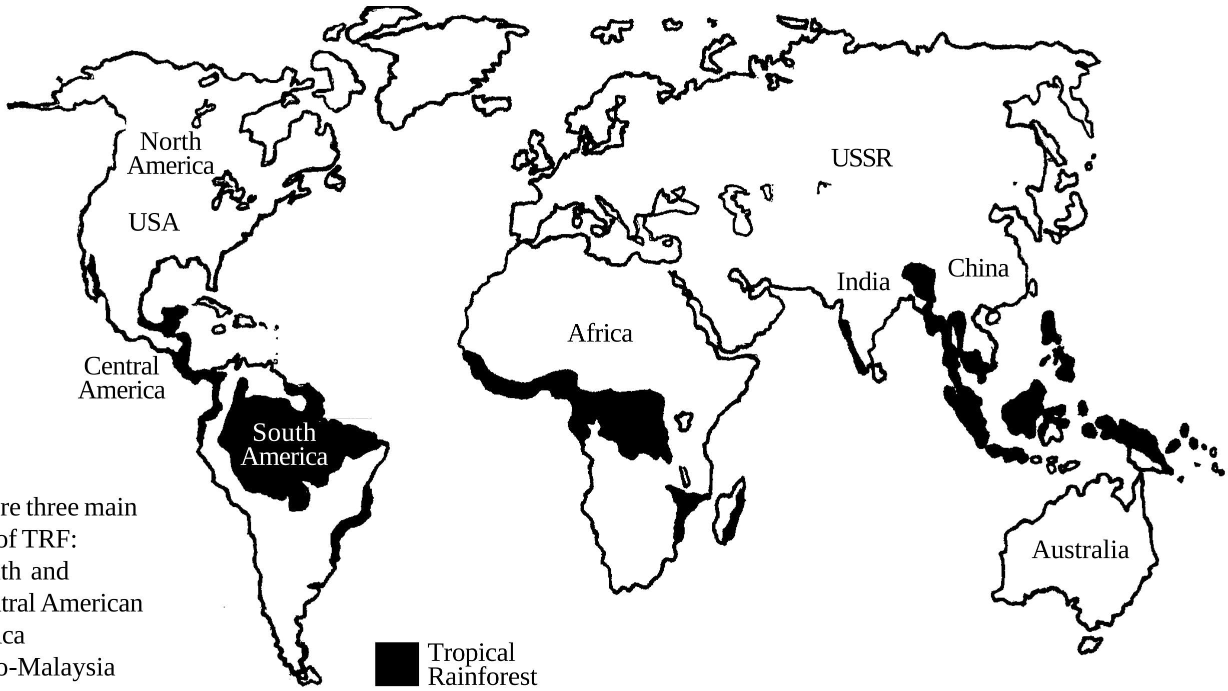
Geo Factsheet

Number 25

Energy Flow and Nutrient Cycling in Tropical Rainforests

Tropical Rain Forests (TRF) develop in areas which experience a combination of high rainfall and high temperatures with little monthly variation in average temperatures. For example, the minimum mean temperature of the coldest month may be as high as 18°C, the annual temperature range will not exceed 5°C and annual rainfall will exceed 1200mm.

Fig 1. The distribution of tropical rainforests



There are three main blocks of TRF:
1. South and Central American
2. Africa
3. Indo-Malaysia

Energy flow

All tropical areas receive high levels of insolation. However, if forests generate their own cloud cover (through massive evapotranspiration) a large proportion of the incident radiation will be reflected and therefore total insolation may be less than in a non-forested area.

In the tropics the amount of incoming radiation exceeds that which is re-radiated as longwave radiation i.e. the tropics are a **net absorber** of solar energy. This ‘energy surplus’ gives rise to global circulation patterns and the Inter Tropical Convergence Zone (ITCZ).

The rainforest vegetation, which is classically described as being made up of 5 above-ground layers or strata is very efficient at absorbing incoming radiation.

Light which manages to penetrate the often-closed canopy is usually absorbed by the smaller trees, epiphytes, climbers, tree ferns and giant herbs or saplings on the forest floor. Thus, incoming solar radiation is effectively converted to chemical energy in the process of photosynthesis. **Gross Primary Productivity** (GPP) - the total amount of organic matter fixed during photosynthesis (kg/m^2/year) is extremely high in the TRF. This is a direct consequence of the high temperatures, high rainfall, huge amounts of photosynthetically active material and extremely rapid rate of nutrient recycling. Plants, like every other organism, use some of the chemical energy fixed during photosynthesis for their own energy needs i.e. they respire. The remainder is known as Net Primary Productivity.

