Hydrological Parameters for Fast Growing Tree Species Cultivation in Shifting Cultivation Areas of Nagaland

Regional Centre
National Afforestation & Eco-Development Board
North-Eastern Hill University, Shillong

2010

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Prof B. K. Tiwari
Coordinator

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1. INTRODUCTION

In the present day scenario lands under shifting cultivation are degrading at a fast rate leading to loss of top soil and depleting natural forest cover which is overtaken by secondary vegetation disturbing the hydrology of the area. Therefore, an understanding of hydrological parameters of the fast growing trees being planted on degraded shifting cultivation lands for selection of trees suitable to site conditions is needed. The production capacity of the shifting cultivation lands also decreases through the cycle of felling of tree species. The present study mainly aims at understanding the hydrological parameters and water budget of the shifting cultivation areas with particular emphasis on the availability of water and on the effect of run-off on the nutrient status of soils.

Shifting cultivation in the history of civilization is regarded as first step in transition from food gathering and hunting to food production. The system is known by several names and varies according to biophysical conditions of the place. In Northeastern India it is known as *Jhum*. Essential features of shifting cultivation are: selection of site on hill slopes, clearing of forest (cutting and burning of jungles), using the site for two years for food production by planting crops in a mixture of crops such as rice, maize, millets, yam, chillies, ginger, potato and thereafter moving to a fresh site for repeating the process. Shifting cultivation in itself is one of the oldest forms of agroforestry known to mankind. In the more permanent forms of shifting cultivation a period of cultivation of food crops is followed by a period under forest fallow during which the fertility of the soil is restored (Jackson, 1984). Shifting agriculture involves clearing a patch of forest land, but retaining useful trees and other perennial plants, cultivating the land for one or two years and then abandoning it for 10-20 years to allow the regrowth of natural vegetation to restore the fertility. The cycle of cultivation, leaving it fallow and coming back to it for cultivation is called the Jhum cycle. With increasing population and declining fertility of land, more and more areas are brought under shifting cultivation and the fallow period decreases thus causing shortening of the shifting cultivation cycle. The short cycle jhum is destructive for soil-water-vegetation system (Tiwari, 2009). It leads to soil erosion, heavy silt load and drying up of perennial water sources of shifting cultivation areas (Singh, 1998).

Traditionally, a village community owns/controls the forest land and decides on such rotational cultivation pattern. Thus the community cultivates land is used to provide the livelihood of the people while practicing conservation and taking care of the ecological balance (Thangam, 1984). Shifting cultivation continues to be the primary agricultural system in Nagaland. Statistics show that it extends to over 917,087 ha of land, inclusive of fallow lands (regenerating forests) at different stages. Shifting cultivation as a system of farming has always been a subject of debate in this state. Some of the off quoted statements in the state include the following :

- *Jhum* is just a subsistence system of agriculture.
- *Jhum* is the reason for the poor productivity of agriculture in Nagaland and the reason why people continue to live in poverty.

- *Jhum* is destructive agriculture.
- *Jhum* contributes to the global climate change due to carbon emission during the burning process.

These statements have some elements of truth but some of them are not fully grounded on sound scientific data. Accurate, comprehensive economic data on forest production and revenues in Northeast India are difficult to obtain. Since the Godavarman decision in 2005 of the Indian Supreme Court, the commercial extraction of timber has been substantially reduced, while illegal logging continues in some areas. However, estimates on the value of trade in sawn or whole logs are hard to ascertain. The benefits and costs of forest in the Northeast can be better assessed in terms of their value to local communities for fuel, non-timber forest products and domestic timber, and as a part of the agricultural system, rather than from the stand point of industrial timber values. At the national level supported by Supreme Court decision, priority is being placed on managing forests to ensure environmental services, especially the hydrological functions and the biodiversity conservation.

The government has historically viewed forests and agriculture as separate entities. The linkages and interdependence of forests and agriculture in much of North-east India have seldom been recognized. As a result, forest managers have regarded *Jhum* as unsustainable land use, while agriculture extension workers and scientists may regard forests as jungle growth on agricultural land (Tiwari, 2007). This was at least partly because the policies were developed centrally and senior personnel were trained for a management approach in which people were considered encroachers and outsiders. However, new thinking is developing that acknowledges that "undistorted" traditional *Jhum* is a viable land use, one that supports the conservation of natural resources (Tiwari, 2009). Hill regions of Northeast India are predominantly inhabited by tribal societies whose livelihood is primarily dependent on agriculture, forest products and limited horticulture and cash crops. Unlike the rest of India, in this region there is often no clear-cut demarcation of forests and agricultural lands. In shifting cultivation areas the same piece of land can be under agriculture at one point of time and under forest at another time. Some planners and managers consider this as "agriculture on forest land," while other regard it as "forest on agricultural land" (Tiwari, 2007).

The abandonment of land after shifting cultivation has normally led to the formation of various stages of fallows or secondary forests. The secondary forests offer a distinct contrast to the primary forests, both structurally and floristically. The common successional categories are usually the grasslands which are established after one year of planting of crops. These grasslands are usually dominated by herbs, sedges, ferns and young shrubs. Emerging shrubs and trees were common in the successional stage of the fast growing species (Ipor *et al.*, 2004). This succession of fast growing tree species affects the hydrology of the shifting cultivation areas.

The process of deriving the hydrological parameters of fast growing tree species includes the estimation of the water balance which can be obtained by temperature and rainfall data which will help in obtaining potential evapo-transpiration and heat index. Such hydrological parameters should estimate the water balance model for fast growing tree species. The diversity and growth of fallow vegetation play an important role in the system's productivity and sustainability. Growing pressure on the land resulting in the reduction of the length of the fallow period and changes in agricultural practices are leading to lower levels of productivity. These attempts to develop improved fallows based on enrichment planting with fast-growing leguminous trees. As a consequence, any attempt to improve the fallow vegetation should take into consideration its diversity and make the best use of it in association with the introduced species, aiming at system, sustainability. Denich *et al* (1995) emphasized the importance of understanding the diversity and growth of fallow vegetation which plays an important role in the system's productivity and sustainability. Growing pressure on the land resulting in the reduction of the length of the fallow period and changes in agricultural practices are leading to lower levels of productivity.

The clear reduction in total and dry season flows observed after afforesting natural grass- and scrubland with pines or eucalyptus in South Africa, south India and Fiji only serve to demonstrate the difference in water use between forest and grassland. In other words, the potentially beneficial effects on low flows afforded by improved infiltration and soil water retention capacities during forest development could not be manifested in these examples. The key question is therefore, whether the reductions in storm run-off generating overland flow incurred by such soil physical improvements can be sufficiently large to compensate the extra water use by the new forest, and so (theoretically) boost low flows. There is no easy answer to this question for several reasons. First of all, the effect of an increase in topsoil infiltration capacity on the frequency of occurrence of infiltration-excess overland flow depends equally on prevailing rainfall intensities. Secondly, the reductions in catchment response to rainfall observed after forestation will also reflect the drier soil conditions prevailing under actively growing forest rather than a reduction in peak-generating overland flow per se. Thirdly, there is also the effect of soil depth which determines both the maximum amount of water that can be stored in a catchment under optimum infiltration conditions, and the possibilities for water uptake by the developing root network of the new trees. Last, but not least, there is the confounding effect of rainfall patterns (e.g. seasonal versus well distributed) and general evaporative demand of the atmosphere, which both exert a strong influence on tree water use, particularly in sub-humid areas. Unfortunately, the results of this interesting experiment were confounded by rainfall variability. Needless to say, differences in soil and climatic factors, plus the absence of detailed information on prevailing storm flow mechanisms before and after forestation, all render comparisons between different sites more complicated and rigorous experimental designs are needed (Bruijnzeel, 2004).

Since the trees grows on the catchment area and its hydrological parameters are influenced by the following characteristics of the river catchment. Surface run-off is a main parameter to assess the available water in a river catchment. The infiltration rate is another parameter that determines the run-off. The measurement of all these depends on the areal characteristics of catchments, stream characteristics, soil and land use characteristics and hydrological characteristics that influences the runoff (Singh, 2007).

Subrahmanyam (1982) also explained the relationship between water balance elements, land use, irrigation and cropping pattern. Much of the botanical work was done earlier in the Swiss Alps where the vertical zonation of vegetation was found to be the consequence of similar zonations of temperature. Simultaneously, workers in the botanical gardens in various cities in Western and Central Europe began making observations on the dates at which certain critical phases like germination, emergence, flowering etc, occurred in various plants. There were variations from one year to another and from place to place. These variations in the vital processes of plants were recognized to be due to variations in climate and a vast amount of labor was expended in an attempt to find the relationships and to express them in a mathematical form. The chief concern was the influence of temperature and sunshine on plant development.

The understanding of hydrological parameters for fast growing tree species would help in regenerating the degraded fallow lands without disturbing the fertility of the land and support tree species without disturbing the productivity level of the shifting cultivation areas. This study will thus help to develop more reliable and productive improved fallow systems. It also aims to contribute to the effective system design and management of fast growing tree species cultivation in shifting cultivation areas.

Kumar *et al.* (2001) studied the importance of water relation that influences the soil properties. Soil hydraulic properties are important to understand the prediction of soil water flow. It is important to know the importance of run-off and infiltration which contributes to the hydrology of the watershed. Singh (2002) has illustrated the interception and evaporation components by using meteorological data and vegetation parameters for hydrological modelling of a watershed. Rao *et al.* (2003) have demonstrated the influence of infiltration by studying various properties such as conditions of soil surface, vegetative cover and properties of soil and moisture content for assessing the hydrological parameters. Singh (2005) studied the effects of PET (potential evapotranspiration), ET (evapo-transpiration), ST (soil storage) and TE (total evaporation) in relation to crop growth factors. He found that these indices help in understanding the parameters of plant growth index, water use efficiency for the growth of plants.

Keeping in view of various aspects of fast growing tree species of Nagaland in mind, the present study focuses attention towards the following objectives:-

i. To study the hydrological parameters of the selected area,

ii. To examine the water budget of the area in order to understand the role of availability of water in growth of different tree species and

iii. To investigate the effect of run-off on the nutrient status of soils for understanding the tree growth in *Jhum* cultivation areas.

2. STUDY AREA

The study area is located in the Dikhu watershed which flows in the four districts of Nagaland namely Tuensang district in the east, Mon district in the north-east, Mokokchung district in the west and Zunheboto district in the south. The watershed is *Jhum* dominated having various plantations with semi-tropical climate with dominance of bamboos, cherry, natural forest trees, etc grown after the fallow period. In Nagaland about 400,000 people practice shifting cultivation over an area of about 6,080 km^2. Rice is the most dominant crop but millets, potatoes, yams, chillies, cotton and maize are also cultivated. It has a latitudinal and longitudinal extent of 26° 0′N to 26°52′N to 94°30′ E to 95°16′ E. The contour extent is from 500 m to 2000 m. The state shares its boundary with Assam on the north and north-west, Manipur on the south and Myanmar on the east.

To study the growth of tree species in the successive stages in the shifting cultivation areas, the most dominating *Jhum* area of Nagaland was selected (Fig.1) from the districts of Zunheboto, Tuensang, Mokokchung and Mon as the testing ground of the above given objectives. The representative sites selected for each district were Lumami village for Zunheboto, Chare village for Tuengsang, Ungma village for Mokokchung and Tamlu-Konyak village for Mon. The major issues of tree growth in relation to hydrological parameters are addressed to consider the Dikhu watershed of about 3000 sq. km a complete geohydrological unit. Within the Dikhu watershed (Fig. 2) the areas of shifting cultivation were identified where successional growth of variety of natural vegetation persists. Selection of the tree species in the identified patches of shifting cultivation was made by considering the following basis of geomorphological parameters of landscape which are directly or indirectly related to the hydrology of the area.

