ESTIMATION OF WATER BUDGET IN THE FORESTED PEAT-LANDS OF WESTERN IRELAND

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KEYWORDS / ABSTRACT: Evapotranspiration / interception / peat-lands

Aspects of the hydrology of a small blanket peat catchment in Cloosh forest, County Galway, were investigated focusing on evapotranspiration during one calendar year in 1996, which was compared with the lysimetric values obtained from the nearest weather station. Using monthly rainfall data from the weather station and published data for through fall and stem flow, a value for the net amount of water reaching the soil was calculated. Runoff was measured using the STARFLOW recorder. It was found that the net effective water was equal to runoff in fully saturated blanket peat. The Penman-Monteith equation was used to calculate the evapotranspiration in the Cloosh catchment and this was compared the water balance equations. The change in the evapotranspiration values were attributed to the difference in through-flow and stem-flow.

1. Introduction

The scientific study of evaporation and transpiration has been underway for many years. Historical review by Rosenberg et al [10], traces research back to Aristotle who concluded in the Fourth Century B.C., that wind is more influential in evaporation than the sun. Direct evaporation from the soil and transpiration occur simultaneously in nature and there is no easy way to distinguish the water vapour produced by these processes. Thus the term evapotranspiration is used to describe the total process of water transfer into the atmosphere from vegetated land surfaces.

J. Krecek and M. Haigh (eds.),
Environmental Role of Wetlands in Headwaters, 107–115.

Evapotranspiration has been widely used as a tool in geographic studies of world climate and in predicting the water needs in dry land and irrigation agriculture. Recently, its use has been extended to studies on the water movement and glacial changes in the temperate regions. The studies on evapotranspiration have further brought about the term potential evapotranspiration, which can be defined as the evaporation from an extended surface of a short green crop which fully shades the ground, exerts little or negligible resistance to the flow of water and is always filled with water. Plant factors affecting evapotranspiration:

- Interception of rainfall by the canopy: interception can be defined as the capture and subsequent evaporation of part of the rainfall by vegetative canopy or other structure, and thus not reaching the 'protected area' [9]. Interception depends on factors like intensity, amount and distribution of precipitation, evaporative flux and the shape, stand, size and number of leaves.
- The morphology of a plant: the size of the leaf maybe important since larger leaves tend to be less efficient in dissipating heat through convective transfer and will, therefore, have more energy available for evaporation than smaller leaves. Other morphological features, including pubescence, colour, leaf shape and presence of awns and other specialised structures may influence the amount of water used by plants.
- Stomatal resistance: considerable efforts have been devoted to understanding the manner in which stomates control transpiration. Hansen [5] has shown that transpiration in Italian Rye grass is a curvilinear function of stomatal resistance or a linear function of stomatal conductance.
- Transpiration ratio: transpiration ratio is the ratio of water transpired to dry matter produced, and is characteristic of the thinking that regards the water requirement of plants as dominantly a biological phenomenon. Transpiration ratio is sometimes affected by the changes in climatic conditions.

2. Importance of the study of water budget in forested peat lands of Ireland

Considerable efforts have been devoted to understanding and estimating evapotranspiration from forests. Since they are aerodynamically rough, and due to their size and distribution of foliage throughout their canopies, significant quantities of sensible heat are exchanged between the air and leaves and even during humid climates sensible heat advection can be an important source of energy for transpiration in forests. Lysimeter studies have been carried out to measure evapotranspiration from salt cedar[4], from Douglas fir [3] or from spruce [2]**.** The studies, however, can't reveal the shortage in the overall water budget and the reasons is the fact that intercepted water can be twice that which has been transpired [2], [8]. Thus, the importance of the study is relevant to the context that the correct estimation of water budget is a difficult task and empirical methods should be adopted to estimate the real count.

In the catchments of Ireland, evapotranspiration is estimated using the following methods:

- Lysimeters
- Empirical formulas (for example Penman-Monteith equation)

The disadvantage of the lysimeteric method is the 'oasis effect'. In dry weather, the soil in the surrounding area is much drier than that in the lysimeter and there is large increase in evaporation from it.

