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HYDROLOGICAL PROPERTIES OF OAK AND PINE FORESTS IN CENTRAL HIMALAYA, INDIA

by
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ABSTRACT

In general, hydrological cycle in forested areas is a complicated phenomenon. In Himalaya the vegetative cover plays a vital role in determining several hydrological characters. For the experimental study of oak and pine forests hydrology, two representative basins are selected in the Central Himalaya. After evaluating the hydrological properties of oak and pine forests, it is decuded that both the vegetation types have different hydrological characteristics. However, with the destruction of vegetation and top soil, rainfall quickly runoff as stormflow instead of soaking into the soils.

The Himalayas are world known for their grandeur, beauty and natural resources. The Himalayan environment provides one of the best biospheres of the world. It preserves diversity of flora and fauna which has a great ecological significance. Besides, flora and fauna it is the major source of many rivers by glaciers with too many seasonal and perennial tributaries from forested watersheds and maintain water table round the year.

In Himalayas, the influence of forest is experienced in three dimensions of the environment - on water resources, on climate and on soil. The study of forest influence on water resources is not only expensive and far reaching itself, but it is linked with the wider and more complex problem of the forest hydrology. One of the main factors in the forest-water relationship is the permeability and porosity. Similarly, the vegetation plays a vital role in determining several other hydrological characters of Himalayan drainage basins. However, the continued increase in livestock population has resulted in the intensive and as well as extensive overgrazing of pastures, degradation of forests, almost absolute removal of vegetal cover and compacting of the soil. The illconcieved human encroachment is forest ecosystem has reduce the water retention capacity (Singh and Pande, 1989) and increased the rapid runoff of nutriens and soil cover from the watersheds (Pande and Joshi, 1991). This has, ultimately damaged

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the ecological balance of Himalayan ecosystem upto breaking stress point (Hindustan Times, 1989).

The significance of basin experiments in the study of forest hydrology (influence of vegetation on the quantity, quality and timing of runoff and sediment yield) is a well known concept now. After the pioneering efforts of Engler and Burger in Switzerland (1893-1919) to explain the hydrological regime of two Emmenthal Valley catchments by observations of precipitation and streamflow, a controversy intensified among meteorologists, engineers and forest ecologists about forest influence on water supplies and hydrological cycle. Disagreements on forest degradation and flood in USA go back to 1863 when Marsh proposed the theory that forest clearing is significantly affecting the erosion, flood and water yield. After that extensive studies on forest hydrology have been progressed in advanced countries.

In Himalaya some of the tree species like Quercus, Salix, Myrica esculanta, Rhododendron arboreum, Alnus nepalensis, Lyonia ovalifolia, Populus ciliata, Juglans regia etc. have extensive root system and have high water holding capacity. The litter of these trees does not only reduce the evaporation from the soil but also increases water holding capacity of soils by adding humus layer. Thus these forests act as an effective natural conifer dominated areas (Pinus roxburghii, P. excelsa, P. patula, Picea, Juniperus, Cedrus deodora etc.) show poor water yielding sources (Singh and Pande, 1989).

THE DISCUSSION

For the experimental study of oak and pine forests hydrology, two representative basins are selected in the Karmi watershed of Central Himalaya. Both the selected basins are spring/rain red. The physical characteristics of both the two experimental basins are given in table 1 and figure 1.

The meteorological data indicates maximum mean monthly temperature (26.62^0 C) in pine watershed which is 8.21^0 C higher than oak watershed. The minimum temperature is recorded in oak watershed (7.3^0 C) which is 3.25^0 C less than pine watershed. The maximum temperature (31.56^0 C) is recorded in pine watershed in the month of June while in oak watershed July registered temperature (25.78^0 C). Both the basins recorded minimum temperatures (0.14^0 C and 3.37^0 C in oak and pine respectively) in the month of December. High temperature in pine forest is an abnormal observation. This may be assigned to low moisture conditions, high light penetration, sandy soil, exposed rocks, absence of humus layer and poor under growth. Comparatively high noon temperature in pine forest suggest the existance of green house effect.

The maximum relative humidity is noticed in oak forest (73.57 per cent) while minimum (44.14 per cent) in pine forest. The maximum precipitation is recorded in pine watershed (1460.47 mm) followed by oak (1428.47 mm). More than 50 per cent precipitation is recorded in monsoon period (mid June to late August) in both the watersheds (58.57 and 56.04 per cent in pine and oak respectively).

