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EFFECTS OF DIMINISHING FOREST AREA ON RAINFALL AMOUNT AND DISTRIBUTION IN NORTHEASTERN THAILAND

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บทคัดย่อ

ข้อมูลน้ำฝนจาก ๓๖ สถานี ในภาคตะวันออกเฉียงเหนือ ซึ่งเก็บบันทึกโดยกรมชลประทาน และกรมอุตุนิยมวิทยา ระหว่างปี พ.ศ. ๒๔๙๔ ถึง ๒๕๒๗ รวมระยะเวลา ๓๔ ปี และข้อมูลป่าที่เหลืออยู่ในช่วงระยะเวลาดังกล่าว ที่ได้จากแผนที่ป่าไม้ซึ่งจัดทำขึ้นจากภาพถ่ายทางอากาศ และภาพถ่ายดาวเทียม โดยกรมป่าไม้และคณะวนศาสตร์ ได้นำมาใช้ในการศึกษาวิเคราะห์ความสัมพันธ์ระหว่างการลดลงของพื้นที่ป่าและพฤติกรรมการตกและการกระจายของน้ำฝนในภาคนี้ การวิเคราะห์โดยใช้ข้อมูลน้ำฝน และพื้นที่ป่า ปี–ต่อปี แสดงให้เห็นว่าการลดลงของพื้นที่ป่าไม่มีความสัมพันธ์ซึ่งกันและกันในทางสถิติ ไม่ว่าจะเป็นฝนรายเดือน รายฤดูกาล หรือรายปี แต่เมื่อวิเคราะห์โดยใช้ค่าเฉลี่ยน้ำฝนและพื้นที่ป่าตามอนุกรมเวลา ๕, ๑๐, ๑๕, ๒๐ ๒๕ และ ๓๐ ปี ปรากฏว่า การลดลงของพื้นที่ป่ามีผลต่อการลดลงของปริมาณน้ำฝนและการกระจายในรอบปีกล่าวคือ ปริมาณน้ำฝนมีแนวโน้มลดลงเมื่อพื้นที่ป่าลดลงแต่มีอิทธิพลค่อนข้างน้อย ในขณะที่จำนวนวันที่ฝนตกมีแนวโน้มเพิ่มขึ้นอย่างมีนัยสำคัญ

ABSTRACT

Based on 36 stations of 34 yr rainfall data (during 1951 to 1984) recorded by Royal Irrigation Department and the Meteorology Department together with the forest maps in different periods produced by Royal Forest Department and Faculty of Forestry, the effects of diminishing forest area in the Northeast on rainfall amount and distribution wihtin the region was investigated. Statistical analysis based on year–by–year observed data showed insignificant relationship between given periodical rainfall amount, i.e., monthly, seasonal and annual, and the remaining forest areas. When considering upon time–trend basis, statistical parameters obtained from using the moving average of time series 5, 10, 15, 20, 25, and 30 year indicated that rainfall amount tends to significantly decrease along with the depletion of forest area while the number of rainy day significantly increase.

INTRODUCTION

Today, world population has been increased rapidly in every country. Basic needs for human lives have been followed insufficient inevitably from time to time. Evidently, fertile lands on earth have been occupied for human

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activities, especially for food production as well as for human settlement, industrial factories, and urbanization. In fact, these lands long time ago used to be forested areas. Whenever people needs lands, they get rid of forests by cutting trees down. After clearing, land have been used for agricultural, resettlement, urbanizing, and industrialized purposes.

The removal of a forest cover has been affected the hydrologic characteristics of a drainage basin. The combined effects on the hydrology are a complicated puzzle to unraveling attempts, and many suggestions have been stated as to how the deforestation has affected the nations' water resource. From the public viewpoint, opinions have been frequently presented that forest destruction has seriously decreased the water yield of the catchments, in particular to the low flow during the dry season. Some even mentioned that the precipitation has been reduced due to the eradication of the trees.

In studying the relationship between forest depletion and rainfall phenomenon, Muttrich (1890) found that a raingage at a forest edge and those installed at a distance of 1,000 m and 2,000 m from the forest catched 97, 94 and 94 percent respectively of rainfall indicated by instruments placed in a forest clearing. The above mentioned observation was however criticized by Molchanov (1960) as it might be due to the real of nature or the error of precipitation measurement and location of gages.