In Ireland, the Penman-Monteith equation is commonly used for the estimation of potential evapotranspiration in forest areas. The shortcoming of the Penman-Monteith equation is that it does not consider the water loss by interception (stem-flow and through-flow) in a forest catchment and sometimes overestimates the water budget. Thus, this study focuses on aspects covering stem-flow, through-fall and interception. The empirical methods are compared with results of the water balance equation.

3. Materials and Methods

3.1. SITE LOCATION

The experiment was carried out in a small forested peatland in the Cloosh forest, County Galway. The experimental plot was situated in a part of Cloosh forest that has been used for several years as a monitoring plot by the forest ecosystem research group (FERG). The forest species grown are mostly Spruce (*Picea sitchensis*) and lodge pole pine (*Pinus contorta*). A small man-made drain was constructed to measure the water flow from the experiment plot and it was judged that all the excess water coming into this plot was collected in this drain.

3.2. MATERIALS USED

The drain was fitted with an automatic flow recorder, complete with a data logger. Meteorological parameters were recorded by a small portable weather station which was installed in the open part of the forest. It uses an MM 900 data logger to store information from the sensors. The rain gauge used is the tipping bucket type and is connected to the weather station and the MM 900 data logger which records the Monthly mean rain data. The weather station also has a wind speed recorder and maximum-minimum temperature recorders. The humidity is measured using the wet bulb thermometer which is also a part of the weather station.

3.3. METHODOLOGY

The methods used for the estimation of evapotranspiration were: a) water balance method, and b) empirical method.

3.3.1. Water balance method

In the water balance method, Rainfall (P), Interception (I), Storage water (Δ S), Drainage (D) and runoff (R) were taken into consideration:

$$ET = P - (\Delta S + R + D) \qquad (1)$$

The soil being saturated by blanket peat, both D and Δ S are taken as Zero. Hence the equation can be simplified as:

$$ET = P - R \qquad (2)$$

Values of P recorded 'in the open' must be modified to account for the interception of rainfall by the dense canopy of the forested plot. Values of the interception percentage for each month of precipitation for the dense coniferous forest in Cloosh are available [1]. These show that interception varies with month and rainfall intensity but reasonable values can be obtained by averaging the interception factor across a number of years (Figure 1).

Hence in Equation (2) P is replaced by Pc, where:

$$Pc = P - (I \times P) \qquad (3)$$

The interception percentage can be obtained by subtracting the water obtained by stem-flow and through-fall and this expressed as a percentage to the rainfall. Than, the equation can be written as:

I = P - (TF +SF)/P x 100………………………........……………..….(4)

where TF = through-flow, and SF = stem-flow.

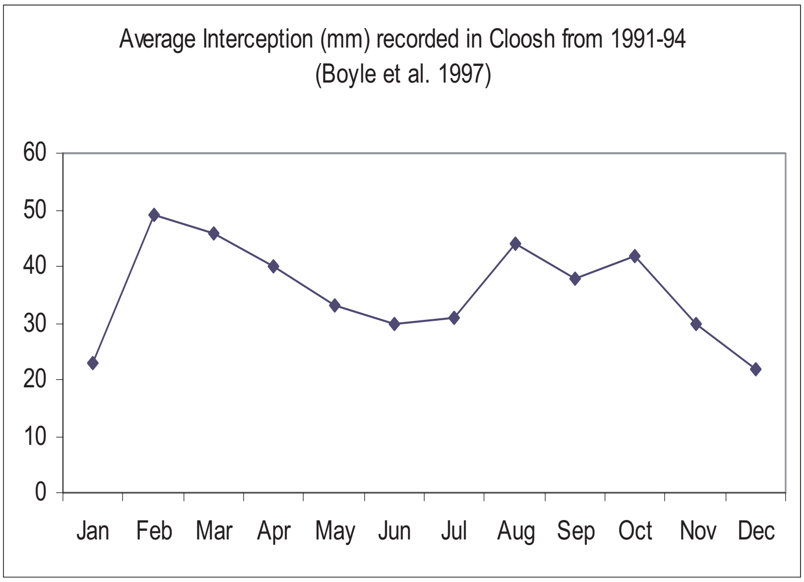

Figure 1. Average interception (mm) recorded in the Cloosh forest in 1991-1994.