Some soil characteristics of pine and oak watersheds are presented in table 2. The maximum soil temperature of 22.6^0 C is recorded for pine watershed in the month of July whereas in oak watershed the maximum temperature in both the watersheds, i.e., pine - 6.7^0 C and oak - 5.5^0 C. Interestingly, soil moisture is always observed higher in oak watershed than pine. In the month of August highest soil moistures 11.87 per cent and 33.19 per cent are recorded in pine and oak watersheds respectively. Bulk density is recorded higher in pine forest soil (1.386 ± 0.08 g/cc) than oak forest soil (0.921 ± 0.08 g/cc), whereas water holding capacity (58.80 ± 4.61 per cent) and porosity (65.06 ± 3.09 per cent) are more in oak watershed than in pine (38.28 ± 4.87 per cent and 47.31 ± 2.88 per cent respectively). Both watersheds register alkaline soils. However, in summer the pH adopts acidic tendency. Important soil erodibility indices, such as clay ratio, silt/clay ratio, clay/ME ratio, disperson ratio, erosion ratio, erosion index, erodibility factor of Wischmeier *et al.* (1971) and Romkens *et al.* (1977), indicate that soils associated with pine watershed are more prone to erosion than oak watershed (Table 1).

Table 1. Physical characteristics of watersheds

Parameter	Oak	Pine
Location	30°01'N to 79°52'E	30°02'N to 79°54'E
Area (sq km)	1.02	0.98
Length of master channel (km)	1.41	1.01
Drainage density (km)	4.20	5.40
Elevation range (m)	1440 - 2100	1440 - 2120
Slope (degree)	28	38
Mean weight diameter	0.37	0.21
pH	6.40	6.10
EC (mmhos/cm)	0.86	0.08
Organic carbon (%)	2.67	0.96
Clay ratio	7.40	13.00
Silt/clay ratio	1.46	1.77
Clay/ME ratio	0.72	0.44
Dispersion ratio	21.80	36.20
Erosion ratio	33.70	83.90
Erosion index	33.80	81.90
K1	0.36	0.41
K2	0.14	0.18

K1 = Wischmeier *et al.* (1971) erodibility factor
K2 = Romkens *et al.* (1977) erodibility factor

An attempt has also been made to evaluate precipitation through different pathways in pine and oak watersheds (Table 2). The annual gross precipitation during the study period is 1044.71 mm for the pine and 844.08 mm for the oak watershed. Total stemflow collected is 7.9135 mm and 3.393 mm for pine and oak forests respectively. The stemflow contributes 0.757 per cent of gross precipitation in pine watershed whereas it is 0.283 per cent in oak watershed. This value is found lower than that reported for Hardwood by Jackson *et al.* (1973) and Addridge *et al.* (1973). However, the results are quite compairable to the mixed beech podocarp hardwood reported by Rowe (1975). Pathak *et al.* (1983) reported 0.13 per cent and 0.2 per cent of gross precipitation for pine and oak stands in Nainital forests (India). Comparatively high stemflow in pine watershed than oak may be due to broad leaved structure and more interception loss in oak forest.