Present investigation is based on two main hydrological aspects of landscape, namely,

(i) The examination of water balance in the environment as well as in the soils of the study area and

(ii) The understanding of soils *in situ* especially in the areas of tree-species for knowing the biophysical factors of the growth of tree-species.

Thus, the study area has two phases of investigation i.e., data collection and examination of facts.

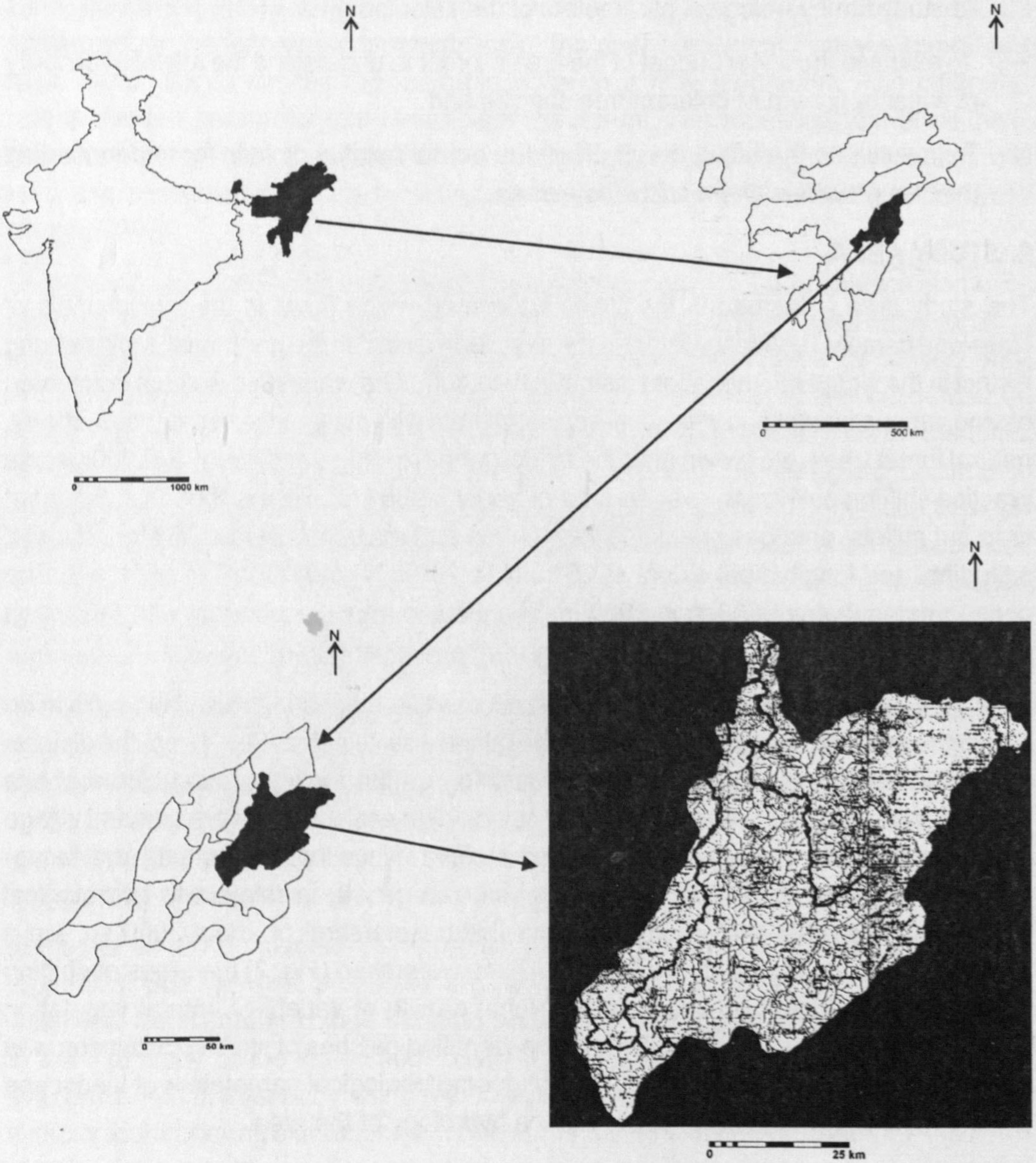


Fig. 1 : Study Area

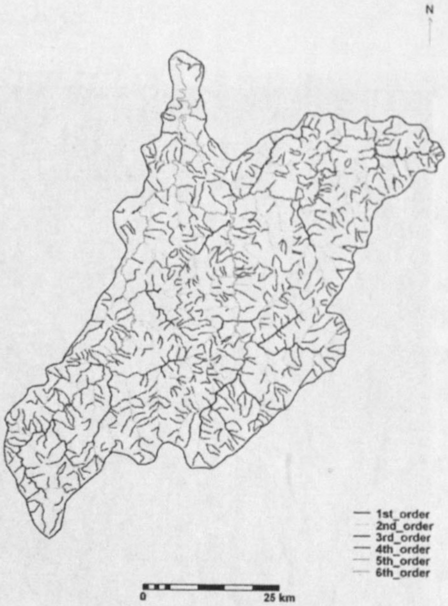


Fig. 2 : Drainage map of Dikhu watershed

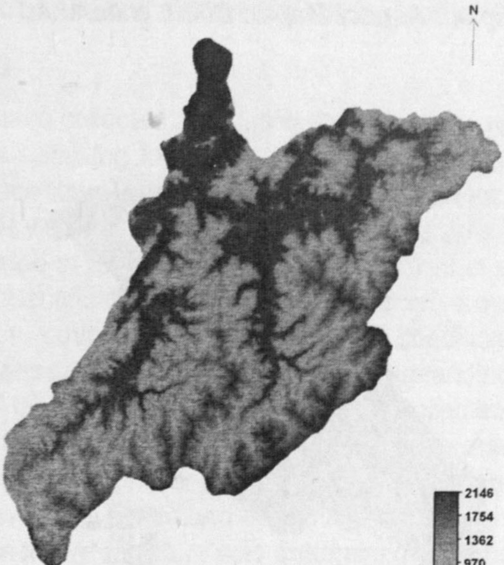


Fig. 3 : Topography of Dikhu watershed (DEM: Digital Elevation Model)

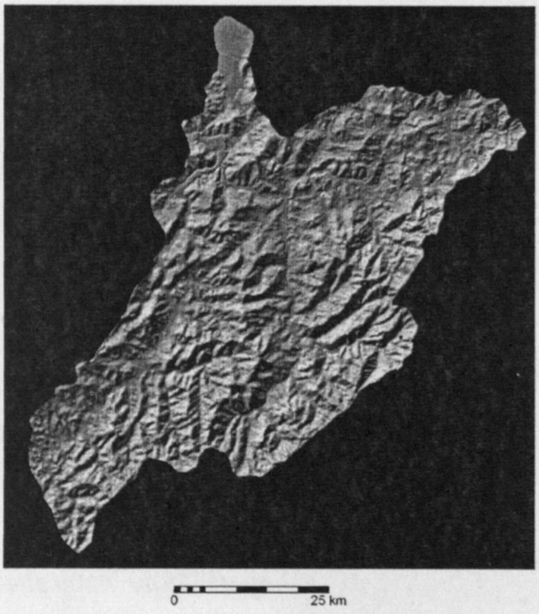


Fig. 4 : Aspect Map of Dikhu watershed

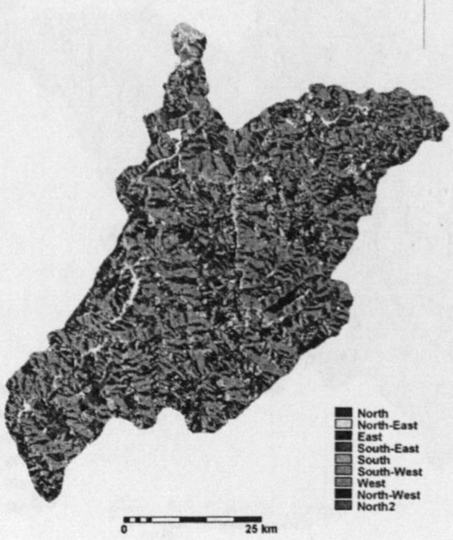


Fig. 5 : Aspect Alignment of Dikhu watershed

3. MATERIALS AND METHODS

3.1 PREPARATION OF WATER BUDGET OF THE WATERSHED

A topo sheet of R.F. 1:250,000 scale was considered ideal for the assessment of hydrological parameters for fast growing tree species cultivation to assess water balance and run-off. Most part of the catchment was covered in two topo sheets of same scale: 83/J and 83/N. Following attributes were generated to show the hydrological parameters for fast growing tree species cultivation such as mean annual potential evapo-transpiration (PET), Infiltration rate, soil texture, soil chemical composition and Water holding capacity. Adoption of water budget is one of the most appropriate ways to assess the hydrological parameters for the fast growing tree species cultivation. The amount of water surplus and deficit were calculated by using water budget (as W= P-PET-INF) which is operative with the conversion tables of the water balance given by Thornthwaite *et al.* (1957). This was prepared by heat index function of temperature as $HI = (T^{o}C/5)^{1.514}$ which was used to calculate PET and ET through the use of conversion tables. Similar table were also used by Subrahmanyam (1982) for the calculation of PET and ET for different meteorological stations in India. The concerned data were collected from secondary sources for the preparation of water-budget of the watershed. Monthly temperature and statistics have been collected for four years (2004 to 2007) from the District Soil Office, Mokokchung. A conversion table given by Thornthwaite et al., (1957) was used to estimate PET and soil moisture for the preparation of the water budget.

3.2 SOIL ANALYSIS

Composite samples were collected from small portions of the soil at a depth of 0-15cm by means of suitable sampling tools from at least 10-15 well distributed spots after scrapping off the surface litter. The soils collected in this manner were thoroughly mixed. The bulk was reduced by quartering process to about 500 grams and packed in polythene bags. The soil was dried at room temperature and packed in cloth or polythene bags with description and identification marks. The soil samples were collected from sites having equal elevation, equal slope, similar weather conditions and similar drainage pattern. Soil analysis was done in the laboratory for understanding the physical properties (texture) and color of the soil. The soil samples were collected from four sites having four different types of tree species in each shifting cultivation zone in Nagaland. The soil samples were collected from Ungma and Lumami villages for Mokokchung and Zunheboto districts respectively, whereas Chare and 16 Tamlu villages were selected for Tuensang and Mon district respectively. Moisture was determined gravimetrically by oven-drying method and soil pH was measured in 1:2.5 fresh soil-water (w/v) suspensions with an electric digital pH meter (Systronics). The detailed methodologies for few parameters are given below:

Construction of Single Ring Infiltrometer

Cylinders made of 14 gauge iron sheet were rolled in a circular fashion and the joints were groomed to a smooth finish. One end of the cylinders was sharpened from outside keeping the inside completely smooth. This facilitates the easy drive of cylinders in the soil. Cylinders were galvanized after fabrication. Inner diameter of the ring was 30 cm. Hammer of sufficient weight was used to drive the ring into the soil. A stop watch was used for recording time. Water was collected from nearby water source.

Procedure : Single Ring Method

1. Surface litter from 50cm X 50cm area of bare soil was removed.
2. The iron ring was vertically driven into the soil to a depth of 2-3 cm. The soil around the base was pressed to minimize water leakage and the soil surface in the ring was covered with sacking.
3. The cylinder was filled to about 10 cm deep, the time was recorded and the water depth was measured.
4. The cylinder was filled to about 15cm, the time was recorded and the distance from the water leveling the inner cylinder to the inner cylinder top was measured.
5. The cylinder was refilled when the level has dropped to about 10 cm. The water level was noted before and after refilling on each occasion. Equivalent water levels were maintained in the ring.
6. The measurement unit was continued until steady state has been reached.
7. A table of results was constructed to show time interval.