3.3.1. Empirical method

The Penman-Monteith method [7] was used to calculate evapo-transpiration empirically. The parameters used are: maximum and minimum air temperatures, wind speed, sunshine hours, and humidity of the air. The Penman-Monteith equation is as follows:

$$Et = \frac{\Delta(Rn - G) + cp\rho a \frac{ea - ed}{ra}}{(\Delta + \delta)^{(\lambda)}} \quad \text{…………………….........…..(5)}$$

where Et = evapotranspiration from a wet canopy (Kg/m^2), Δ = slope of saturation vapour pressure curve (Kpa/^{o}C), Rn = net radiation in $J/m^2/d$, G = heat flux density to the soil ($J/m^2/d$), cp = specific heat of dry air at constant pressure, ea = saturated vapour pressure at air temperature Ta, ed = prevailing vapour pressure at the same height as Ta, λ = Latent heat of water vaporisation (J/Kg), ra = aerodynamic resistance, g = psychrometric constant, ρa = density of moist air (Kg/m^3). The Et values were converted to mm/day by multiplying with 86,400.

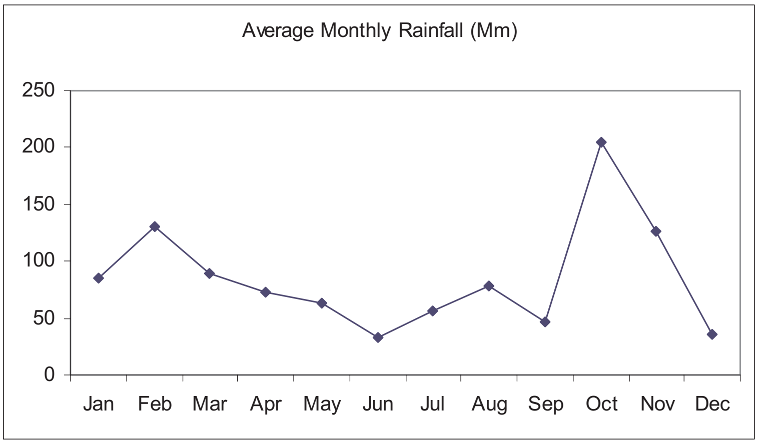

Figure 2. Average monthly rainfall recorded in Cloosh during the year 1996.

4. Results and discussion

The main source of water for the forest is rainfall. The average monthly rainfall data for the year 1996 in Cloosh is shown as Figure 2. Since a considerable proportion of the rainfall is captured by the forest canopy, the interception values were reduced from the actual rainfall and are termed as corrected rainfall Pc.

The results show that measured evapotranspiration values from the Cloosh catchment differ from those calculated from the Penman-Monteith equation. The potential evapotranspiration values obtained from the automatic weather station at the experiment site in Cloosh show similarity to the nearby Met-Eirenn station at Claremorris (synoptic weather station).

