Geo Factsheet

Number 20

The Role Of Vegetation In The Hydrological Cycle

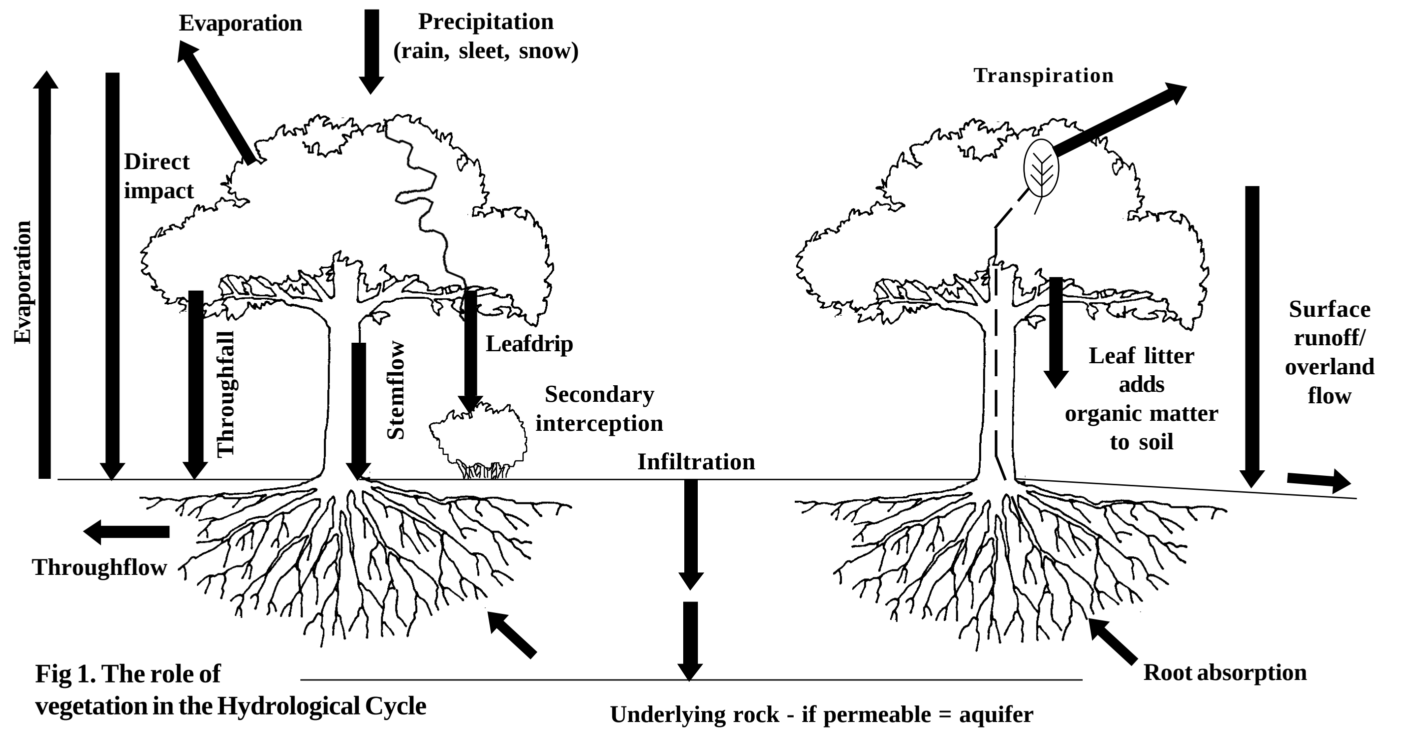


Fig 1. The role of vegetation in the Hydrological Cycle

Interception
When precipitation lands on vegetation it is said to have been **intercepted**. Intercepted water may then evaporate and this represents **interception loss**. The rate of evaporation is influenced by temperature, air humidity and movement along with the length of insolation period. The volume of water which is intercepted is dependent on the nature of the vegetation; woodlands will intercept more than patchy grassland.