According to the observations of Klingen (1893), the plant cover, small forest clearings, field–protective forest strips, and all such features which interrupt the smoothness of the earth's surface, play a greater role in the increase of precipitation than any continuous tracts of forest. Such obstacles act mechanically upon the flow of air currents, the vertical component of the wind's velocity increase, and this results in some increase of rainfall in regions with scattered forest. However any plant cover, small forest clearings, farms, meadows, marshes, and waters, all enhance the condensation of water vapors carried by cyclones. Such areas would get an additional 9–30 percent (on the average an additional 17 percent) rainfall, as compared with ordinary fields.

Voeikov (1884, 1894) found that the least amount of precipitation occurs on fields, somewhat more falls on small clearings in leafy forests. Anri (1902) asserted that the woods, by extracting moisture from deep horizons of the soil and giving it off into the atmosphere, contribute to the moistening by atmospheric precipitation of both the forest clearings and the nighboring fields. Meteorological stations in forested areas indicated a rainfall which was higher by 20 mm, on the average, than the amouts falling on open terrain, and Zon (1927) maintained that the forests may enhance rainfall not merely on a local scale but even within very extensive regions. Indeed, the moisture entering a continent is soon returned into the atmosphere with the help of forest evaporation and transpiration, and these water vapors will be the main source of further precipitation.

Based on Kittredge (1948) referred to Hamberg (1896), indicated that an increase or decrease of this rainfall amount might be expected as a result of the effective height of tne ground due to the presence of the forest. For reanalyzed, twenty–four forest stations had an average altitude of 77.3 m and an average forested area of 58 percent. Thirty–two open stations had a mean altitude of 66.8 m and an average forested area of 17 percent. The average rainfall of the forest stations exceeded that of the open by 8.6 percent. By the way, the result of same study found that the tropical forest on high elevation or the forest along the coastal areas where high from fog belts can slow the movement of fog and make it condense. Ekern (1964) found that the forest of this characteristic in Hawaii made more rainfall in total 760 mm per year, and the same phenomena are found in the hill–evergreen forest at Doi Pui in Chiengmai about 1,300 m above the mean sea level in which the total annual rainfall in the forest is 50 mm higher than the open area (Lekavijit, 1982). For the same case, Chunkao (1979) concluded that the rainfall amount will depend not on only forest factor, but also other factors such as the character of area location, amount of water vapor that cause the rainfall. Forest may affect to increase rainfall in arid zone because 1) forest add water vapors to the air by evapotranspiration 2) the different of altitude forest increase the opportunity of mixing of cold and warm air masses to increase condensation and 3) most of forests are in the highlands that have low temperature, so that when the wind carry some water vapor and are uplifted by elevation, the condensation likely to be occured more than usual. Thus, it can conclude that forest may have some influences on rainfall more than areas that have no forest.

In case study, the large watershed area which covers the tropical rain forest as the Amazon Basin, Salati et al. (1979) found that the forest of characteristic can be engendered precipitation in the basin itself. The basin acts not only as a source of its own moisture but also triggers the rain pro duction process dynamically. Forest destruction in widely and permanently may decrease the amount of rainfall in that area. In similar manner Tangkitjavisuth (1979) said that forest encroachment in Northeast Thailand may cause drought as it has recently prevailed by the over hot and cold weather and more frequent flood in this region. Bunkert (1983) also believes that when large areas of forest are encroached, the balance of nature will be altered, natural phenomena in forms of storm, flood and drought are frequently occurred. Prachaiyo (1983) said that forest encroachment will destroy source of water vapors or atmospheric moisture so that it created arid weather. Water vapors from the sea and ocean will be carried away to other places. It can not be formed a cloud and condensed as precipitation.

For the study of 28 stations of Western Karnataka and one of Kerala, India showed that greater the area of deforestation around a station, higher is the number of criteria showing declining trend of rainfall/rainy day and larger is the decrease. Exception to this rule are the coastal stations where evaporation from the sea maintains sufficient humidity in the atmosphere (Meher-Homji, 1979).

The above literature review revealed that the effect of deforestation on the hydrologic cycle has been a controversial issue for long time among foresters and scientists. In this case, many scientists have suggested that it is difficult to make clear that the forest affects the rainfall, and forest destruction make the decrease of rainfall amount and uneven distribution. In acquiring further informations to ensure this thought, it would currently be an interesting issue waiting for general acception. Analysing techniques are well developed to solve the controversial. This investigation is hoped to obtain some results that can partially expand this thought. The Northeast Thailand was selected as study area because it is considered to be a large ecosystem in which tremendous conversion in its primitive would affect on some characteristics of rainfall.