Moisture Content (Gravimetric Method)

When moist soil is heated at 110 °C for about 24hr, only the water, which had been absorbed or held within the soil pores, is evaporated. There is no loss of water of crystallization and the oxidation of organic matter does not occur at this temperature.

Equipments : Drying oven; Top-pan balance reading to 0.01g; Paper boxes

Procedure :

1. The empty paper box was weighed.
2. About 100g of soil sample bearing moisture was taken.
3. The soil sample was immediately kept in the paper box and was closed. It was weighed immediately to prevent moisture loss.
4. The lid was removed and placed in the paper box containing soil sample in the oven to a temperature of about 110 °C and the soil sample was dried for 24 hours.

5. The oven dried soil sample was weighed and the soil moisture content was calculated.

$$\text{Moisture Content (\%)} = \frac{\text{Loss of Moisture } (m_2 - m_3), \text{ g X } 100}{\text{Weight of oven- dried sample } (m_3\text{-}m_1), \text{ g}}$$

Where, m_1 = Weight of the empty paper box, m_2 = Weight of paper box + Moist Soil and m_3 = Weight of paper box + Oven dry Soil

pH measurement

Equipments : 100 ml beaker; Distilled water; pH meter; Top-pan balance reading to 0.01g;

Soil sample

Procedure : 20 g of soil was taken in a 100 ml beaker to which 50 ml of distilled water was added. The suspension was stirred at regular intervals for 30 minutes and pH was recorded. The suspension was stirred well before the electrode was immersed. The pH value obtained usually increases with increase in the volume of water used. The increase in pH value was caused by the dilution of the H^+ ion concentration in solution.

The secondary data for temperature and rainfall was collected from Soil Conservation Department, Mokokchung (Nagaland) and water level data was collected from Central Water Commission, Guwahati. These data were used for the calculation and tabulation of the results. The soil samples collected during the fieldwork were brought to the laboratory of Soil and Water Conservation Department, Shillong for analyzing their chemical and physical properties. This also involves tracing and making of various maps of the study area by the Map-info software and making charts and analyzing the findings observed during the field work.

4. OBSERVATION

4.1 VARIATION IN TEMPERATURE

The seasonality of temperature throughout the year from 2004 till 2007 in Dikhu watershed in Nagaland seems normal (Fig. 6). Monthly trends of temperature clearly distinguish the year into three seasons: the summer season from March to October, the rainy season from June to October and winter from November to February. Temperatures recorded maximum during August to September in the rainy season characterized as 'monsoon climate' while winters are dry and cold. The highest temperature for the year 2004 was 26.42 °C during the summer month of August and the lowest recorded temperature was 16.23 °C during the winter month of December. In 2005, the highest temperature was recorded in the month of September having a record of 26.85 °C and lowest was recorded as 14.55°C in the month of December. The highest temperature for the year 2006 was recorded as 28.15 °C in the month of September and the lowest was recorded as 13.54 °C in the month of January. While the highest temperature for the year 2007 was recorded in the month of August having 28.90 °C, the lowest temperature was recorded as 17.41°C. It was observed that the growth of the tree species was favored during the months of

August and September while December, January and February were not as favorable. Of all the four years of temperatures recorded, the year 2006 had maximum fluctuation in temperature consistency which fluctuated from as high as 37 ºC in summer months to as low as 13 ºC during winter.

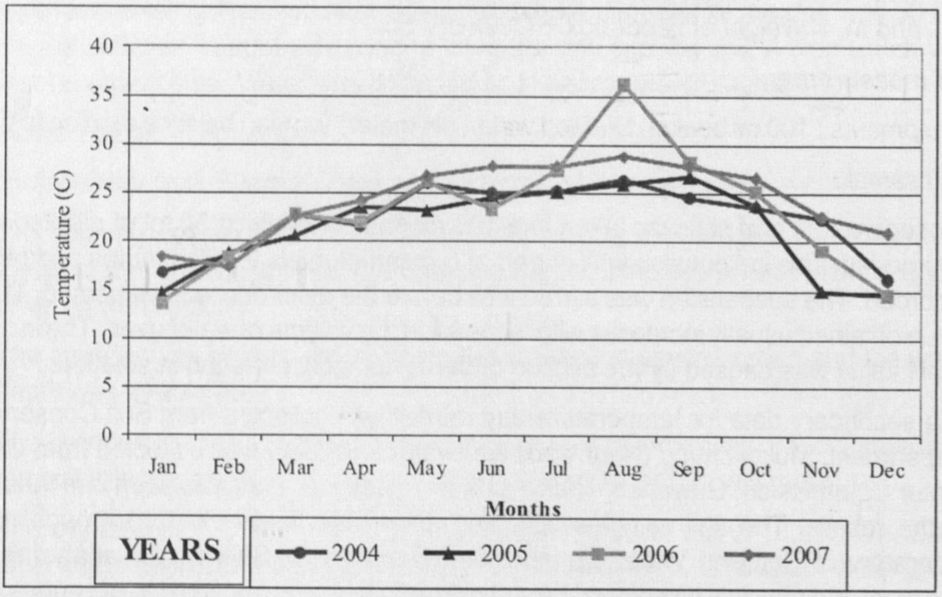


Fig. 6 : Variations of temperature from the year 2004 to 2007 in Nagaland

4.2 TREE SPECIES COMPOSITION AND DIVERSITY IN SELECTED PLOTS

The sample plantation tree species were identified from the field area. In the sample village of Lumami the plantation tree species selected were: *Terminalia myriocarpa*, *Gmelina arborea* and *Duabanga grandiflora*. *Terminalia myriocarpa* had the stand ages of 10, 15 and 20 years, and the associated tree species found were: *Alstonia sp, Gmelina arborea, Schima wallichi, Cassia fistula, Mangifera indica* and *Prunus* sp.

The *Gmelina arborea* plantation areas had the stand ages of 5, 10 and 15 years and the associated tree species were: *Prunus* sp., *Schima wallichi, Tectona grandis and Alnus* sp. The *Duabanga grandiflora* plantation area had the stand ages of 3 and 8 years. Other associated tree species found were: *Schima wallichi, Terminalia chebula, Terminalia myriocarpa* and *Michelia champaca* (Table-1).

The plantation tree species selected in Chare village were: *Melia azaderach*, *Terminalia myriocarpa* and *Duabanga grandiflora*. *Melia azaderach* had the stand age of 2, 3 and 5 years, and the associated tree species found were: *Bombax ceiba*. *Terminalia myriocarpa* plantation had the stand age of 3, 5, and 10 years. *Duabanga grandiflora* plantation area had the stand ages of 1, 3 and 5 years and other associated tree species found were: *Macaranga denticulata* and *Toona ciliata* (Table 2).

The sample plantations selected in Ungma village were: *Alnus nepalensis* with an age stand of 7, 10 and 15 years, *Prunus* sp. of an age stand of 5, 10 and 15 years and *Terminalia myriocarpa* stand of 5, 10 and 15 years. It was found that the plantation of all the three stands in this area is of pure stand with no associated species present in the selected sites (Table 3).

In Tamlu-Konyak village, the plantation stand of *Gmelina arborea* age 5, 12 and 15 years, *Duabanga grandiflora* age 5, 8 and 15 years and *Macaranga denticulata* of age 1, 4 and 10 years were selected. Associated tree species of *Alnus nepalensis*, *Ficus hispida*, *Schima wallichii* and *Prunus* sp. were found in *Gmelina arborea* stand. In the plantation site of *Duabanga grandiflora* the associated species found were: *Melia azaderach*, *Artocarpus* sp, *Gmelina arborea*, *Mangifera indica* and Olonmodung (Table 4).

Table 1 : Plantation stands of Lumami village

Species	Density(per ha)	Mean CBH(cm)	Mean Height(m)
***Terminalia myriocarpa* stand (*10)**			
Cassia fistula	1	91	12
Mangifera indica	1	38	5
Prunus sp.	2	83	13
Terminalia myriocarpa	17	46	12
***Terminalia myriocarpa* stand (* 15)**			
Alstonia sp.	2	62	8
Gmelina arborea	1	82	9
Schima wallichi	1	30	5
Terminalia myriocarpa	16	58	12
***Terminalia myriocarpa* stand (*20)**			
Terminalia myriocarpa	18	150	13
***Gmelina arborea* stand (* 5)**			
Gmelina arborea	18	25	7
Prunus sp.	2	21	6
Schima wallichi	1	40	12
Tectona grandis	2	27.5	5
***Gmelina arborea* (*10)**			
Gmelina arborea	18	35	10
Prunus sp.	2	23	6

Gmelina arborea **(*15)**			
Alnus nepalensis	1	40	6
Gmelina arborea	16	52	11
Prunus sp.	2	33	7
Duabanga grandiflora **(* 3)**			
Duabanga grandiflora	16	18	7
Schima wallichi	1	20	3
Terminalia chebula	1	190	14
Terminalia myriocarpa	2	45	13
Duabanga grandiflora **(* 8)**			
Duabanga grandiflora	15	51	14
Michelia champaca	1	21	9
Terminalia chebula	1	45	15
Terminalia myriocarpa	1	25	6

Table 2 : Plantation stands of Chare village

Species	Density(per ha)	Mean CBH(cm)	Mean Height(m)
Melia azaderach **(*2)**			
Melia azaderach	17	8	3
Melia azaderach **(*3)**			
Melia azaderach	13	69	13
Melia azaderach **(*5)**			
Bombax ceiba	1	57	15
Melia azaderach	13	97	15
Terminalia myriocarpa **(*3)**			
Terminalia myriocarpa	21	22	8
Terminalia myriocarpa **(*5)**			
Terminalia myriocarpa	24	43	15
Terminalia myriocarpa **(*10)**			
Terminalia myriocarpa	16	106	18
Duabanga grandiflora **(*1)**			
Duabanga grandiflora	17	33	8
Macaranga denticulata	1	6	5
Toona ciliata	1	21	9
Duabanga grandiflora **(*3)**			
Duabanga grandiflora	25	54	11
Duabanga grandiflora **(*5)**			
Duabanga grandiflora	17	90	12

Table 3 : Plantation stands of Ungma village			
Species	Density(per ha)	Mean CBH(cm)	Mean Height(m)
Alnus nepalensis **(*7)**			
Alnus nepalensis	37	31	8
Alnus nepaleansis **(*10)**			
Alnus nepalensis	27	54	11
Alnus nepaleansis **(*15)**			
Alnus nepalensis	21	77	15
Prunus sp.	1	96	15
Prunus sp. **(*5)**			
Prunus sp.	25	22	10
Prunus sp. **(*10)**			
Prunus sp.	26	40	12
Prunus sp. **(*15)**			
Prunus sp.	25	60	15
Terminalia myriocarpa **(*5)**			
Terminalia myriocarpa	24	20	8
Terminalia myriocarpa **(*10)**			
Terminalia myriocarpa	25	43	9
Terminalia myriocarpa **(*15)**			
Terminalia myriocarpa	22	66	21

Table 4 : Plantation stands of Tamlu-Konyak village			
Species	Density(per ha)	Mean CBH(cm)	Mean Height(m)
Gmelina arborea **(*5)**			
Duabanga grandiflora	2	37	9
Gmelina arborea	18	21	5
Gmelina arborea **(* 12)**			
Gmelina arborea	26	57	11
Gmelina arborea **(* 15)**			
Alnus nepalensis	1	40	6
Ficus hispida	1	20	8
Gmelina arborea	19	76	13
Prunus sp.	3	40	7
Schima wallichi	4	48	11
Duabanga grandiflora **(*5)**			
Duabanga grandiflora	32	32	11

