

# The Hydrological Roles of Forests In Thailand\*

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## INTRODUCTION

The hydrological roles of forests have been studied extensively in western and some Asian countries. There have been some studies done in Thailand, but in-depth investigation with empirical prediction is lacking. In fact, there has been a good deal of controversy in scientific circles in the past several decades on the relationship between forests and rainfall, the relationship between forests and water yields, and soil erosion and sedimentation control in Thailand. Empirical findings on these topics were mainly produced by university researchers. Unfortunately, however, long-term records of changes in water yields corresponding to land-use changes are rare. It is thus rather difficult to make valid conclusions; and in many cases such findings still need more reliable data to make them more conclusive.

This report is an attempt to summarize the empirical findings in Thailand relating to: (1) the relationship between forests and rainfall; (2) the relationship between forests and runoff, soil erosion, sedimentation, water quality and stream flow timing; (3) the relationship between forests and aquifers; (4) forest type and water consumption; and (5) the impact of land-use changes on water yields in the northern regions. It is hoped that the information compiled here will contribute to the formulation of national and regional policy on forest and land resource management.

## THE INFLUENCE OF FORESTS ON RAINFALL

Rainfall is generally believed to be a result of monsoonal effects. International evidence and simulation models suggest two conditions under which forests generate rainfall. First, montane forests in very high altitudes (2000 m+) can harvest clouds. In Thailand, this is confirmed at Doi Pui. Lekavijit (1982) investigated the effects of high altitude hill-evergreen forests on rainfall in Chiang Mai province, in northern Thailand. He recorded about 50 mm per year of additional annual rainfall in forested areas over and above cleared areas of the same altitude. Second, deforestation of vast tracts of land, i.e., more than 250,000 km<sup>2</sup> could reduce the probability of rainfall from water cycling.

Salati et al. (1979) showed that forests in the Amazon Basin can engender precipitation in the basin itself. The basin acts not only as a source of its own moisture, but also triggers the rain-producing process. Widespread and permanent forest destruction may decrease the amount of rainfall in affected areas.

Ekern (1964) found that rainfall increased by almost 700 mm per year in tropical forests in highly elevated regions and at the coastal areas where high pressure from fog belts slows the movement of fog and makes it condense.

In Thailand, despite intense interest in this issue, little systematic research efforts have been encouraged, resulting in scant evidence which is not free from confounding factors and speculation, based on some theoretical reasoning and statistical analysis. Bunkert (1973) believed that when large areas of forests are encroached, the balance of nature can be altered, and natural phenomena in the forms of flood and drought frequently occur. Similarly, Tangkitjavisuth (1979) said that forest encroachment in northeastern Thailand can cause drought, as was recently seen in wild temperature fluctuations and frequent flooding in this region. Prachaiyo (1983) also supported the idea that large deforested areas inhibit the creation of water vapor or atmospheric moisture and bring on arid weather.

Chunkao (1979) believed that forests may add water vapor to the air by evapotranspiration and may increase rainfall in arid zones. High altitude forests can increase the likelihood of cold and warm air masses mixing, and consequently may contribute to condensation. This is especially true for mountainous forest areas where air temperature is usually low. Chunkao concluded that forests may have some influence on rainfall besides affecting topographic conditions and monsoon air circulation.

An investigation of the influence of forests on rainfall in depleted forest areas in Thailand was carried out by Tangtham and Sutthipibul (1988). They compared the changes in average regional rainfall with changes in forest cover in the northeast between 1951 and 1984. Yearly statistical analyses showed an insignificant relationship between monthly, seasonal and annual rainfall patterns and the remaining forest areas. In other words, there was no correlation between rainfall parameter and the percentage of remaining forest area, although annual rainfall generally exhibited a weak negative trend during the period under consideration. When considering time trends, statistical parameters obtained by using moving averages for 10, 15, 20, 25 and 30 year periods indicate that rainfall has tended to decrease significantly as forest areas decrease, while the number of rainy days significantly increased.