The main objectives of this investigation are (1) to find out relationship between rainfall amount/rainy days and forest area reduction in the Northeast, (2) to analyze trends of deforestation effect on rainfall amount and distribution in Northeastern Thailand. It is also hoped that this investigation can produce applicable data to beneficial for the Regreening Esan Project and those projects concerning watershed managemant and water resources development.

MATERIALS AND METHODS

1. Data Collection :

Amount of rainfall and numbers of rainy day during 1951 to 1984 of 36 raingage stations distributed over the Northeastern Region were obtained from the Royal Irrigation Department and meteorological Department.

The statistics of forest area in percentage of total area of Northeastern region for differing periods were derived from the LANDSAT Image and Forest Mapping Sub-Division, Royal Forest Department. The remaining forest areas in each year during 1951 to 1984 in percentage were derived from the depletion line interpolated based on the actual figures of existing forest areas in 1961, 1973, 1978, 1982, and 1985.

2. Data Analysis :

In this study, the mean areal depth of rainfall over the Northeastern region was calculated by finite element analysis techniques (Akin, 1971). By this method, mean annual rainfall, mean monthly rainfall, mean rainy season (May—October) and mean dry season (November–April) rainfall were obtained. The technique was converted into BASIC software to be used with the IBM microcomputer.

The mean areal depth of rainfall for 5, 10, 15, 20, 25 and 30 year period was analysed through the Time Series Analysis method (shultz, 1973) in order to smooth out some random variation of rainfall patterns. The mean annual rainy-day, mean monthly rainy-day, mean rainy and dry seasonal rainy-day were estimated by arithmetic mean. Retroactive average of rainy-day for different moving intervals of 5, 10, 15, 20, 25 and 30 year was also analysed in coresponding with the remaining forest areas of each period.

A simple linear regression was employed to determine relationships between percentage of existing forest areas and rainfall amount or rainy day.

RESULTS

1. Forest land–use evolution in Northeastern

In 1985, the remaining forest area in the Northeast was about 24, 224 sq. km or about 14.35 percent of total regional area. The trace–back trend indicated that during the past 35 year (from 1951 to 1985), the Northeast region has lost 38 percent of its total area or equal to 72 percent of its forest area appeared in 1951. Deforestation rate in the Northeast is thus estimated at 1.07 percent per year.

2. Normal rainfall amount and its distribution in Northeast

Data of rainfall amount and rainy day recorded during 1951 to 1985 indicate rather high variation in both time and space distribution (Table 1). Long –term average of mean annual rainfall was estimated at 1,351 mm. The large portion (about 80%) occurs during May to September. The rainy day ranges from 93 to 122 days with an average of 107 days. in which about 80 persent occurs in wet season.

3. Relationship between rainfall amount/rainy day and the periodical existing forest areas in the Northeast

3.1 Year–by–Year Relationships :

Statistical parameters obtained from regression analysis indicate insignificant relationships between those given periodical rainfall amounts and existing forest areas. The coefficient of determination (R^2) indicating the influence of remaining forest area (if other factors are assumed constant) on the amount of annual, seasonal and monthly rainfall ranges from 0.0001 to 0.08. The R^2 value for annual, wet and dry period was computed at only 0.0387,0.220 and 0.0426 respectively. Based on the regression analysis, the depletion of forest area in the northeast during the past 34 years showed insignificant effect on annual, monthly and seasonal rainfall amount when considering from year–by–year basis. Regression lines in Figure 1, however

Table 1. Mean monthly rainfall and rainy day of northeastern region obtained from observed data during 1951 to 1984 years record

Month	Rainfall amount (mm)		Rainy day (days)	
	Range	Mean	Range	Mean
January	0-36.3	5.8	0-5.29	0.89
February	0.7-45.7	16.6	0.17-3.88	1.95
March	3.8-118.4	39.1	0.79-7.25	3.75
April	33.2-127.6	79.5	3.58-10.00	6.74
May	69.6-367.0	180.4	9.42-18.88	13.82
June	93.6-305.6	193.7	9.33-20.79	15.31
July	122.1-323.9	195.0	12.38-20.96	16.20
August	138.6-344.5	232.2	14.04-22.25	18.33
September	137.2-430.1	276.6	13.21-20.88	17.00
October	43.9-198.5	113.2	1.33-16.33	9.17
November	0.6-80.0	19.0	0.29-6.46	2.43
December	0-15.5	3.3	2.67	0.63
Annual	1,118.0-1,569.4	1,351.2	92.67-121.42	106.55
Wet period	987.2-1,380.6	1,189.8	80.21-102.42	90.15
Dry period	92.3-223.8	163.6	11.38-21.04	16.34

showed the trend that rainfall amount either in terms of monthly, seasonal or annual average decreases with decreasing forest area.