Duabanga grandiflora **(* 8)**			
Duabanga grandiflora	22	63	12
Melia azaderach	1	43	12
Duabanga grandiflora **(*15)**			
Artocarpus sp.	2	25	6
Duabanga grandiflora	18	96	14
Gmelina arborea	1	34	6
Mangifera indica	1	45	5
Olongmodung	1	130	12
Macararanga denticulata **(*1)**			
Macararanga denticulata	27	2	2
Macararanga denticulata **(*4)**			
Macararanga denticulata	25	16	4
Macararanga denticulata **(* 10)**			
Macararanga denticulata	23	35	11

*** Age**

4.3 PRECIPITATION AND PET (POTENTIAL EVAPO-TRANSPIRATION)

Potential Evapotranspiration is calculated by multiplying monthly values of unadjusted PET and location specific values of PET. The fluctuation in precipitation and potential evapotranspiration affects the growth of the tree species as the water cycle is balanced by evaporation from the land surface and evapotranspiration of water from plants. Figures 7-10 show the levels of precipitation and PET for the four years (2004-2007). During 2004 The levels of precipitation in Dikhu watershed was highest in April and August receiving up to 385.60 mm and 375.50 mm respectively and the PET was maximum in August having 147.84 mm, which was the wettest period of the year. From April to October precipitation exceeded the PET and during this period the temperature was maximum along with available moisture conditions which resulted in the luxuriant growth of the tree species in shifting cultivation areas. Thus, this extra moisture conditions led to the favorable growth of tree species. From the months of November to March, PET exceeded precipitation since precipitation was low and this coupled with low temperature contributed to the slow growth of the tree species (Fig. 7)

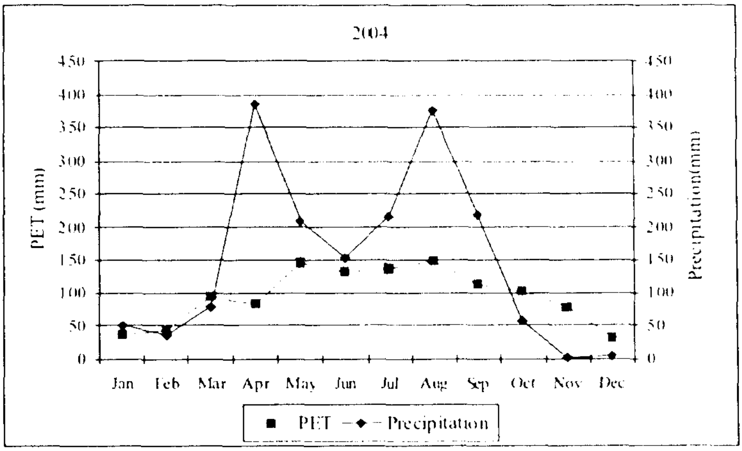


Fig. 7 : Precipitation and PET (Potential Evapotranspiration) trend for the year 2004

There were fluctuations in the Precipitation and PET level in 2005, the highest precipitation received was in the month of August accounting for 507 mm and the PET was 136.89 mm and 137.70 mm in July and September respectively. The rainfall period extended from May to August and the dry period was from the months of September to April. During May to August precipitation exceeded the PET and so there was a luxuriant growth of the trees in the shifting cultivation areas. During September to April there was a minimum precipitation and PET exceeded the precipitation: and this showed that it was a dry period and so, the growth of trees is slow due to deficient soil moisture (Fig. 8).

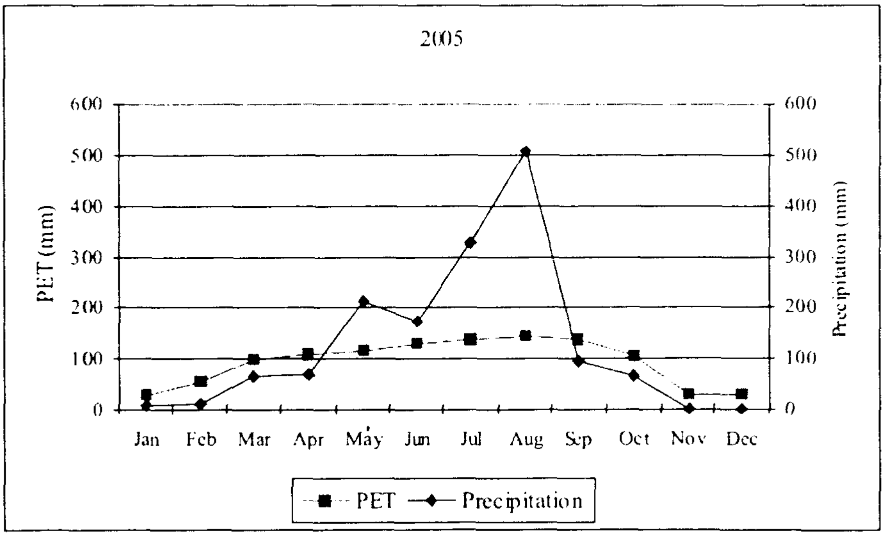


Fig. 8 : Precipitation and PET (Potential Evapotranspiration) trend for the year 2005

The year 2006 showed a great fluctuation of precipitation and PET period. The highest rainfall was received during April to September; the highest precipitation (579.80 mm) was recorded in the month of July. This was the wettest period of the year which supported the luxuriant growth of the tree species grown in shifting cultivation areas. The period from October to March was the period of dry season where PET exceeded the precipitation. One very important feature shown in this figure is that the month of August showed a period of sudden drought where the PET values were more than the precipitation received in the area. This factor may lead to sudden dying of tree species due to sudden dry period coupled with very high temperature since this period comprised the hottest summer months in shifting cultivation areas where plant requires more water for its growth (Fig. 9).

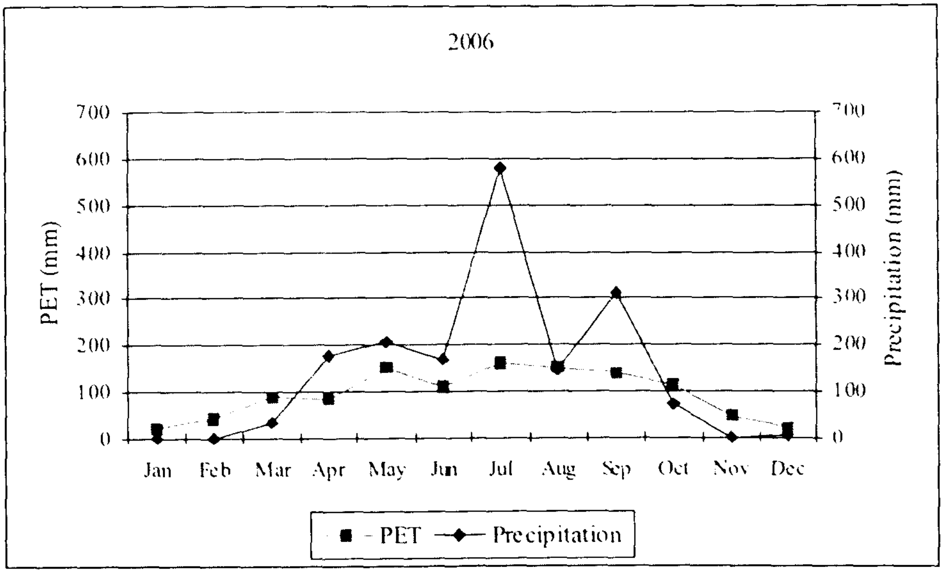


Fig. 9 : Precipitation and PET (Potential Evapotranspiration) trend for the year 2006.

Precipitation and PET values showed a great fluctuation in 2007. Precipitation was high in the month of February. Its value dropped down in the month of March and it remained high till the month of October. The highest precipitation (338 mm) was received in the month of July. The PET values exceeded the precipitation values in the month of February while it decreased in the month of March and it again increased from the month of November to December. The highest PET recorded was 157.95mm in the month of July. This shows that precipitation was higher than PET and this condition favored the growth of the trees (Fig. 10).

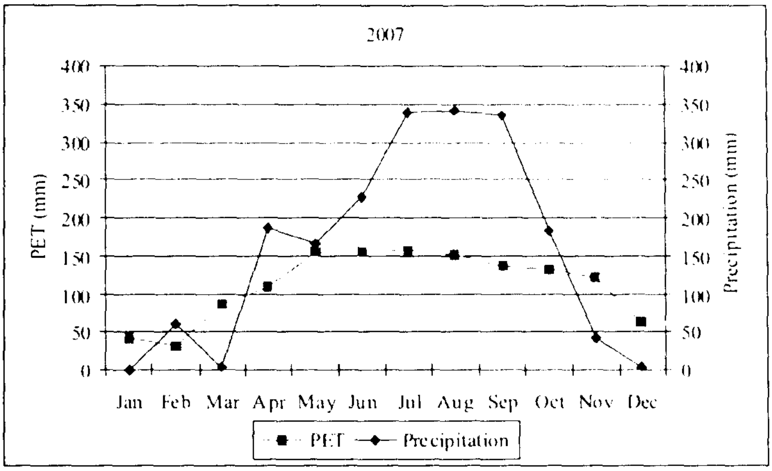


Fig. 10 : Precipitation and PET (Potential Evapotranspiration) trend for the year 2007

Precipitation and PET play an important role in the growth of trees, availability of moisture in the soil and in the atmosphere which is one the factors which contribute most to the growth of trees. Table 5 shows the precipitation (P), heat index (HI), actual evapotranspiration (A.E), unadjusted potential evapo-transpiration and potential evapo transpiration (PET) and soil storage (ST) from 2004 to 2007.

Table 5 : Hydrological parameters for the fast growing tree species cultivation in shifting cultivation areas in Dikhu watershed

2004

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (□ C)	16.9	18.46	22.85	21.69	25.97	24.94	25.18	26.42	24.53	23.58	22.4	16.23
Heat Index (HI)	6.32	7.22	9.98	9.22	12.11	11.39	11.56	12.43	11.11	10.47	9.68	5.95
Unadjusted PET monthly (mm)	1.3	1.7	3.1	2.6	4.2	3.8	3.9	4.4	3.7	3.4	2.9	1.2
PET(mm)	36.14	44.88	95.79	83.46	146.16	131.1	136.89	147.84	113.22	100.98	79.17	32.76
P (mm)	52	37	79	385.6	209	152.7	215.6	375.5	217.2	57.6	3.2	5.3
Δ=P-PET(mm)	15.86	-7.88	-16.79	302.14	62.84	21.6	375.5	227.66	103.98	-43.38	-75.97	-27.46
Accumulated wet loss (mm)	130.95	138.83	155.62	0	0	0	0	0	0	-43.38	119.35	146.81
Soil Storage (ST) in mm	104	99	91	200	200	200	200	200	200	161	109	96
Δ ST (mm)	-8	5	8	-109	0	0	0	0	0	39	52	13
Actual Evapo-transpiration(mm)	44	42	87	276.6	209	152.7	215.6	375.5	217.2	96.6	55.2	18.3