Leafdrip
The total volume of water which drips from leaves is influenced by the shape of the leaf, the presence or absence of any waxy cuticle and the surface form of the leaf - hairy leaves will retain more water which may then evaporate. Although much is written about the soil-conserving effect of trees which intercept rainfall, rainsplash erosion as a result of leafdrip is not insignificant. **Secondary interception** of rainfall may be more important in preventing rainsplash erosion than the original interception by the trees.

Large raindrops reach their greatest velocity **(terminal velocity)** after any fall of 9m - well within the height of mature forest canopies. Thus, if a forest contains a high canopy above bare soil, erosion as a result of large raindrops reaching terminal velocity may actually be as great as when the soil is not covered at all; tree cover **per se** does not automatically guard against soil erosion.

Stemflow
Stemflow is greatest on trees which have smooth-barked and steeply-angled branches. The leaves, branches and stems of trees may be covered in acid pollutants, e.g. sulphur particles. The pH of rainfall may therefore be decreased between the point of initial interception and the point when it reaches the ground.

Throughfall
This refers to intercepted water dripping off leaves and branches to the ground.

Direct impact
Raindrops possess considerable kinetic energy. The total amount of energy transmitted to the soil surface is proportional to the product of rainfall intensity and duration. Accumulating leaf litter dissipates the energy of falling raindrops.

Transpiration
This is the loss of water through microscopic pores (stomata) in leaves. The combination of evaporation and transpiration is known as **evapotranspiration** and in temperate zones such losses will be greater in summer. Transpiration loss from trees is greater than that from crops because humid air adjacent to the leaves is more rapidly removed by air currents. This maintains a steeper diffusion gradient between the stomata and the atmosphere. The loss of water from the plant by transpiration effectively 'pulls' water up through the xylem tubes of the entire plant - this is known as the **transpiration stream**. This movement encourages water to be absorbed from the soil by the root hairs.

Infiltration
Infiltration refers to the absorption of water into the soil. The infiltration rate is influenced by soil porosity, which is itself determined by the nature and arrangement of the soil peds. Decomposed leaf litter adds organic matter to the soil, improving it's **structure**, hence permeability, encouraging more efficient infiltration.

Throughflow
Water will always move downwards as a result of gravity but water may be deflected laterally by soil particles and impermeable soil components.

Overland flow/surface runoff
Water which is unable to enter the soil (infiltrate) will collect on the soil surface and, at some point in time, begin to flow away over the surface - a process known as surface runoff. This may be caused by naturally impermeable surfaces e.g. tarmac or those which have become so as a result of compaction. Surface runoff may also occur during very heavy precipitation when rainfall exceeds the rate at which water can infiltrate.

Case Study
Plynlimon

Catchment studies at **Plynlimon** (Fig.2) have indicated that total evaporation rates are in the region of 15-20% of rainfall from grassland - almost solely from transpiration - and 30% from forests, mainly from interception. The relative importance of interception and transpiration changes from west to east. Lower rainfall in the south and east increases the significance of transpiration losses. This point has significant implications for water supply management since the afforestation of predominantly grassland catchments will reduce total supplies.

Unlike naturally-regenerated forests, the afforestation of upland catchments may lead to increasing soil erosion and sediment loads because of ploughing and ditching, which expose unstable subsoil to erosion in steep channels.

The species composition of forests also impacts on interception and transpiration losses. (Tables 1 and 2)

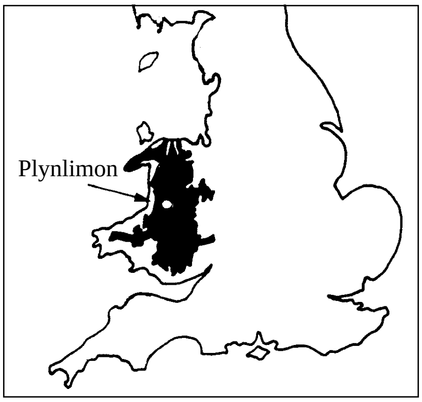


Fig 2. Plynlimon watershed

Although it is widely accepted that forests may reduce run-off, the actual volume by which runoff is decreased is dependant upon species, season, management pattern, soil characteristics and climate.