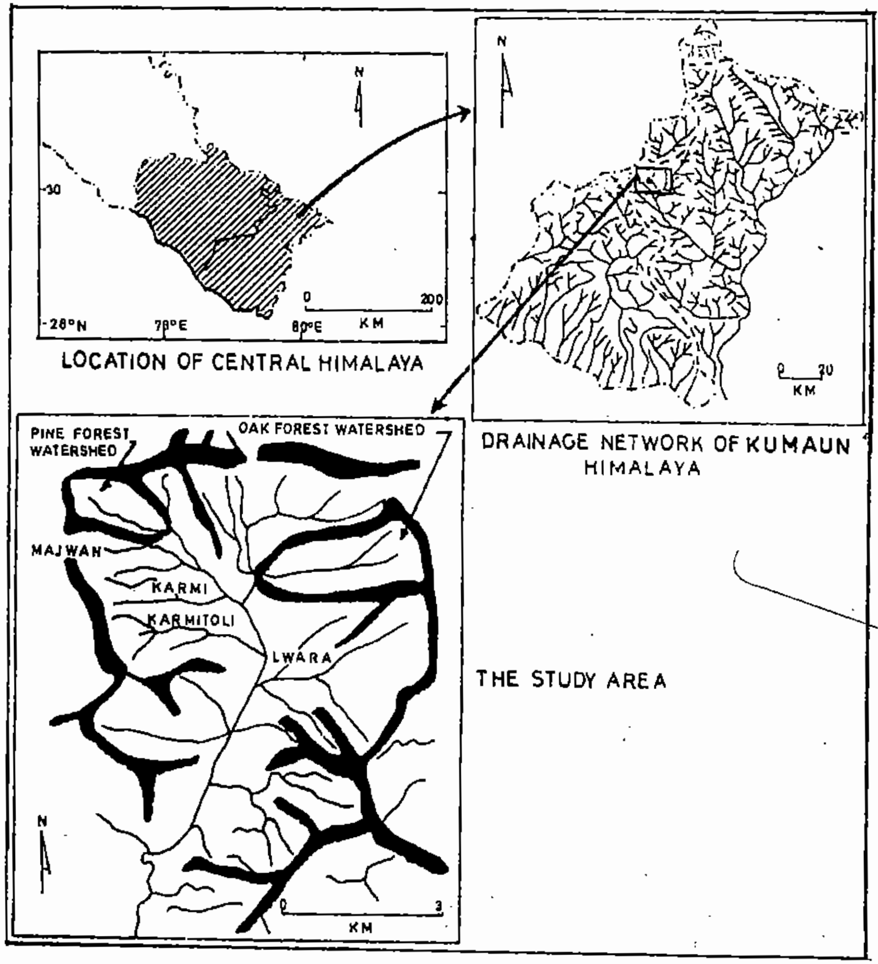

Figure 1. Location of the Study Area in Central Himalaya, India

Table 2. Average annual hydrological properties of oak and pine forested watersheds (please also refer to Figure 2)

Parameter	Oak	Pine
Temperature (°C)		
Maximum	18.41	26.62
Minimum	7.30	10.55
Relative humidity (%)	73.57	44.14
Precipitation (mm)	1428.47	1460.47
Soil temperature (°C)	12.66	16.67
Soil moisture (%)	22.41	11.43
Water holding capacity (%)	58.41	38.28
Bulk density (g/cc)	0.92	1.38
Porosity (%)	64.76	47.31
Stemflow (mm)	3.39	7.91
Throughfall (mm)	518.99	961.49
Interception loss (mm)	322.34	76.40
Evaporation (ml/m/month)	49515.12	64637.14
Surface runoff (mm)	6.57	6.13
Sediment loss (kg/ha)	71.56	115.92
Stream discharge (m^3/day/sq km)	857.81	260.11

Total throughfall collected in this period is 961.49 mm which accounted 92.03 per cent of gross rainfall in pine watershed. In oak watershed throughfall is 518.99 mm (61.486 per cent of gross rainfall). The throughfall value for pine watershed is higher than the values reported by Addridge and Jackson (1973) for hardbeech at Taita (45.4 per cent), by Miller (1963) also for hardbeech at Taita (50-60 per cent), Rowe (1975) for beech podocarp hardwood forest (73 per cent). However, the throughfall value is near to the reportings of Miller (1963) for hardbeech at Taita (50-60 per cent). Pathak *et al.* (1983) have reported 53 per cent and 78 per cent throughfall for pine and oak forests respectively in Nainital Hills (India). In the present case higher percentage of throughfall in pine watershed than oak may be due to the less crown cover (58.75 per cent), open canopy and needle like leaves in pine.

The interception losses are 0.757 per cent and 0.283 per cent of gross rainfall in oak and pine watersheds respectively. The interception loss in pine is 75.60 mm (7.31 per cent of gross precipitation). This value is much lower than reported by Pathak *et al.* (1983). However, higher interception loss is recorded (38.13 per cent) in oak watershed. Comparatively higher interception loss in oak watershed than pine may be ascribed to more crown cover and broad leaved nature of leaves. It has also been observed that rainfall and interception loss have negative relationship.

The maximum evaporation loss is observed in the month of June, i.e., 3576.279 ml $day^{-1}m^{-2}$ in pine and 2725.548 ml $day^{-1}m^{-2}$ in oak. The evaporation loss is recorded more throughout the year in pine than oak. This may be due to less crown cover through which more light penetrates below pine cover which coupled with high temperature and low relative humidity accelerates the rate of evaporation loss. Evaporation losses calculated on per hectare bases reveal minimum evaporation loss of 11434 lit $ha^{-1}day^{-1}$ and 6278 lit $ha^{-1}day^{-1}$ in pine and oak watersheds in the months of February and December respectively. A gradual increase in evaporation losses is noticed with the advent of summer which reach to the maximum of 30645 lit $ha^{-1}day^{-1}$ and 23355 lit $ha^{-1}day^{-1}$ in pine and oak watersheds respectively in the month of June.