The relationships between numbers of rainy day in terms of monthly, seasonal and annual average and the percentages of existing forest area for the past 34 years are in the same manner as that described for the case of rainfall amount (Figure 1). Statistical parameters (R^2 and F–value) however, indicate that numbers of rainy day for August, annual and wet period

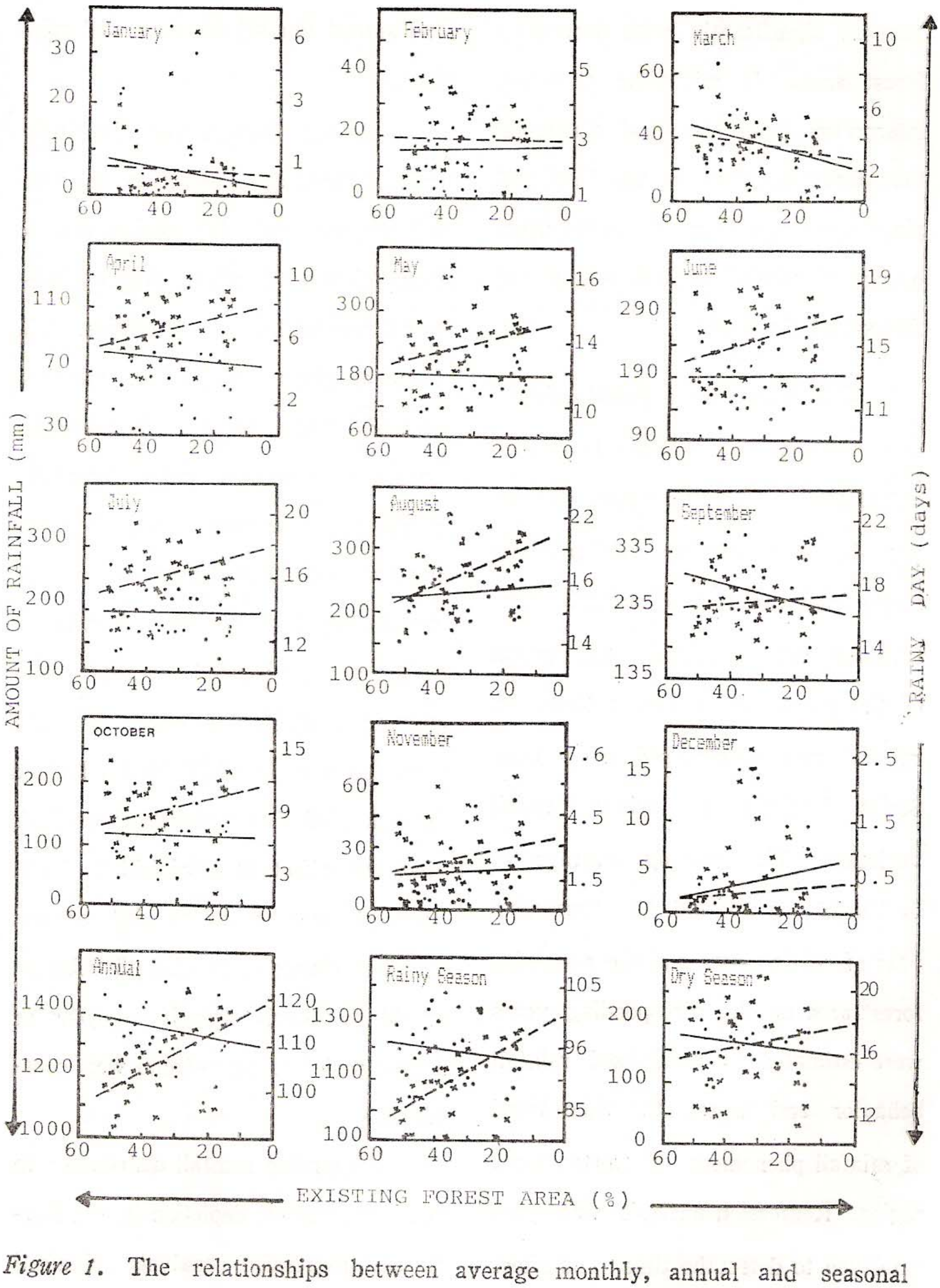

Figure 1. The relationships between average monthly, annual and seasonal (wet & dry) and year-by-year remaining forest area (● = amount of rainfall, × = rainy day)

increase significantly with decreasing forest area. It might be therefore interpreted from statistical standpoint that forest coverage in the Northeast plays some significant role on the distribution of rainfall in wet season and throughout the year.