					2005							
Temperature (□ C)	14.58	18.82	20.69	23.65	23.29	24.62	25.24	26.08	26.85	23.86	14.95	14.55
Heat Index (HI)	5.05	7.44	8.59	10.51	10.27	11.17	11.6	12.19	12.74	10.65	5.25	5.04
Unadjusted PET monthly (mm)	1	2	3.1	3.4	3.3	3.7	3.9	4.3	4.5	3.5	1.1	1
PET(mm)	27.8	52.8	95.79	109.14	114.84	127.65	136.89	144.48	137.7	103.95	30.03	27.3
P (mm)	7.6	10.3	65.8	66.5	210.8	174.1	327.3	507	93.7	63.8	0	0
Δ=P-PET(mm)	-20.2	-42.5	-29.99	-42.64	95.96	46.45	190.41	362.52	-44	-40.15	-30.03	-27.3
Accumulated wet loss (mm)	161.68	204.18	234.17	276.81	180.85	-134.4	0	0	-44	-84.15	114.18	141.48
Soil Storage (ST) in mm	88	71	61	49	80	102	200	200	160	131	112	98
Δ ST (mm)	10	17	10	12	-31	-22	-98	0	40	29	19	14
Actual Evapotrans-piration (AE) in mm	17.6	27.3	75.8	78.5	179.8	152.1	229.3	507	133.7	92.8	19	14
					2006							
Temperature (□ C)	13.54	18.46	22.76	22.1	26.14	23.35	27.44	36.21	28.15	25.16	19.12	14.6
Heat Index (HI)	4.52	7.22	9.92	9.49	12.23	10.31	13.17	20.04	13.69	11.55	7.62	5.07
Unadjusted PET monthly (mm)	0.7	1.6	2.9	2.6	4.3	3.2	4.5	4.5	4.5	3.8	1.7	0.8
PET(mm)	19.46	42.24	89.61	83.46	149.64	110.4	157.95	151.2	137.7	112.86	46.41	21.84
P (mm)	0	0	34	177.4	205.5	168.5	579.8	145.9	310.9	69.9	0	5.3
Δ=P-PET(mm)	-19.46	-42.24	-55.61	93.94	55.86	58.1	421.85	-5.3	173.2	-42.96	-46.41	-16.54
Accumulated wet loss (mm)	0	0	-55.61	0	0	0	0	-5.3	167.9	124.94	78.53	61.99
Soil Storage (ST) in mm	200	200	151	200	200	200	200	200	86	107	135	147
Δ ST (mm)	0	0	49	0	0	0	0	0	114	-21	-28	-12
Actual Evapotrans-piration (AE) in mm	0	0	83	177.4	205.5	168.5	579.8	145.9	424.9	48.9	-28	-6.7
					2007							
Temperature (□ C)	18.31	17.41	22.65	24.25	26.74	27.77	27.9	28.9	27.73	26.52	22.7	21.1
Heat Index (HI)	7.14	6.61	9.85	10.92	12.66	13.41	13.5	14.24	13.38	12.5	9.88	8.85
Unadjusted PET monthly (mm)	1.5	1.2	2.8	3.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	2.3
PET(mm)	41.7	31.68	86.52	109.14	156.6	155.25	157.95	151.2	137.7	133.65	122.85	62.79
P (mm)	0	60.9	5	187.8	167.1	227.3	338	341.7	333.7	184	41.5	3.4
Δ=P-PET(mm)	-41.7	29.22	-81.52	78.66	10.5	72.05	180.05	190.5	196	50.35	-81.35	-59.39
Accumulated wet loss (mm)	182.44	153.22	234.74	156.08	145.58	-73.53	0	0	0	0	-81.35	140.74
Soil Storage (ST) in mm	64	173	129	119	93	95	200	200	200	200	133	79
Δ ST (mm)	15	-109	44	10	26	-2	0	0	0	81.35	67	54
Actual Evapotrans-piration (AE) in mm	15	-48.1	49	197.8	193.1	225.3	338	341.7	333.7	265.35	108.5	57.4

The **Heat index (HI)** is an index that combines air temperature and relative humidity in an attempt to determine the human-perceived equivalent temperature. The human body normally cools itself by perspiration or sweating, which evaporates and carries heat away from the body. However, when the relative humidity is high, the evaporation rate is reduced, so heat is removed from the body at a lower rate causing it to retain more heat than it would in dry air. Measurements have been taken based on subjective descriptions of how hot subjects feel for a given temperature and humidity, allowing an index to be made which corresponds temperature and humidity combination to a higher temperature in dry air.

Heat index (HI) was calculated by using the formula, Heat index (HI) = (T / 5) ^1.514, where T = Temperature in °C, 5 = Constant. In 2004 the heat index value was highest (12.43) in August. In 2005 the highest value (12.74) in September, in 2006 and 2007 the heat index was again highest in September, 13.69 in 2006 and 13.28 in 2007. There was a gradual rise in heat index values during 2004-2007. In the year 2004 the heat index was recorded highest in August but in the successive years its highest values occurrence was shifted to the month of September.

Actual Evapotranspiration (A.E) gives the water balance in the watershed. It is calculated by using the formula, A.E = P-PET, where P= precipitation in mm and PET = potential evapo transpiration. The status of water balance was obtained by graphically plotting A.E against the months of the year to present a clear picture of water surplus and water deficiency throughout the year. Such graphical presentation also reveals the accumulation and depletion of soil moisture. The water deficiency represents the amount by which precipitation fails to meet the demands of evapotranspiration after all the soil moisture has been used up. This is meant for understanding the amount of moisture available in the root zone of the soil and its periodical variations. Water balance enables us to understand the moisture needs and find measures to cope with the deficiency of moisture.

The water balance diagram for the year 2004 is presented in Fig. 11 for the whole watershed. The dry seasons were observed from the months of January to March and also from October to December. In the month of July, actual evapotranspiration exceeded the rainfall conditions. Potential evapotranspiration shows the use of moisture from the soil. From the months of April to September, the recharge of soil moisture in the catchment area increased to a considerable extent due to excess availability of moisture. The months of March to April and from June to August, the soil moisture recharge took place in these months and water was available in surplus from the months of May and from September to October.

The water balance curve of the watershed for the year 2004 is presented in Fig. 12. There was a decline in the water balance curve only from the months of May to October which showed the availability of moisture for a short period of time. The recharge season declined considerably as compared to the year of 2004. There was a moisture deficit

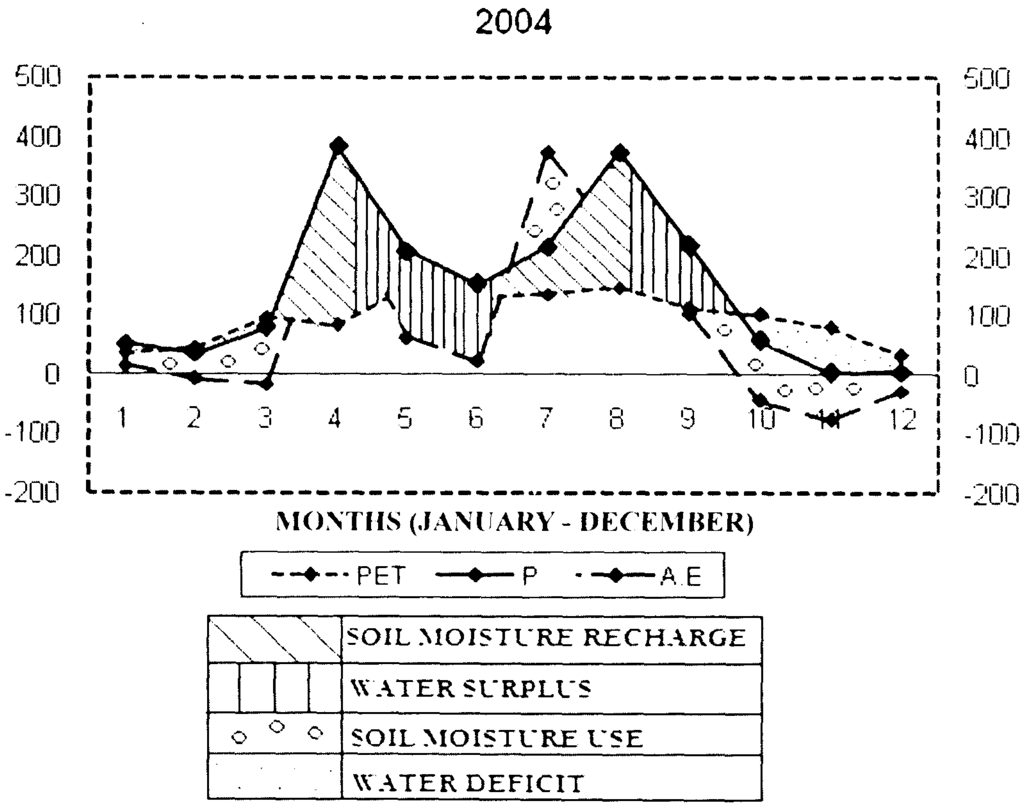
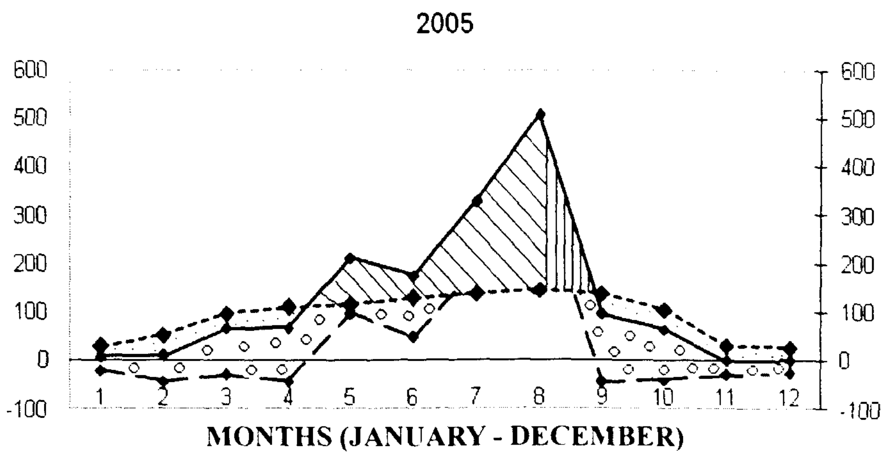


Fig. 11 : Water Balance Curve for the Year 2004

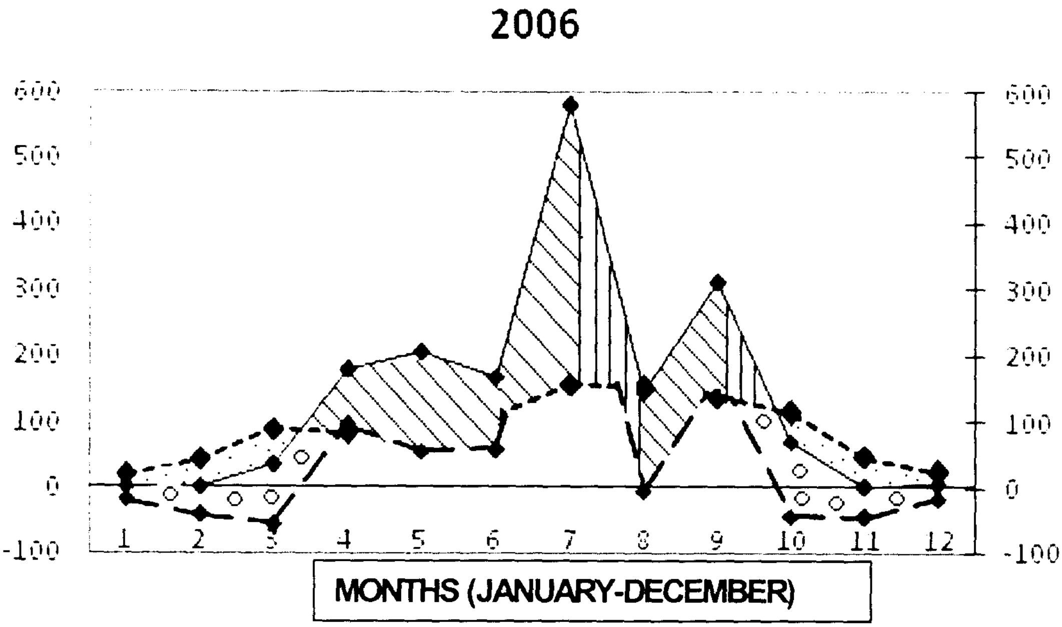


Legends: same as Fig. 11

Fig. 12 : Water Balance Curve for the year 2005

from the months of January to April and from September to December. Potential evapotranspiration rates remained very high throughout the year except during the rainy season. Soil moisture recharge was observed from the months of March till August but the water surplus period was only in the month of September.