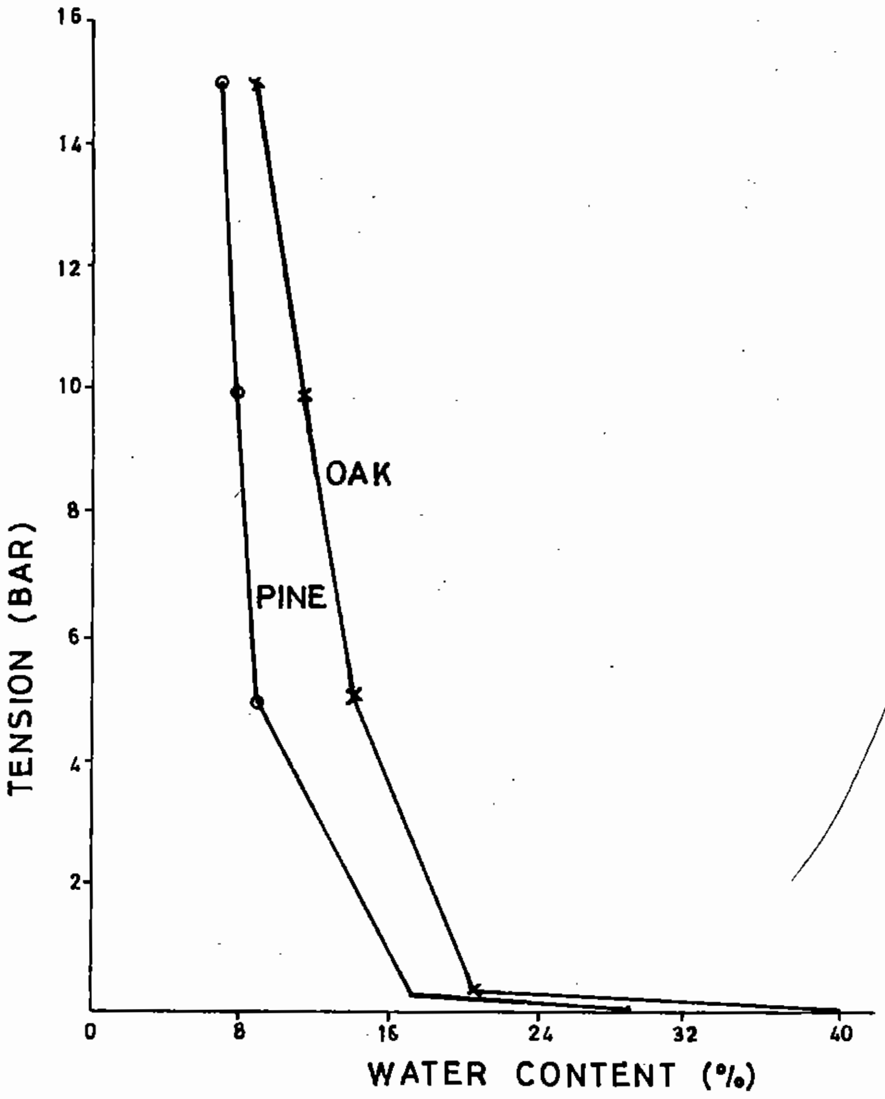

Figure 2. Moisture Characteristic Curve for Oak and Pine Forest

Surface runoff and sediment losses in pine and oak watersheds are presented in table 2. It is observed that surface runoff and sediment loss vary with the frequency and intensity of rainfall. The maximum surface runoff of 0.58 per cent and 0.79 per cent is recorded in the month of July in pine and oak watersheds respectively. After July surface runoff decreases gradually. These recorded values are in agreement with the findings of Pande *et al.* (1983) for certain forested and non-forested sites of Nainital hills (India). The maximum sediment loss is recorded in the month of July being 57.87 kg ha^{-1} and 58.81 kg ha^{-1} for pine and oak watersheds respectively. About 34.00 per cent of sediment loss is recorded in the month of July. The total annual sediment loss of 165.59 kg ha^{-1} and 171.579 kg ha^{-1} is recorded for pine and oak watersheds. Subba Rao *et al.* (1973) have recorded 492 - 1533 kg ha^{-1} soil loss year between 1967-1970 from moist deciduaous sal forest in Dehradun.