The changes and variation in annual rainfall patterns in different regions of Thailand were also studied by Wongvitavas (1989). The relationship between rainfall and forest depletion was not studied. Wongvitavas recorded sharp decreases in annual rainfall in the central, northern and southwestern regions of the country. The same was true in the east, while the northeastern and southeastern regions showed a slight downtrend in rainfall.

## **THE INFLUENCE OF FORESTS AND FOREST CONVERSION ON STREAMFLOW AND WATER CONSUMPTION**

Theoretically, watershed hydrological behavior, such as streamflow and sediment discharges, is dependent on the types of watershed cover and the geomorphological and pedological setting. Climate, especially rainfall, certainly plays an essential role in determining water yields. Research in Thailand indicates that the major factor contributing to runoff in forested watersheds is the amount and intensity of rainfall. Geological formation is, therefore, another important factor which contributes to variations in annual runoff. High altitude watersheds covered mostly with hill-evergreen trees produce water yields which are not less than 1 million cubic meters per km<sup>2</sup> per annum (Chunkao and Mukarabhirom, 1979). Between ten and 20 percent of the annual rainfall discharging on mixed deciduous forests becomes annual runoff (Euvananon, 1994; Suksawang, 1991).

The water consumption of forest and tree plantations was investigated by using water balance equations and by measuring transpiration rates. The evapotranspiration (Et) loss estimated by water balance indicated that almost all types of forests in Thailand consume more than 1000 mm/year of water if annual rainfall is not inhibited by drought (Suwanarat, 1981; Chotibal, 1982; Tangtham, 1991). This figure seems to conform with those Et losses observed in the tropical forests of Southeast Asia (Bruijnzeel, 1990). For those areas where rainfall is limited, such as the dry-evergreen and the dry dipterocarp forests in the northeast, Et loss is between 700 and 1000 mm/year. Compared to the Et loss in deciduous forests or even in the temperate zone evergreen-pine forests, as reported by Shiklomanov and Krestovsky (1988), tropical forests consume almost double the amount of water than temperate regions.

In a preliminary study on the transpiration rate of tropical tree species in Thailand, Dhammanonda et al. (1992) reported that eucalyptus plantations (*E. camaldulensis*) consumed about 208 ton/ha of water, equivalent to a 20.8 mm water column. The daily transpiration rate in an *Acacia Mangium* plantation was about half of that in a *E. camaldulensis* plantation. The daily transpiration rate of pioneer species in secondary forests was very low, reflecting the small leaf biomass in this type of forest. The transpiration rates of various native and exotic species seem to be unusually high, since most evaporation from pan measurement is in the range of 3 to 7 mm. This is considered to be the maximum possible loss per day in Thailand.

## **THE RELATIONSHIP BETWEEN FOREST AND AQUIFER RECHARGE**

There is almost no scientific investigation in Thailand on forests' effects on the conversion of groundwater, and groundwater's fluctuation and recharge. In theory, timber harvesting or deforestation opens the ground to receive more rainfall and decreases evapotranspiration loss, which in turn might increase the amount of groundwater recharge.

The author's experiences in observing the effects of both deforestation and reforestation on shallow well groundwater in Thailand suggest that mountainous watersheds with deep soil, when covered with dense forests, produce large amounts of baseflow discharge. This is perhaps due to the fact that almost all rainfall reaches the ground recharge at its deeper levels beyond the root zone. The same topographic conditions exist with shallow soil which is usually covered by mixed deciduous and dry dipterocarp forests; a small percentage of rainfall recharge becomes groundwater. Therefore, forest conversion in shallow-soil watersheds shows insignificant effects on aquifer recharge. Forest conversion in deep soil watersheds results in an increase of groundwater recharge for several years if the topsoil can be kept at good infiltration capacity. In almost all cases, topsoil was rapidly lost, due to soil erosion and poor conservation practices. More overland flow is generated and less rain percolates to deeper layers. Thus there is less aquifer recharge. In northern Thailand, Chunkao (personal comm. Hamilton and King, 1983) reported a decrease in well level in dry seasons following teak reforestation. It also was suggested that groundwater recharge in native forests in northern mountainous watershed regions is greater than the recharge in *P. merkusii* plantations. Eucalyptus plantations with 1.5x1.5 m spacing in the eastern regions and teak plantations with 2x8 m and 4x4 m spacing in the north were observed to have a decrease in water table.