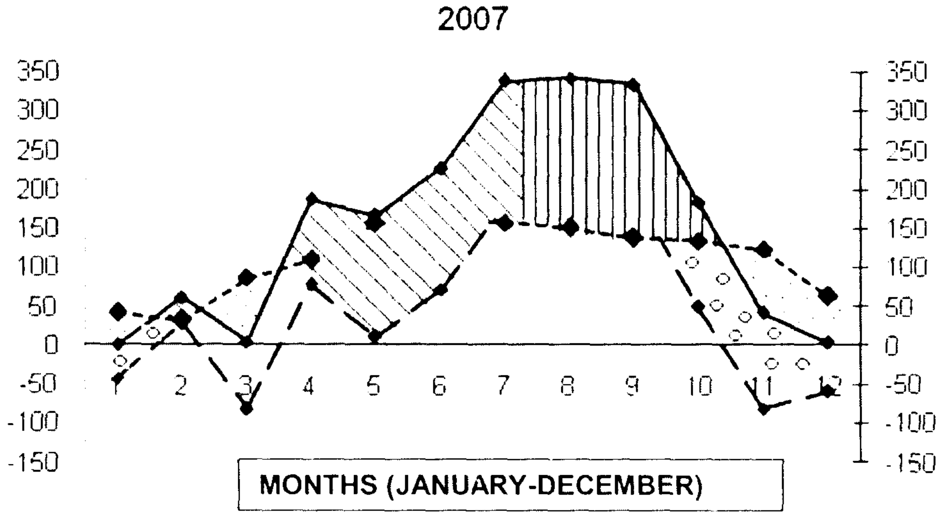
In Fig. 13 the water balance showed a decline in the availability of rainfall in the year 2006. The recharge in soil moisture decreased annually. There was a deficit in moisture from January to March and from October to December. The potential evapotranspiration rates remained high from the months of January to March and from October to December which shows the use of moisture from the watershed. The period of moisture recharge took place from March till June and also from August till September. The months of August and September represented the water surplus period.



Legends: same as Fig 11

Fig. 13 : Water Balance Curve for the year 2006

During the year 2007, the water balance curve showed a decline in precipitation (Fig. 14) and increase in the use of moisture i.e. actual evapotranspiration and Potential Evapotranspiration. The water recharge rate also decreased having less than 200mm of rainfall from the month of April to October. The recharge period occurred from March till July and water surplus period extended from mid-July till September. The water deficiency period extended from January to March and from November to December.



Legends: same as Fig 11

Fig. 14: Water Balance Curve for the year 2007

4.4 SOIL COMPOSITION AND PROPERTIES

Soil is one of the most distinctive geographical constituents, which covers the entire landscape. Soil is very important for sustenance of life on earth. The world's most ecosystems are impacted by the influence of soil. The quality of soil determines the nature of vegetation and the capacity of land to support living beings. The degree to which humans are dependent on soil is likely to increase gradually with the rise in population. Water is an essential component of soil responsible for most of the processes in the soil. It affects the properties of soil and influences the production of crops. The movement of water within the soil leads to profile differentiation. The soil moisture content affects the properties of soil. Soil acts as a store- house of water during rainfall which is used by plants. It is interesting to know that about 85-90% of plant biomass is made up of water which is made available through soil.

4.4.1 SOILS OF THE STUDY AREA

The classification of Soil Survey Manual of United States, Department of Agriculture was used in the study so that the results can be correlated with those in other areas, regions and countries.

The soils of Nagaland are classified into 4 orders, 7 sub-orders, 10 great groups, 14 sub-groups and 72 soil families (Soil and Water Conservation Department, Nagaland). The 4 orders found in Nagaland are (i) Alfisols (ii) Entisols (iii) Inceptisols and (iv)Ultisols.

Inceptisols dominate the soils of the State and constitute 66% of the total 16.6 million Ha of the States Geographical Area followed by Ultisols (23.8%), Entisols (7.3%) and Alfisols (2.9%).

The soils of the study area represent Entisols, Ultisols and Inceptisols (Fig. 15). The major portion of the study area is covered by Inceptisols soil, followed by Ultisols soil and a small portion of Entisols soils in the southern part of the study area.

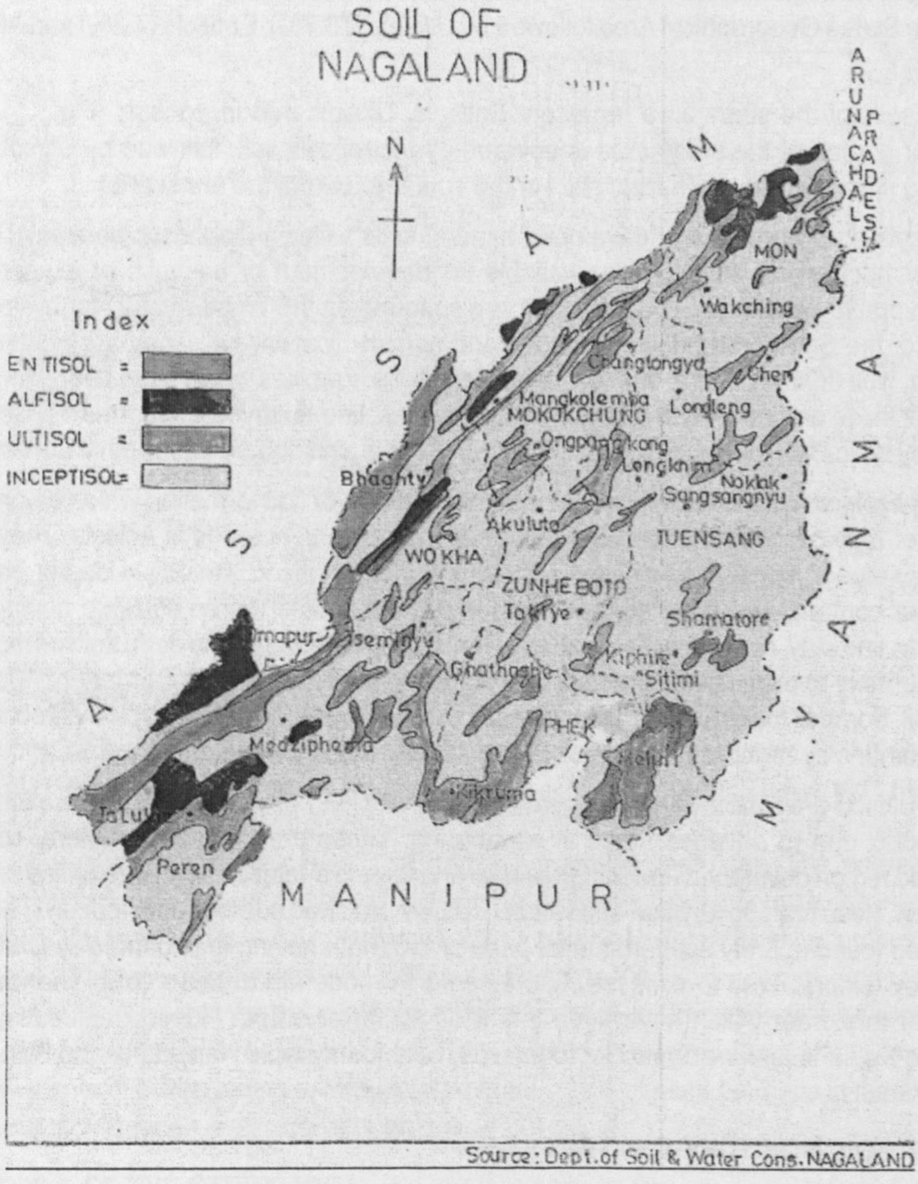
Entisols soils are recently developed mineral soils with no diagnostic horizon. This is either because of limited time available for development or because of exceedingly unfavorable conditions. This soil order is also found on the Western and North Western part of the State on the low hill slopes and narrow river valleys. They are moderately deep, well drained, fine to fine loamy textured soils. Families which have been identified under these orders are fine-loamy typic Udifluvents, fine-loamy typic Udorthents, Coarse-loamy typic Udorthents, fine-loamy lithic udorthents and coarse-loamy lithic udorthents.

Inceptisols soil order represents the beginning stage of soil formation which belongs to that of Entisols but still short of the degree of development found in Alfisols. They may have some accumulation of clay in the sub-surface horizon, limiting in depth, organic matter content, and base saturation. This soil dominates the entire State having fine loamy, fine clay, clay loam, soil textures with moderately shallow to deep soils, which are moderately to excessively drained. The identified families under this order are 16 types of soil. Some of these are fine-loamy umbric dystrochrepts, Fine loamy typic dystrochrepts, fine umbric dystrochrepts, loamy, skeletal umbric dystrochrepts etc.

The Ultisols are similar with Alfisols except for having low base saturation on the exchange complex due to advance stage at weathering. These are base-poor mineral soils of humid region developed under high rainfall and forest vegetation. They are characterized by low, (less than 35%) base saturation and clay enriched sub-surface horizon. This soil is also found sparely scattered in all parts of the State having fine loam, clay loam and clayey texture. Well to excessively drained with moderate to deep soils. The families under this order which have been identified so far are: Fine Humic Hapludults, Fine Typic Paleudults, Fine Typic Haplohumults, Fine loamy typic Hapludults and Fine typic Hapludults.

4.4.2 SOIL MOISTURE CONTENT

Soil moisture is one of the most essential factors determining growth of plants. Its content in the soil affects the growth of the plant species. Table 6 shows the values of soil moisture content of each sampled shifting cultivation village areas of the four districts of Nagaland. The experiment was conducted following gravimetric method. The soil moisture content in the sample plantation area in the shifting cultivation sites of Lumami village showed that the Location-1 and Location-3 dominated by *Terminalia myriocarpa* had a soil moisture content of 32.1 and 43.2 percent, respectively. Location-2 and Location-4 were dominated



Source: Dept. of Soil & Water Cons. NAGALAND

Fig. 15 : Soil Map of Nagaland

by *Gmelina arborea* and its moisture content was found to be 40.8% and 45.5% respectively. Location-5 was dominated by *Duabanga grandiflora* having a moisture content of 46.2%. Location-5 had the highest percentage of soil moisture content and Location-1 recorded the lowest percentage of soil moisture content.

The soil moisture content of sample sites in plantation areas in Tamlu Konyak village was recorded. The soil moisture content of Location-6, dominated by *Melia azaderach* was 33.8 percent, Location-7 dominated by *Terminalia myriocarpa* showed 47.2%, Location-8 was dominated by *Duabanga grandiflora* with 44.2% , Location-9 dominated by Macaranga sp. showed 29.9 % and Location-10 showed dominance of *Gmelina arborea* species with the soil moisture content recorded as 40.9%. Location-7 had the highest percentage of soil moisture content and Location-9 recorded the lowest moisture content.