CONCLUSION

The overall analysis reveals distinct hydrological characters of pine and oak watersheds.

a. The vegetation type have significant effects on the water regime.
b. With the destruction of vegetation and top soil, rainfall quickly runoff as stormflow instead of soaking into the soils.
c. In pinewatershed due to poor soil thickness, less humus content and sandy nature of soil maximum amount of rainfall is immediately discharged through surface and sub-surface flow.
d. Oak forest has high water holding capacity due to its typical ecology (40.6 per cent approximately) while pine forest shows comparatively low water holding capacity (about 28.7 per cent). The moisture contents at 1/3, 5, 10 and 15 bar pressures are 19.8, 11.2, 9.9 and 8.8 in oak and 14.2, 7.4, 6.8 and 5.5 in pine forest respectively.
e. The water stable aggregates in the soils of oak on 8.0-5.0, 5.0-2.0, 2.0-1.0, 1.0-0.5, 0.5-0.25, 0.25-0.1, and 0.1 mm are 1.7, 3.1, 4.6, 4.7, 4.0, 5.9 and 75.8 per cent respectively. However, water stable aggregates in the soils of pine on similar values are 0.9, 2.5, 3.2, 2.8, 3.0, 3.9 and 84.0 per cent.
f. The geomorphic properties of pine and oak watersheds are also found characteristically different. The values of microscopic link density, source area size and shape index are 0.537 km, 0.316 square km and 2.39 respectively for pine forest and 0.726 km, 0.510 square km and 4.737 respectively for oak forest. The typical character of pine forest ecosystem affects the hydrologic cycle, for example poor seepage + poor percolation rate + poor soil moisture = comparatively high surface runoff = sufficient amount of discharge in the channels to maintain there flow depths = restricted microscopic exterior link lenght and source area size development + high soil loss rate = increase in surface gradient + transformation of basin shape from lemniscate to circular. However, in the case of oak forest the runoff friction of rainfall is quite controlled. It has a high water retaining capacity as it produces considerable amount of litter which generates high humus percentage. The basic tendency of soil moisture provide favourable conditions to undergrowth. These all properties of oak forest cumulatively restricts the surface flow. It is therefore

microscopic exterior channel lenght increases with source area size in order to generate sufficient amount of discharge for the maintenance of the channel depth. The undergrowths and tree cover provide significant resistance to soil loss. It will automatically reduce the slope formation processes and gradients will be moderate. The increasing tendency of lenght with poor erosion factor will also affect the basin outline form and the basin will tend to remain elongated (Pande, 1991; Singh and Pande, 1989).

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In pine forests poor undergrowth (mainly cactus type - indicator of dry climate), low water holding capacity, poor porosity, high stemflow, high throughfall, poor interception and high surface runoff with high sediment loss are the principal characteristics.

Thick undergrowth in oak forests increases the water holding capacity. High porosity, poor stemflow, comparatively low throughfall, high interception loss, controlled surface runoff etc. generate low sediment loss. The soils are rich in nutrients (specially organic matter) and have poor erodibility.

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IMPLICATIONS OF RAINFALL FOR AGRICULTURAL AND URBAN DEVELOPMENT OF ELDORET, KENYA

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ABSTRACT

This paper examines the role of rainfall in the urban development of Kenya. The rainfall characteristics have been analysed and their influence on agricultural and urban development assessed. It is noted that since Eldoret is one of the rapidly expanding towns in Kenya located in highly potential agricultural region, variability of rainfall and drought can seriously affect urban development as farmers in the hinterland will abandon their farms and migrate to the town thus creating food shortage. Secondly, in times of drought, the water supply problems in the town will be exacerbated as it depends on surface water source. The tempo of rural-urban migration will be speeded up and this will create more socio-economic problems.

LOCATION

Eldoret is located on latitude 0°32'N and longitude 35°17'E (Fig. 1). It is located on the Uasin Gishu plateau at an altitude of about 2084 metres. It has a sub-humid climate. Altitude and aspect exert a great influence on temperature in Eldoret and its environs. As a result, mean temperatures are low. The mean annual maximum and minimum temperatures are 23.5°C and 10.3°C respectively. The coldest months are from June to September. High relative humidities are obtained in July and August. Mean annual pan evaporation is about 2000 mm. Eldoret has a mean annual water deficit of about 937 mm.

The most important geographical features which enhance the agricultural productivity of the region is its location and altitude. The climate is very ideal for large-scale production of crops and livestock. Its modified equatorial type of climate with double rainfall season and mild temperatures support the cultivation of both cash crops and timber. The fertility of the soil coupled with the favourable climate has made Eldoret and its environs a rich agricultural region. In consequence, most of the industries in the town are agro-based. The availability of raw materials has been the motivating factor in the town's industrialisation. Some of the industries include Raymond which is based on wool and cotton, Rivatex is based on cotton, Ken-Knit on wool and East African Tanning Extract company (EATEC) on timber products.

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