### **THE IMPACT OF FOREST CONVERSION IN THE MOUNTAINOUS REGIONS ON SOIL EROSION, WATER QUALITIES AND FLOW TIMING**

The ecological impact of forest conversion in mountainous regions has created a good deal of controversy over the past two decades. Empirical findings and predictive models on this subject, however, are rather few. Investigations reveal that soil erosion resulting from traditional methods of cultivation on slopes steeper than 35 percent is much greater than the tolerance limit (12.5 ton/ha/yr) (Samapuddhi and Suvanakorn, 1962; Pirintra et al., 1982; Takahashi et al., 1983; Janmahasatien, 1986). Permanent plantations, such as para-rubber trees grown on terraces, cause severe erosion in the first year but this rapidly declines to the same level observed in natural forests within five years (Thainoogul et al., 1981). Erosion control measures, such as grass-strips, intercropping and hillside ditches, can effectively reduce soil erosion.

Although conservation measures have been introduced to reduce erosion on such steep-sloping areas, fertility decline, due to nutrient leaching and organic matter depletion, is still a problem (Lapuudomlert et al., 1974; Anecksamphand and Budee, 1987). The conversion of moist-evergreen forests to rubber plantations in steep mountain areas induced severe landslides and major floods in the south when it experienced abnormal rainfall (ESCAP, 1989; Milintangkul, 1989). The conversion of mountainous forests for agriculture also brought pesticide and fertilizer contamination of streamwater. Fortunately, the concentrations of N, P, K, heavy metal and organochlorine insecticides in the forms of Dieldrin and Total DDT have not yet reached hazardous levels (Doungsawat, 1988; Panichayakul and Santisopasri, 1988; Sombutsiri, 1988).

The adverse effect of forest conversion on the physical, chemical and biological qualities of water is becoming an important consideration, since significant alterations of water quality have been shown to exist.

Regarding flow regime alteration stemming from forest conversion, only two flow-timing parameters—first-quarter flow date and half flow date—are affected when less than 30 percent of the forest area in a given watershed is traditionally converted for cultivation. This also affects the five percent flow interval—the longest dry season period that accounts for five percent of annual runoff. A good deal of forest conversion in any watershed region could thus shorten both the amount and the timing of water flow in the summer season (Tangtham, 1991).

## SUMMARY AND CONCLUSIONS

Based on the above studies and the ways in which Verry (1986) summarized his studies for the temperate region, the following conclusions can be made with special reference to Thailand with regard to the hydrological role of forests and their conversion effects.