Table 1. The effect of tree species on interception loss

Species	Interception (% of total rainfall)
Sitka spruce	36%
Norway spruce	34%
Larch (deciduous conifer)	20%

Table 2. Annual transpiration rates of selected tree species.

Species	Transpiration rate (mm y^{-1})
Sitka spruce	340
Norway spruce	290
Oak	325
Beech	340

Consequences of removing vegetation

The general effects of deforestation on catchment hydrology are well understood. The kinetic energy of raindrops causes splash erosion which breaks up soil aggregates, throwing soil particles up into the air. On falling to the ground these soil particles may then be carried away in surface runoff or may block the soil pores, resulting in a sealing crust of very fine silt and clay particles. Runoff will then be accelerated.

Deforestation changes the processes which occur both at the soil surface and within the soil. The death of roots which have bound the soil together, the decrease in organic matter which maintains soil structure along with the increased diurnal temperature range to which the soils are exposed mean that soil structure and the infiltration capacity of the soil are greatly reduced. Surface runoff therefore usually accelerates and efficiently carries away soil particles loosened by rainsplash and the greater volume of water which now naturally reaches the soil. However, in reality, things may be more complicated as the following Tropical Rainforest Case Studies illustrate.

Exam Hint *- This is a topic where an accurate diagram, which clearly shows the inter-linked nature of the cycle, is worth a thousand words. Only the most able candidates will be able to show an excellent understanding of the* ***subprocesses*** *involved and may be expected to use exemplification to elaborate the intricacies involved.*

Case Study
Draix watershed, SE France

The Draix watershed consists of two distinct areas; Laval with 22% forest cover and Brusquet with 87% forest cover. Otherwise the two areas are similar in altitude, bedrock and rainfall, Fig.3 shows the floodwater hydrographs of 8th and 9th March 1991 for the two watersheds.

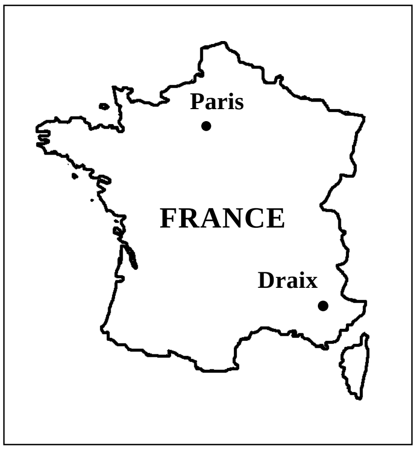
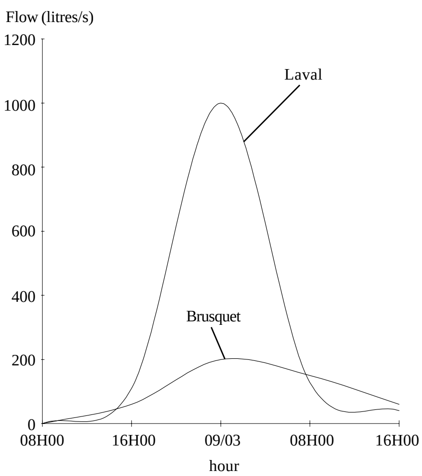


Fig 3. Floodwater in the Laval and Brusquet watersheds, 8th and 9th March 1991



Deforested watershed:
faster runoff, peaks reached faster, greater floodwater values.

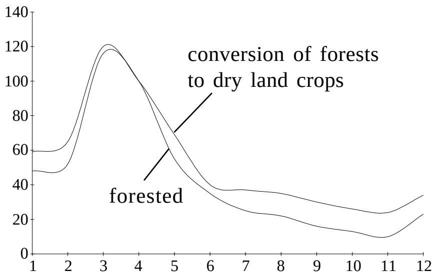
Afforested watershed:
delayed runoff or subsurface runoff, peak flow rates much lower.

