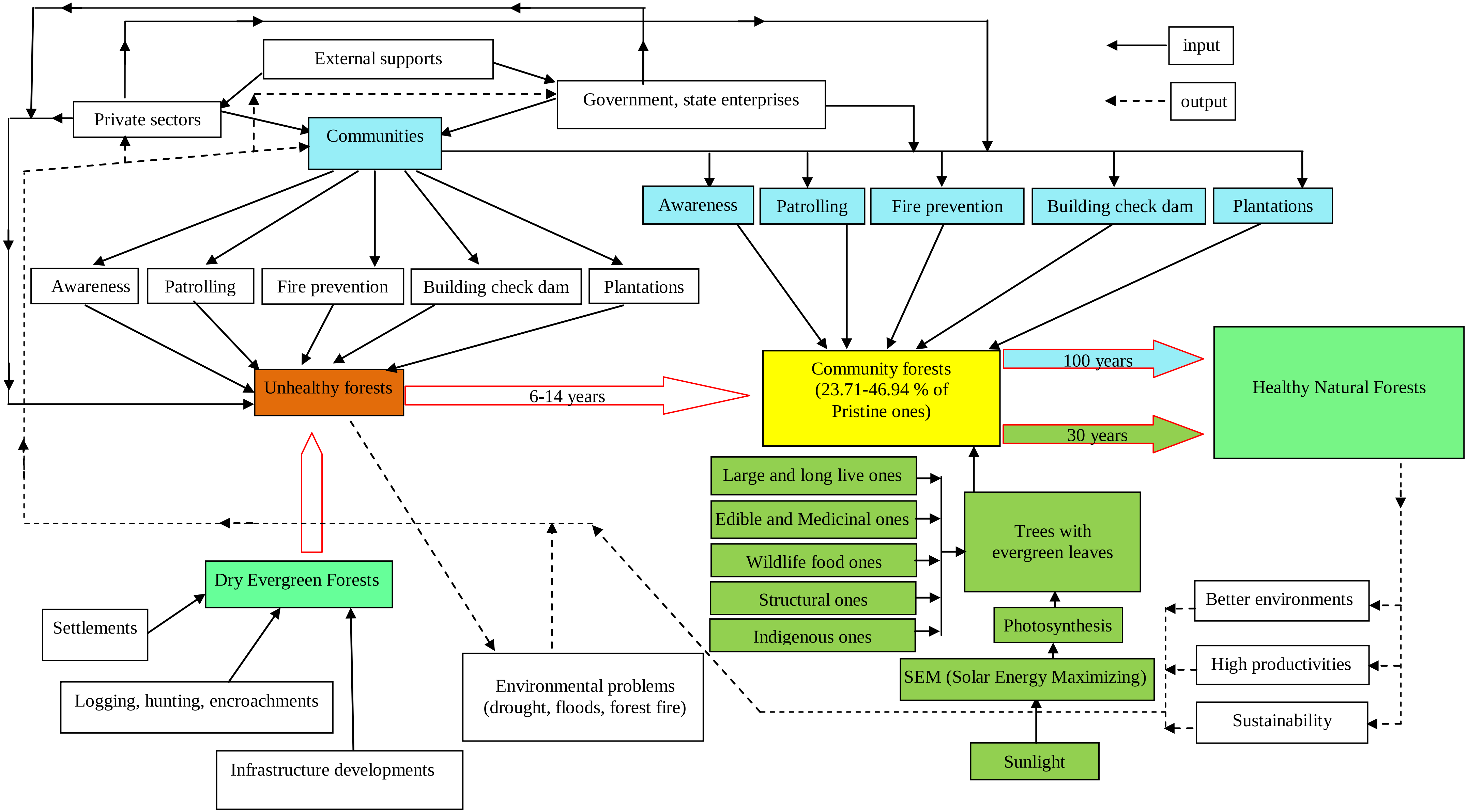


**Fig. 1** The model of rehabilitating a forest with the "Water-drawing trees' roots" process.
The model would shorten forest development to 30 years.

Water quantity in an area depends mainly on 3 components: 1) size of the catchment, 2) rainfall quantity, and 3) efficiency of the area in absorbing, storing, and releasing water.

In each area, catchment size is constant. Rainfall quantity may vary slightly. However, efficiency of the area in storing and releasing water is highly inconstant and manageable.

According to Fig. 1, traditional knowledge and wisdom can turn an unhealthy forest with little benefit to the community into a forest that provides basic necessities to the community. However, the community still needs to do activities like in the past, including building check dams, growing trees, extinguishing fire, etc. Efficiency of the forest is developed gradually and cannot cope with changes in the environment. Without additional activities to accelerate development, the forest can be degraded. Thus it is critical to apply the “Water-drawing trees’ roots” model for supporting local wisdoms and enabling the forest to maintain itself. The community will only need to support it by setting rules for sustainable benefits.