3.2 Time–trend Relationships

By assuming that the insignificant effect of deforestation resulted from year–by–year data analysis partially stems from variation of annual, monthly and seasonal rainfall, the impact of the mentioned human activity on rainfall was re–analysed using Time Series Analysis to reduce rainfall variation. The moving average of 5, 10, 15, 20 25 and 30 successive year of rainfall data and the remaining forest area of the coresponding years were estimated to normalized rainfall behavior and to see the time trend of rainfall phenomena of Northeastern region. Regression analysis was again employed to detect the time trend effect of deforestation on monthly, seasonal and annual rainfall amounts and rainy days.

Results showed that the influence of forest area depletion on rainfall amount and distribution can be more distinctive when longer time–trend was applied to determine. The R^2 of all given periods, i.e., monthly, seasonal and annual relationships gradually increases with increasing numbers of year employed in the moving average. The longer the period, particularly that one closes to what is called normal rainfall, i.e., 30 year moving average, the larger R^2 and F–value were found (Table 2). It could be concluded from statistical analysis that the effect of diminishing forest area on depletion of rainfall amount and disturbance of rainfall distribution would be clearly seen if 10 year or longer period of time–trend was considered.

Regarding rainfall distribution in relation to forest depletion in the Northeast, regression analysis obtained from applying long – term moving

Table 2. Regression analysis of the moving average of 10, 15, 20, 25 and 30 years of rainfall amount (AR)/numbers of rainy day (RD) and percentage of forest area (FOR) for the annual, rainy and dry periods in Northeastern Thailand

Duration	Amount of rainfall (mm)			Numbers of rainy day (days)		
	Regression equation	R^2	F-value	Regression equation	R^2	F-value
Annual period :	AR_{10} = 1277+2.35 FOR	0.4380	17.92^{**}	RD_{10} = 120−0.39 FOR	0.9329	354.52^{**}
	AR_{15} = 1273+2.55 FOR	0.6537	33.96^{**}	RD_{15} = 120−0.39 FOR	0.9386	275.37^{**}
	AR_{20} = 1294+1.94 FOR	0.6282	21.96^{**}	RD_{20} = 120−0.38 FOR	0.9345	185.56^{**}
	AR_{25} = 1340+0.53 FOR	0.1595	1.52	RD_{25} = 119−0.36 FOR	0.9626	206.19^{**}
	AR_{30} = 1285+1.96 FOR	0.7463	8.82^{**}	RD_{30} = 102−0.36 FOR	0.9781	133.55^{**}
Rainy season :	RS_{10} = 1110+2.52 FOR	0.4890	22.01^{**}	RRD_{10} = 100−0.29 FOR	0.9466	291.77^{**}
	RS_{15} = 1107+2.65 FOR	0.6819	38.59^{**}	RRD_{15} = 100−0.28 FOR	0.9337	253.28^{**}
	RS_{20} = 1130+1.99 FOR	0.6688	26.24^{**}	RRD_{20} = 100−0.29 FOR	0.9328	180.46^{**}
	RS_{25} = 1200+0.80 FOR	0.0034	0.03	RRD_{25} = 100−0.31 FOR	0.9653	222.74^{**}
	RS_{30} = 1160+0.92 FOR	0.2734	1.13	RRD_{30} = 102−0.36 FOR	0.9781	133.55^{**}
Dry season :	DS_{10} = 164+0.03 FOR	0.0009	0.02	DRD_{10} = 20−0.94 FOR	0.6261	32.82^{**}
	DS_{15} = 163+0.04 FOR	0.0035	0.06	DRD_{15} = 19−0.09 FOR	0.6274	28.62^{**}
	DS_{20} = 163+0.02 FOR	0.0034	0.04	DRD_{20} = 19−0.08 FOR	0.8817	89.38^{**}
	DS_{25} = 136+0.76 FOR	0.6762	14.65^{**}	DRD_{25} = 17−0.02 FOR	0.4088	4.84
	DS_{30} = 111+1.45 FOR	0.7534	6.11	DRD_{30} = 17−0.01 FOR	0.0514	0.11