Case Study
Tropical Rain Forest removal and hydrology in Java and Tanzania

It is often assumed that forest destruction inevitably leads to streams and springs drying up. However, in tropical rainforest ecosystems, although this is often the case, the overall picture is much more complex. Conversion of tropical forests to tea, rubber and cocoa plantations in East Java led to increased streamflow for the next three years, with the increased water yield being proportional to the fraction of biomass removed. Thereafter, streamflow in the converted watershed fell but average flow rates still remained higher than when the catchment had been forested. Such gains are due to much reduced evapotranspiration. One implication of these findings is that conversion of degraded crop or grasslands to exotic plantation species e.g. eucalyptus may result in a drastic reduction in streamflow.

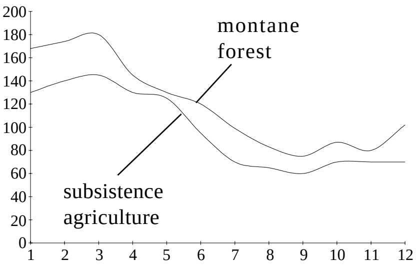
Why then, in hundreds of studies has deforestation led to a long term decrease in streamflow?

Fig 4a. Konto, East Java



Conversion of forest to tea, rubber or cocoa plantations increases streamflow as a result of decreased evapotranspiration losses and because of the effective maintenance of soil structure by soil conservation techniques. This led to increased infiltration, increased baseflow and decreased surface run-off.

Fig 4b. Mbeya, Tanzania



Streamflow decreases because of decreased infiltration which leads to decreased baseflow which supplies the streams. Surface runoff increases.

The answer is that usually, deforestation drastically decreases the infiltration capacity of the soil leading to rapid surface run-off. In the rainy season this will cause flooding but in the dry season, baseflow - which, as a consequence of decreased infiltration is much lower - is unable to maintain streamflow, which may stop completely. This is despite the fact that evapotranspiration is much reduced. Fig.4a and 4b illustrate the complexity of the possible hydrological effect.

Case Study
Hubbard Brook

The effects of forests on the hydrological processes within a temperate watershed have been investigated at the ***Hubbard Brook*** *Experimental forest in New Hampshire USA. This is one of the oldest and most intensively studied experimental catchments.*

Hubbard Brook is a mountainous area of deciduous woodland. The granite bedrock is largely impermeable and the area is drained by many small streams, all of which have been fitted with weirs allowing the volume and chemical consumption of the drainage water to be constantly recorded. This has allowed:

1. *Quantification of most of the processes shown in Fig.1*
2. *Detailed investigation of the hydrological effects of various forest management operations such as clear felling, thinning and drainage digging (Table.3).*

Table 3. Nutrient budgets for Hubbard Brook.

		Forested watershed	kg ha^{-1} yr^{-1}	***Cut watershed***
Element	**Precipitation input**	**Stream-flow output**	**Difference (net output)**	**Difference (net output)**
Calcium	2.6	11.7	9.1	77.9
Sodium	1.5	6.8	5.3	15.4
Magnesium	0.7	2.8	2.1	15.6
Potassium	1.1	1.7	0.6	30.4
NH_4 - nitrogen	2.1	0.3	-1.8	1.6
NO_3 - nitrogen	3.7	2.0	-1.7	114.0
Sulphur	12.7	16.2	3.5	2.8
Aluminium	trace	1.8	1.8	20.7

In the forested watershed the streams contain more Ca, Na, Mg, K, S, and A1 than was supplied in rainwater, suggesting that the soil and bedrock are constantly leached and weathered. The large net inputs of sulphur are thought to be a result of acid rain. As a result of deforestation run-off increased by 30% but the concentration of minerals lost increased much more dramatically. Such data reveals the importance of trees in maintaining essential biogeo chemical cycles. Huge mineral losses of this kind may cause eutrophication if nitrate and phosphate are lost (and declining soil fertility which may necessitate the use of artificial fertilisers.

Acknowledgements;
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