The soil moisture content of sample plantation plots in the shifting cultivation areas of Chare village of Location-11 and Location-14, dominated by *Duabanga grandiflora*, was recorded to be 30.2% and 46% respectively. The soil Location-12 was dominated by *Terminalia myriocarpa* and its soil moisture content was recorded as 35.8 %. Location-13 was dominated by *Gmelina arborea* tree species and it recorded 28.9%. It was observed that the Location-14 recorded the highest and Location-13 recorded the lowest percentage of soil moisture content.

It was observed that the sample plantation areas in the shifting cultivation region of Ungma village was afforested by *Alnus nepalensis* in Location-15,16 and 17 which recorded the soil moisture content of 39.7%, 38% and 41.9% respectively. Location-18, dominated by tree of *Prunus* sp. had soil moisture content of 30.6% and Location-19 dominated by *Terminalia myriocarpa* recorded 43.4% soil moisture. Location-19 recorded the highest percentage of moisture content and Location-18 recorded the lowest percentage of moisture content in the area.

Table 6 : Soil moisture content value of the soil Sample in different shifting cultivation plots

Villages	**Soil moisture content (Gravimetric Method)**				
Lumami	**Loc 1**	**Loc 2**	**Loc 3**	**Loc 4**	**Loc 5**
% of moisture content	32.1	40.8	43.2	45.5	46.2
Tamlu-Konyak	**Loc 6**	**Loc 7**	**Loc 8**	**Loc 9**	**Loc 10**
% of moisture content	33.8	47.2	44.2	29.9	40.9
Chare	**Loc 11**	**Loc 12**	**Loc 13**	**Loc 14**	
% of moisture content	30.2	35.8	28.9	46	
Ungma	**Loc 15**	**Loc 16**	**Loc 17**	**Loc 18**	**Loc 19**
% of moisture content	39.7	38	41.9	30.6	43.4

4.4.3 pH OF THE SOIL

pH of the soil is the measure of H^+ ion concentration of the soil water system. It indicates whether the soil is acidic, neutral or alkaline in nature. The pH is defined as the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration. As the scale is logarithmic, so a change in pH of one unit represents a ten-fold change in hydrogen ion concentration. The growth of plants suffers much both under very low (strongly acidic) as well as high (alkaline) pH. The pH for all the sample shifting cultivation plots is shown in Table 7.

The pH of Ungma village recorded for the four sites were: 6.09, 6.61, 5.85 and 5.41 for the sites S11, S12, S13 and S14. The soil was acidic in nature. Site S12 had the highest pH and site S14 had the lowest pH.

The pH recorded for Lumami village of sites S21, S22, S23 and S24 were: 5.49, 4.64, 4.60 and 4.63 respectively. The pH value for site S21 and S23 were 5.49 and 4.60 values respectively. The pH values show that the soil of the shifting cultivation areas of Lumami village was acidic in nature. The pH values of Chare village for sites S31, S32, S33 and S34 were recorded as 5.80, 5.34, 6.13 and 5.20 respectively. The soils of these sites were also acidic in nature. The highest acidic content was recorded in site S33 and lowest in site S34. The sites S41, S42, S43, and S44 the shifting cultivation plots of Tamlu-Konyak village were 5.29, 4.69, 5.09 and 5.30 respectively. The highest pH value was recorded in site S41 and the lowest in site S42.

The overall acidic content of the soil varied within a small range in all the shifting cultivation plots. Overall, the lowest acidic content was recorded in site S23 having pH value of 4.60 and highest was recorded in S12 having pH of 6.61.

Table 7 : pH value of the Soil Samples in shifting cultivation plots

Village names	**pH content of the soil**			
Ungma	**S11**	**S12**	**S13**	**S14**
	6.09	6.61	5.85	5.41
Lumami	**S21**	**S22**	**S23**	**S24**
	5.49	4.64	4.60	4.63
Chare	**S31**	**S32**	**S33**	**S34**
	5.80	5.34	6.13	5.20
Tamlu Konyak	**S41**	**S42**	**S43**	**S44**
	5.29	4.69	5.09	5.30

5. INFILTRATION RATE OF THE SOILS

Infiltration refers to the vertical intake of water to the soil sub-surface. The most commonly used method to determine infiltration is to flood an area contained within a bund and to record the water level over a period of time. Infiltration rates measured under a sprinkler or under natural rainfall may not be the same. The measured infiltration rate is markedly affected by the cylinder diameter, the rate measured being lower for larger diameters because of the reduced effect of lateral flow. Infiltration is an example of phenomena of water movement in porous media. It is often viewed by engineers as a loss and by agriculturist as a gain. It is the process which provides water for all terrestrial plants and much of the animal life, furnishes ground water for wells and most of the stream flow in period of fair weather, reduces flood and soil erosion (Singh 1980).

A special case of water movement is the entry of free water into the soil at the soil atmosphere interface where porosity distribution of the soil material is the determining factor. This process greatly influences the moisture regimes for plants and the potential for soil degradation, chemical run-off and down valley flooding. The process by which water enters the soil pore spaces and becomes soil water is termed as 'infiltration' and the rate at which water enters the soil is termed 'infiltrability' and is calculated by the formula;

$$i = \frac{Q}{A \cdot t}$$

Where, Q = Volume quantity of water (m^3) infiltrating

A = Area of the soil surface (m^2) exposed to infiltration

i = Infiltrability rate

t = Time in seconds (s)

It is measured in m/s or cm/h. The infiltration rate is not constant over time, but generally decreases during rainfall or irrigation episode. If the soil is quite dry when infiltration begins all the macro pores open to the surface to conduct the available water into the soil. And as it proceeds further the macro pores are filled with water. The infiltration rate then tends to decline sharply at first and then tends to level off, remaining constant there after. The factors that affect infiltration are soil porosity, type of vegetation, stem flow, soil management, soil texture, soil structure and initial water content.

The time required for infiltration in different locations at different depths were recorded and it was observed that *Terminalia myriocarpa* in site I required maximum time for infiltration and *Gmelina arborea* in site 10 of Tamlu Konyak village required shortest time for 0.7 m depth of infiltration (Table 8). The overall data also revealed (Table 9) that *Gmelina arborea* plantation area had the highest infiltration rates followed in descending order by *Duabanga grandiflora*, *Prunus* sp., *Alnus nepalensis*, *Terminalia myriocarpa*, *Macaranga denticulata* and *Melia azaderac,* plantations.

Table 8 : Infiltration Time (seconds) of different sampled tree species in shifting cultivation areas of Nagaland									
Village	Location	Species	Depth (in m)						
			0.1	0.2	0.3	0.4	0.5	0.6	0.7
Lumami village	1	*Terminalia myriocarpa*	0.9	1.45	3.57	7.9	10.29	15.54	20.46
	2	*Gmelina arborea*	0.18	0.41	1.06	1.33	2.05	2.36	2.54
	3	*Terminalia myriocarpa*	0.36	2.08	4.09	6.14	9.04	12.25	15.2
	4	*Gmelina arborea*	0.09	0.16	0.32	0.59	1.18	1.42	2.05
	5	*Duabanga grandiflora*	0.23	1.31	3.01	5.35	7.52	11.14	13.47
Tamlu konyak village	6	*Melia azaderach*	0.32	1.44	3.21	5.27	7.12	10.19	12.49
	7	*Terminalia myriocarpa*	0.59	1.58	3.11	4.41	5.45	7.13	9.06
	8	*Duabanga grandiflora*	0.04	0.06	0.1	0.16	0.18	0.22	0.25
	9	*Macararanga* sp	0.89	0.19	0.38	0.59	1.29	2.19	2.56
	10	*Gmelina arborea*	0.02	0.03	0.05	0.06	0.08	0.13	0.18
Chare village	11	*Duabanga grandiflora*	0.09	0.21	0.36	0.47	0.52	1.03	1.19
	12	*Terminalia myriocarpa*	0.03	0.05	0.1	0.17	0.23	0.3	0.37
	13	*Gmelina arborea*	0.12	0.39	1.51	3.12	4.59	7.18	9.14
	14	*Duabanga grandiflora*	0.05	0.12	0.24	0.33	0.43	0.5	1.02
Ungma village	15	*Alnus nepalensis*	0.19	0.5	1.27	2.33	3.13	3.59	4.32
	16	*Alnus nepalensis*	0.04	0.12	0.32	1.04	1.42	2.29	3.44
	17	*Alnus nepalensis*	0.06	0.17	0.29	0.38	0.45	1.02	1.09
	18	*Prunus* sp	0.07	0.18	0.38	0.57	1.24	1.46	2.17
	19	*Terminalia myriocarpa*	0.35	1.35	3.15	5.31	8.09	9.58	12.21

Table 9 : Infiltration time and depth of different sampled tree species in shifting cultivation areas of Nagaland			
Species	Time (secs)	Depth (metres)	Infiltration Rate (m/s)
	Average	Average	Average
Terminalia myriocarpa	5.197	0.400	0.613
Gmelina arborea	1.512	0.400	1.736
Duabanga grandiflora	1.771	0.400	1.273
Melia azaderach	5.720	0.400	0.115
Macaranga denticulata	1.156	0.400	0.510
Alnus nepalensis	1.308	0.400	0.733
Prunus sp.	0.867	0.400	0.738

The comparable data on infiltration rate of different species in shifting cultivation area are presented through graphical representation in Figure 16. The infiltration rate of *Gmelina arborea*, *Duabanga grandifloia* and *Prunus* sp were higher whereas infiltration rates were very less in *Melia azaderach* and *Macaranga denticulate* plantations.

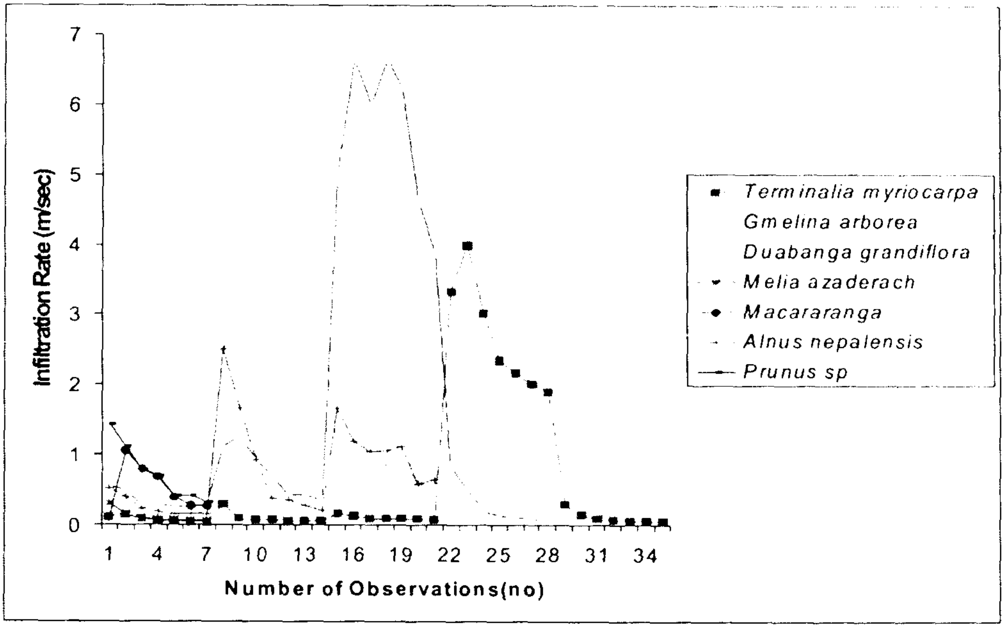


Fig. 16 : Infiltration rate of the sampled tree species in shifting cultivation areas of Nagaland

6. GENERAL DISCUSSION

Every tree species has its own minimum and maximum temperature requirement for its growth and beyond that temperature range the growth of any tree species will not be favorable and this will ultimately result in loss of soil moisture, stunted growth, dying of the trees and will lead to the wastage of soil nutrients by the presence of such tree species. The diversity and growth of fallow vegetation plays an important role in sustainability of the systems. Growing pressure on the land resulting in the reduction of the length of the fallow period and changes in agricultural practices are leading to lower levels of productivity. This study on shifting cultivation areas of Nagaland showed the importance of fast growing tree species in hydrology of specific areas. The hydrological parameters of fast growing tree species was estimated by understanding the water balance which can be obtained by temperature and rainfall data and subsequently by potential evapo transpiration (PET) and heat index (HI).