- Although annual rainfall in all regions of Thailand has tended to decrease during the past three decades, its fluctuation is still in the range of the maximum and minimum annual rainfall ever recorded for the country. Statistical analysis of annual rainfall in relation to deforestation in the northeast showed insignificant correlation, but negative trends were observed. High altitude forests, or the so-called "cloud forests," such as the hill-evergreen forests in the north and the montane forests of Doi Inthanon National Park, experienced an increase in rainfall frequency and abundance.
- High altitude forest watersheds yield greater than 1 million cubic meter/sq.km., mainly in the form of subsurface flow. Due to their high capacity for water penetration to deeper layers, heavy rain—as much as 280 mm/hr—can reach the water table beneath the rooting zone of forest trees and discharge to streams as subsurface flow. Head watershed areas in the north which have deep soils and are covered by hill-evergreen forests regulate 70 percent of the wet period flow and 30 percent of the annual runoff during the dry season. This type of forest could be classified as the best water conservation forest in Thailand.
- The soil erosion rate for varying forest types in Thailand was found to be less than 3 ton/ha/yr. Fire, however, induces soil erosion in forests at a higher rate (about two to ten times higher), depending on the type and intensity of fire. The installation of rubber plantations causes severe soil erosion in the first year; within five years soil loss will reduce at the same rate as that of natural forests. Conservation measures, such as grass strips, terraces and hillside ditches, can reduce erosion by about 80 to 90 percent.
- Forests' regulation of groundwater recharge is another controversial issue. At the slopes of upland watersheds in northern Thailand, the groundwater level has been observed to rise after the upper slopes were cleared for cultivation. This rising water table, however, is a temporary phenomenon. It gradually falls when the topsoil of cultivated areas in upslopes becomes compact; and it generates larger amounts of overland flow which is drained directly to stream channels. The rise of the water table was due to a decrease in evapotranspiration loss and the maintenance of soil structure and high permeability.  
The water table in eastern areas where cassava was once grown lowered and dried out after these areas were converted to densely planted (1.5x1.5m) eucalyptus plantations. There was minimal change in groundwater recharge in the northeast where trees were spaced wider apart (4x4 m or 2x8 m). Less dry season baseflow was also observed after the installation of pine and teak plantations in the north.
- Regression analyses of the relationship between annual runoff discharge and biophysical factors in the northeast indicated that annual rainfall is the most significant factor in this relationship. In nearly all cases, forest cover insignificantly affects river flow, although trends of increasing annual runoff have been found in many tributaries after deforestation occurs. Exceptions were also found in the smaller and higher altitude watersheds of Khao Yai National Park where deforestation seems to decrease the amount of annual streamflow.
- Generally, forests tend to equalize streamflow throughout the year. Empirical findings from the Khao Yai Ecosystem Study showed that: 1) annual rainfall is still a major factor which controls streamflow timing; 2) only two flow-timing parameters, i.e., one quarter-flow date and half-flow date, were affected by forest cover; 3) in general, forest cover plays a significant role on five percent flow intervals, but not on quarter-flow and half-flow intervals; and 4) a larger proportion of forest cover in the basin and a greater amount of annual rainfall are two factors causing the five-percent flow interval.
- The ratios of wetflow and dryflow for catchments in Khao Yai National Park and the four main tributaries of the north are nearly constant; the ratios range from 85:15 to 95:5 and seem to vary with the magnitude and timing of rainfall during the wet season and the drainage morphology, rather than the percentage of forest cover.
- Regarding the hydrological impact of forest conversion, Verry (1986) stated that "climate and climate

change" are long-term controls which help regulate streamflow, springs, floods, and droughts.

Forest conversion in Thailand is almost totally different than forest conversion in temperate region countries. Cleared and cultivated areas cannot be changed back to forest, and it is difficult to reintroduce permanent trees, as the land would already be used by local residents for agriculture. When top soil which has lost its capability to store water and has had its fertility degraded is left idle, it takes a very long time to recover. Studies on the hydrological impact of forest conversion in Thailand have not yet been accepted by water resource engineers, because they are not fully substantiated by scientific evidence. One reason for this is that the droughts and floods which Thailand has experienced so far are believed to be the results of annual and cyclical rainfall variations rather than land-use changes. If this is true, Thailand will enjoy good rainfall in the near future. If it is not true, instances of drought will increase.

Thailand should play a greater role in international cooperation in doing research on a global scale to better understand the role of vegetation change on site impoverishment and on the alteration of regional heat and water balances. This will be beneficial in formulating policy on forest resource management in the future. Intensive research concerning the effects of forest conversion on chemical and biological water qualities, including low flow quantity and duration, should be immediately carried out. The role of high altitude forests on occult rainfall should also be intensively investigated to support policy on protecting head watershed forests.

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