In a dry season, these 4 forests remain evergreen trees to protect forest floor for only 10.83-37.50%. Open ground leads to soil humidity loss from sunlight burning. Thus water stored in the soil during rainy season evaporates rapidly. Adding no less than 57% of evergreen trees according to the “Water-drawing trees’ roots” model will help protect soil moistures by preventing sunlight. As a direct effect, more humidity stored by the evergreen trees will allow original trees to grow and store $CO_2$ longer and utilize more sunlight. Heat, drought, and evaporation will decline. An indirect effect is the formation land dams from roots, network. These dams will trap an unburned litter, sediments and reduce evaporation. A research found land dams to be capable to keep sediments in the surface for as high as 46.37-70.66% and reduce water loss for 61.84-92.11% [15]. This can lead to higher water flow for hydropower generation if these forests are developed to be like Mae Mon forest.

Sparse forests like dry dipterocarp forests and mixed deciduous forest can be developed to become dry evergreen forests with efficient fire control and check dams [16-17]. A dry evergreen forest can store water in the soil for 509.49 $m^3$/rai [18], or 2.2 and 1.22 times of dry dipterocarp and mixed deciduous forests, respectively. The increased water retention capacity will keep humidity in the dry season and allow water to flow all year long like Mae Mon forest. Therefore, developing the 4 community forests is a key in obtaining an alternative water source for the hydropower generation.

The experiment of growing evergreen trees in a dry dipterocarp forest of Hang Chat Arboretum, Lampang, revealed that the trees can grow well. This supports the idea of planting evergreen trees in the 4 forests to enable them to provide benefits faster. Evergreen trees not only prevent sunlight and reduce humidity loss but also help eliminate carbon dioxide and release more oxygen from their photosynthesis process as shown in the following equation:

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light (400-700nm) 0.47 MJ}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

In each photosynthesis process, 6 molecules (mole) of carbon dioxide are absorbed and 6 molecules of oxygen are emitted. One molecule of $CO_2$ weighs 44 g, while each $O_2$ molecule weighs 32 g [19]. In Addition, one mole of $H_2O$ weights 18.0153 grams and one mole of $C_6H_{12}O$ is 180.156 grams [20].

Substituting the weights in photosynthesis equation comes up with:

$$264gCO_2 + 216.18gH_2O \xrightarrow[\text{Chlorophyll}]{\text{Light (400-700nm) 0.47 MJ}} 180.16gC_6H_{12}O_6 + 192gO_2 + 108.09gH_2O$$

Dry dipterocarp and mixed deciduous forests use carbon dioxide for 2.84 and 2.66 tons/rai/year, respectively [21]. Meanwhile, a dry green forest use carbon dioxide for photosynthesis for 3.26 tons per rai per year [22]. Therefore, if a dry dipterocarp forest is turned into a dry evergreen forest, $CO_2$ will be eliminated for 420.0 kg/rai, and $O_2$ will be released for 305.45 kg/rai. Since 1 g of $O_2$ has a volume of 0.7 liter [19], $O_2$ will be increased for 213.82 $m^3$/rai, and this can greatly benefit the human society.

All alternative energy sources including solar energy, wind, biogas, etc, can help reduce dependence on fossil fuel. However, hydropower is particularly interesting because it not only reduces fossil fuel use but also promotes better quality of the environment. More $CO_2$ is used by the forest with sustainable ecosystem that can provide water for hydropower generation all day all night.

In addition to promoting water storage and release for benefits of the community, the "Water-drawing trees' roots" model protects the environment by getting rid of $CO_2$ from the ecosystem with all-year-long photosynthesis of added evergreen trees in community forests.

By applying the "Water-drawing trees' roots" model with a community forest, it will provide alternative energy faster. This is in agreement with the AEDP2015 plan; a framework for procuring national energy for a period of 20 years (from 2015-2036). As the model increases evergreen trees, natural development of a forest that normally takes 100 years [18, 22] can be shortened to only 30 years.

## IV. CONCLUSIONS

According to the comparison, the 4 community forests in Sam Kha, Sa Sob Hok, Ton Tong, and Rai Sila Thong villages were found to be inferior to the natural Mae Mon forest in Chae Sorn National Park. Growing evergreen trees as dominant species (≈57%) in the area can rehabilitate the forests and accelerate development. Instead of taking 100 years, the community forest will be able to provide water all year long like a natural forest within just 30 years.

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**(Arranged in the order of citation in the same fashion as the case of Footnotes.)**

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