The study shows that the fluctuation in precipitation and PET affects the growth of the tree species as the water cycle is balanced by evaporation from the land surface and evapotranspiration of water from plants. It was observed from the precipitation and PET trends of three years i.e., 2004-2007 that during the months of April to October precipitation exceeded the PET and during this period the temperature was maximum along with available moisture conditions which contributed to the luxuriant growth of the tree species in shifting cultivation areas. Thus precipitation and PET plays an important role in the growth of trees, availability of moisture in the soil and in the atmosphere which is one the factors which contribute most to the growth of trees. These conditions led to the favorable growth of tree species in the shifting cultivation area.

While studying different hydrological parameters it was observed that beside a gradual rise of heat index values over the year 2004-07 there was also change in the monthly value e.g. in the year 2004 the heat index was recorded highest in the month of August but in the successive years its highest values occurrence shifted to the month of September. The data of potential evapotranspiration shows the use of moisture from the soil. From the months of April to September, the recharge of soil moisture in the catchment area increased to a considerable extent which might be due to excess availability of moisture.

The year 2004 showed the availability of water throughout the year while the years 2005, 2006 and 2007 showed dry periods as well. The water balance curve showed a steep decline in the availability of moisture and this condition affects the growth of trees. This water balance curve helps in understanding the problems of availability of moisture which is one of the factors that contribute to the growth of trees in shifting cultivation areas. It is important to understand the magnitude of seasonal availability of rainfall and the duration of water surplus throughout the year. The seasonal moisture regimes and the length of the day are the major determinants of plant growth and development.

Water balance curve through the four years of study from 2004 to 2007 was not constant. The use of moisture increased year after year and the recharge period decreased every year as well as water surplus period also began to decrease in each consecutive year due to decrease in precipitation. There was a clear visibility in the loss of moisture in the consecutive years in each season i.e. the availability of rainfall became scarcer each year which hampered the growth of tree species in the shifting cultivation areas.

High soil moisture content (>45%) recorded in location 4, 5, 7 and 14 might be ascribed to the litter quality and greater accrual of litter and roots in the shifting cultivation area. However, most acidic pH was recorded from S13 site in Lumami village (4.60) and maximum soil pH (6.61) was recorded from most basic soils was recorded on site 12 from Ungma village (6.61). The organic matter content, nutrient availability and species composition of the sites are seen to be responsible for the differential pH values.

The vegetation is not the only factor that determines the infiltration rates. Inorder to derive a relationship between the tree species and infiltration rates the other factors are assumed to remain constant. This would allow inferences to be drawn on the influence of the planted tree species on the infiltration rates. The study revealed that *Gmelina arborea* had the highest infiltration rates followed in descending order by *Duabanga grandiflora*, *Prunus* sp., *Alnus nepalensis*, *Terminalia myriocarpa*, *Macaranga denticulata* and *Melia azaderach*. One of the most important factors that affects infiltration is the soil moisture content. A soil can allow water to enter it until it reaches the *field capacity*. Thereafter water drains away allowing new water to enter. Hence, the entry of water into the soil depends on the current soil moisture content. Water is also taken by vegetation for their physiological needs and metabolic processes and thus water is continuously extracted by vegetation from the soil. In case of a tree species that extracts water continuosly at a high rate, the soil moisture content remains low throughout. Hence, the soil needs continuous replenishment and is characterised by high infiltration rate.

Shifing cultivation areas are characterised by lack of proper soil management. Being practised mostly in slopes that have a high degree of inclination, the soils are in a constant danger of being eroded. The plantation of trees would not only provide the biomass that would help the soil to recover its fertility but also bind the soil from being eroded which is very important. But a tree species that is characterised by high extraction rates of soil water, leading to high infiltration rate, has many negative consequences. Firstly, such species tend to dominate over other plant species in the competition to grow and survive. Other plants suffer as they are not able to meet their water requirements for growth. Such tree species, therefore, suppress the plant diversity of the place where they are growing and for shifting cultivation areas that needs good vegetation cover in order to recuperate.. Secondly, the soil moisture content is diminished which makes the soil dry and susceptible to erosion. Degradation of the soil then ensues, which again is harmful for the area.

Hence, it can be said that *Gmelina arborea*, *Duabanga grandiflora* and *Prunus sp.* are not suitable tree species for shifitng cultivation areas as they prevent the area to recurperate. Of the tree species considered for this study, *Macaranga denticulata* and *Melia azaderach* seem to be the most favourable. However, the method of analysis is comparative, based on relative measures within the tree species considered (Fig 16). Hence the infiltration rates are also relative which is good for within the group comparison but not helpful in knowing the absolute values that would determine the suitability of the tree species in general. Thus, it is with an amount of caution that it can be stated that out of the tree species considered for this study, *Macaranga denticulata* and *Melia azaderach* the most suitable trees for plantation in shifting cultivation areas whereas *Gmelina arborea*, *Duabanga grandiflora* and *Prunus sp.* are the least suitable.

7. SUMMARY

In the present day scenario the lands shifting cultivation are degrading at a fast rate leading to loss of forest cover in the northeastern region of India and these are eventually occupied by secondary vegetation. Thus the hydrology of the area is adversely disturbed.

Therefore, hydrological parameters of trees that could be planted on such degraded land needed to be determined. The process of deriving the hydrological parameters of fast growing tree species includes the estimation of the water balance which can be obtained by temperature and rainfall data that in turn will help in obtaining potential evapo-transpiration and heat index. Such hydrological parameters help estimate the water balance model for fast growing tree species. The present study mainly aims at analyzing the hydrological parameters and for assessing water budget of the shifting cultivation areas for understanding the availability of water in development of different tree species and also to study the effect of run-off on the nutrient status of soils and on the tree growth in *Jhum* cultivation areas.

The districts of Zunheboto, Tuensang, Mokokchung and Mon were selected as the testing ground of the above given objectives. The study area is located in the Dikhu watershed. It is *Jhum* dominated watershed having various plantations with semi-tropical climate with dominance of bamboos, cherry, natural forest trees grown after the fallow period.

In the sample village of Lumami, the plantation tree species selected were: *Terminalia myriocarpa*, *Gmelina arborea* and *Duabanga grandiflora* while those selected in Chare village were: *Melia azaderach*, *Terminalia myriocarpa* and *Duabanga grandiflora*. In Ungma village, the sample plantations selected were: *Alnus nepalensis*, *Prunus* sp. and *Terminalia myriocarpa* and in Tamlu-Konyak village the plantation stand of *Gmelina arborea*, *Duabanga grandiflora* and *Macaranga denticulata* were selected.

The growth of trees is usually dependent on temperature and higher temperature helps in their luxuriant growth. The seasonality of temperature through the years 2004 till 2007 in Dikhu watershed in Nagaland seems optimum. The growth of the tree species was favored during the months of August and September while December, January and February were not as favorable.

Potential evapotranspiration (PET) was calculated by multiplying monthly values of unadjusted PET and location-specific values of PET. The fluctuation in precipitation and PET affects the growth of the tree species as the water cycle is balanced by evaporation from the land surface and evapotranspiration of water from plants. In the year 2004, the levels of precipitation of Dikhu watershed was highest in the month of April and PET was maximum in the month of August. From the months of April to October precipitation exceeded the PET. During this period the temperature was maximum along and moisture was surplus which contributed to the luxuriant growth of the tree species. From November to March 2004, tree growth was slow due to a combination of low precipitation and low temperature. In 2005, the highest precipitation was in the received month of August. From the month of May to August the moisture availability exceeded the PET which accounted for the luxuriant growth of the tree species in the shifting cultivation areas. The PET from the month of September to April showed a negative precipitation and this checked the growth of trees due to deficient soil moisture. In 2006, the highest rainfall was received during April to September and the highest precipitation level was recorded in July. This supported the luxuriant growth of tree species. One important feature is that the month of August showed a period of sudden drought where the PET values exceeded the precipitation. This factor may lead to sudden dying of tree species due to sudden dry period which was accompanied with very high temperature in shifting cultivation areas. In 2007, precipitation was high in the month of February followed by a decrease in March and then it remained high upto October. The highest precipitation and PET were recorded in July. PET exceeded the precipitation in the month of February while it decreased in March. It again increased from the month of November to December. This shows that precipitation was higher than PET and that the wet season was longer than the dry season which favored the growth of the trees. Thus a proper balance between precipitation and PET is important for growth of trees.

Another factor that was taken into consideration was the heat index (HI) which is combines air temperature and relative humidity. It was observed that the heat index values increased through 2004 to 2007. There was a gradual rise in heat index values from year to year and also there was change in the monthly HI values e.g. in the year 2004 the heat index was recorded highest in the month of August but in the successive years its highest values were observed in September.

Actual evapotranspiration (A.E) which gives the water balance in the watershed was also considered in this study. The water balance curve helps in understanding the problems of availability of moisture which is one of the factors that contribute to the growth of trees in shifting cultivation areas. The water balance curve throughout the four years from 2004 to 2007 was not constant and it depicted a steep decline in the availability of soil moisture and this condition affected the growth of trees. There was a clear visibility in the loss of moisture in the four consecutive years in each season i.e., the availability of rainfall became scarce reach year which hampered the growth of different tree species in the shifting cultivation areas.

The soil moisture content affects the properties of soil and is one of the most essential components for the growth of plants. The soil moisture content in the sample plantation site in the shifting cultivation area of Lumami village was determined in different location. The Location-5, dominated by *Duabanga grandiflora,* had the highest percentage of soil moisture (46.2%) and Location-1, dominated by *Terminalia myriocarpa,* had the lowest soil moisture content (32.1%). The soil moisture content in the sample plantation sites of shifting cultivation area in Tamlu Konyak village was also recorded. Location-7, dominated by *Terminalia myriocarpa,* had the highest soil moisture (47.2%) and Location-9, dominated by *Macaranga* sp, had the lowest soil moisture content (29.9%). In the shifting cultivation areas of Chare village, the soil moisture content of sample Location-14, dominated by *Duabanga grandiflora,* was the highest (46%) while in Location-13, dominated by *Gmelina arborea*, it was the lowest (28.9%). In Ungma village, Location-18, dominated by *Prunus* sp, recorded lowest soil moisture value (30.6%) while Location-19 dominated by *Terminalia myriocarpa* had the highest soil moisture content (43.4%).

The pH of the soil in the shifting cultivation plots of all the villages i.e., Ungma, Lumami, Chare, Tamlu-Konyak was found to be acidic. The study revealed that the overall acidic content of the soil was similar in all the shifting cultivation zones.

The data on water infiltration rate showed that *Gmelina arborea* had the highest infiltration rate followed in descending order by *Duabanga grandiflora*, *Prunus sp.*, *Alnus nepalensis*, *Terminalia myriocarpa*, *Macaranga denticulata* and *Melia azaderach*. From the present study it emerged that *Gmelina arborea*, *Duabanga grandiflor* and *Prunus sp.* are not suitable tree species for planting in shifitng cultivation areas as they have high extraction rates of soil water. On the other hand, *Macaranga denticulata* and *Melia azaderach* were found to be the most suitable trees for planting in shifting cultivation areas.

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