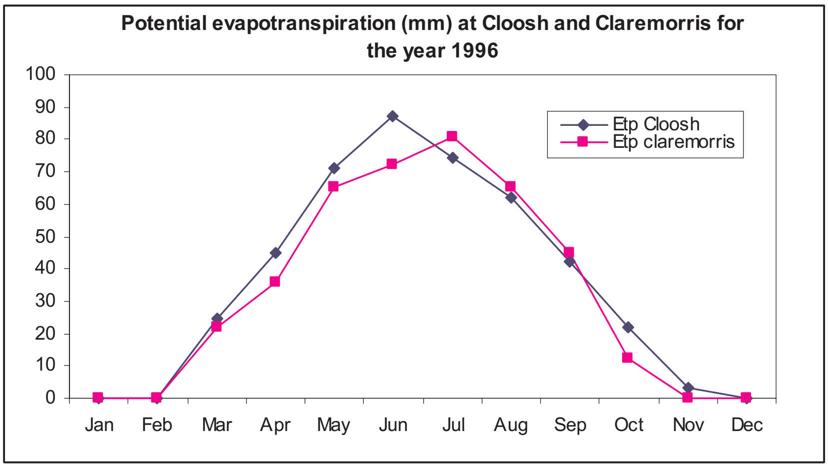

Figure 3. Comparison of potential evapotranspiration at Cloosh and the nearby Meteorological Station at Claremorris.

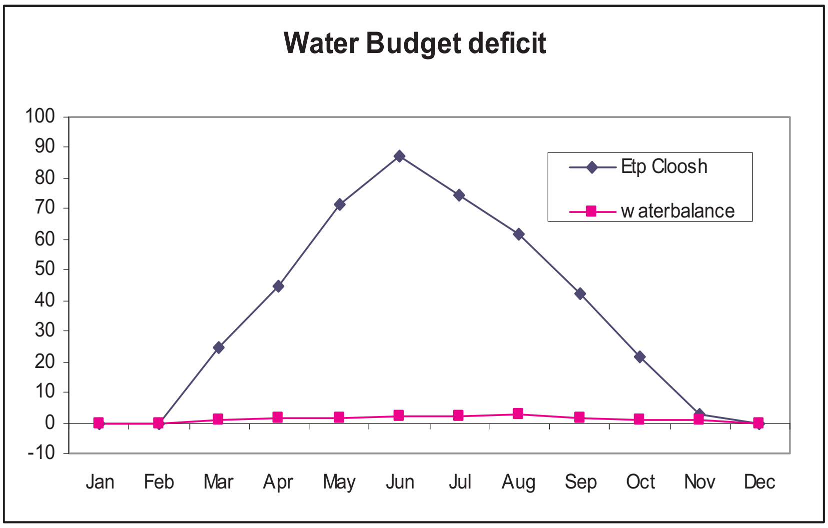

Figure 4. Differences in estimates of evapotranpiration (mm).

The climatic parameters, when applied to the Penman-Monteith equation, produce a fairly typical symmetrical curve, with 80/90mm of water passing through the evapo-transpirational pathway in June/July. Spring and autumn are half these values, while little or no water is transpired or evaporated in the period December/February (Figure 3).

The water balance method provides a completely different pattern to calculated by the Penman-Monteith equation (Figure 4). These differences in estimates of the evapotranspiration can be attributed to high interception by the forest canopy. In fact, much rain water is trapped by the canopy and so net precipitation is higher than that recorded in the open.

However, given the same amount of radiation, evaporation from this intercepted water was 3 times the average transpiration from a pine forest [6]. One reason is the fact that the canopy intercepts much radiation, and in a very dense forest, can prevent a lot of radiant energy from reaching the forest floor. For evaporation, there is a minimum energy for reaching the latent heat of vaporisation, which is not present during the early months of January, February and March and during the later years during October November and December. This is the reason for low evaporation from the forest floor during these months. The turbulent wind characteristic of forests is responsible, on the one hand, for reducing the energy available for evaporation but, on the other hand, ensures rapid removal of water vapour from exposed surfaces. This type of boundary layer conductance is most important when the canopy is wet and it means that there is more rapid evaporation of intercepted water from a forest canopy than from a smooth grass sword.

5. Conclusions

It is concluded that the value obtained for rainfall in the open and at ground level with standard gauges does not reflect the actual amount of rainfall captured by canopy of a mature Sitka spruce crop in western Ireland. The amount of water intercepted was found to be high and this was attributed to the evaporation taking place in the canopy and much less from the forest floor. Thus, the water balance equation needs to be modified to show the actual evapotranspiration taking place in the forest areas. However, the Penman-Monteith method is found to be suitable for the estimation of evapotranspiration in this Cloosh forest area, despite its limitations in estimating actual interception levels.

6. References

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