Remark : ** Significant at 95% level ; Figures as subscrip indicate numbers of year used in the moving average for time series analysis.

averages indicate rather clear on the effect of deforestation on numbers of rainy day, especially for rainy season and annual period. Based on time series analysis using 25 year moving average, depletion of forest area had about 96 percent influence on the numbers of rainy day for both the rainy season and throughout the year. This influence indicated very highly significant for both the short–term and long–term basis.

The impact of diminishing forest area on the mentioned phenomena is, however, not large if we consider form the magnitudes obtained from the regression equations. Equations representing 30 year moving average demonstrated that only 196 mm/yr and 46 rainy–day/yr would be the differences for the case that the Northeast covered by the forest area ranging from 0 to 100 percent. These figures are still in the ranges of mean deviation of annual rainfall and of mean annual number of rainy day of the Northeast (see Table 1).

DISCUSSION

Based on the results obtained from statistical analysis plus the investigator's experiences and feeling, the brief discussion on the effect of diminishing forest area on the rainfall phenomena in the Northeast are as follows: Physiographically, there are several high mountain ranges in the Northeast which could affect on orographic rain fall and create the fog drips or the so–called horizontal precipitation. Unfortunately, this kind of phenomenon has never ever monitored in this region. The effect of forest depletion on rain fall amount and distribution in this aspect could not be discussed. Since historical rainfall data recorded by the Meteorological Department and Royal Irrigation Department have been mostly collected from the raingages locating in the lowlands, the effect of deforestation on horizontal precipitation is thus beyond the scope of this investigation.

In general, it has been well recognized that Thailand is situated in the monsoon climatic zone. Large amount of all region's rainfall is therefore dependent upon the prevailing south-west monsoon rather than the influence of intracycling of moisture of the Northeast itself. This is why the effect was not so large compared to that has been occurred in the Amazon Basin. It might be also possible that several man-made reservoirs existed after dam construction were the large source of moisture contributing to higher variation of rainfall amount and numbers of rainy day during the recent years. The uncertain numbers of depression and Typhoon are also another sources of variation dominating the influence of forest depletion on rainfall patterns.

However, it might be postulated that the deforestation in the Northeast altered the time distribution of rainfall. The significant increasing numbers of rainy day with decreasing forest area implies the larger numbers of rainy day to cover the same or a bit less amount of annual rainfall. This could be, in other words, said that the pattern of rainfall in term of time distribution is not the same as that it was happened in the past. This is, perhaps, the only significant impact on rainfall characteristices caused by deforestation in the Northeast.

One must be however cautious that relationships between the diminishing forest area and rainfall characteristics may not be in the form showed in this study due to data indicating the reduction of forest area during 1951 to 1960 is obtained by backward extention based on 1961–1985 data which interpreted from LANDSAT. Trend of deforestation rate during 1951 to 1960 might not be the same as that derived by this investigation.

CONCLUSIONS

The investigation on the effect of diminishing forest area in the Northeast on rainfall amount and distribution using 34 year historical records of rainfall, numbers of rainy day and depletion forest area of the Northeast can be concluded as follows :

1. The existing forest area in 1984 was only 14 percent of the region's total area. Rate of forest depletion during 1951 to 1984 was estim ated at 1.07 percent/year.

2. Mean annual rainfall over the region was about 1,351 mm. in which about 1,190 mm or 80 percent occurred in the wet season. The mean of rainy day was about 107 days with 91 days occurred in the rainy season.

3. Based on year–by–year ana lysis, the effect of forest depletion on rainfall amount as well as on numbers of rainy day for any given periods, i.e., monthly, seasonal and annual was insignificant.

4. Statistical analysis for time – trend consideration indicated that annual rainfall amount and that of wet period tend to significantly decrease with decreasing forest area. Time distribution of rainfall representing by numbers of rainyday for monthly, seasonal and annual periods increase significantly with decreasing forest area. The trend for both the case of rainfall amount and rainy-day is clearly seen when longer period of time series was applied to determine.

Results obtained from this invest igation are certainly not the final conclusion. There are many questions remain to be answered in which longer period of rainfall record and better techniques of analysis are needed for the valid conclusion in the future.

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