NPP	=	GPP	-	R
Net Primary Productivity	=	Gross Primary Products	-	Respiration

Both NPP and biomass are high in the TRF (Table 1)

Table 1. Net annual primary production and biomass

Ecosystem	Mean NPP per unit area g/m^2	Mean Biomass per unit area kg/m^2
Tropical Rainforest	2200	45
Temperate deciduous forest	1200	30
Boreal forest	800	20
Desert	90	0.7

Note: GPP is extremely high in TRF but R is also high because of the huge plant biomass which the photosynthesising tissues have to support. Despite this, NPP is still greater than in almost all other ecosystems on earth (algal beds and reefs are commonly greater).

Primary consumers (herbivores) gain their energy by eating the primary producers (the plants). Since primary production is high in the TRF, the numbers and biomass (dry weight per unit area e.g. mg/m^2) of primary, secondary and tertiary consumers which this primary production supports, is also high.

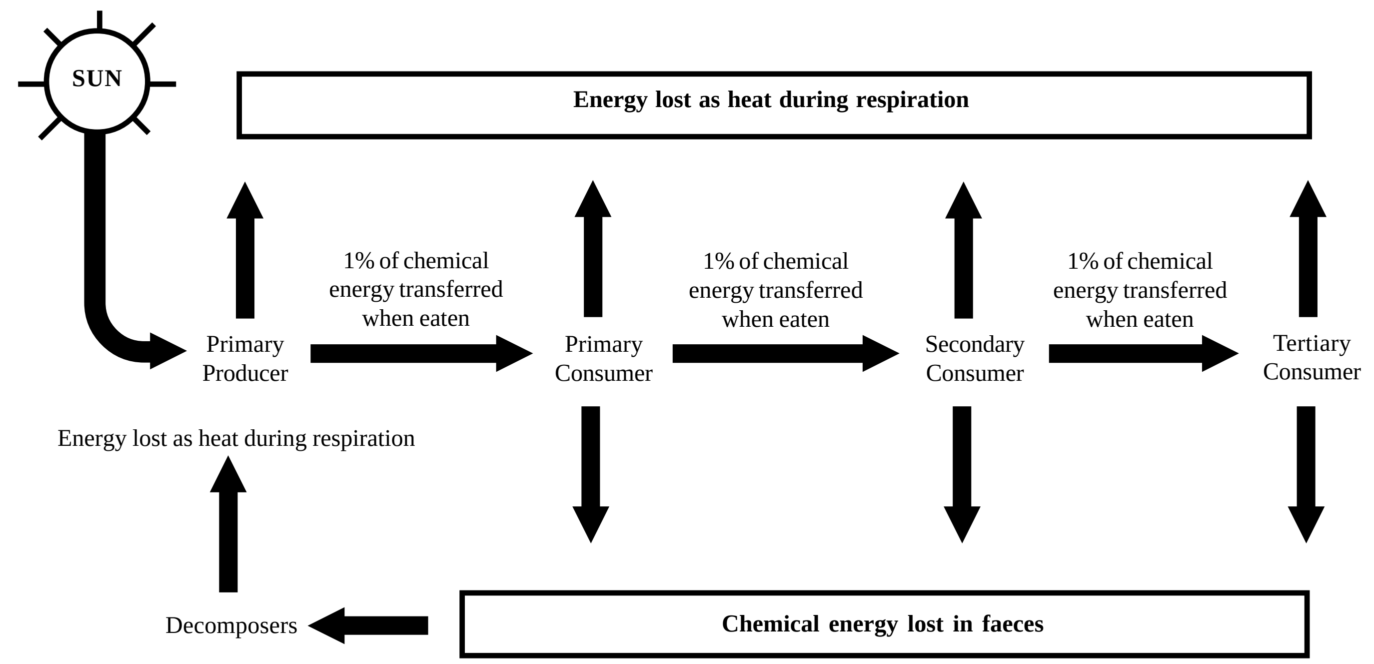
Tropical Rain Forests contain more species of animals than any other ecosystem on earth. Food chains and webs are complex, but as in all other ecosystems, animals gain their energy by consuming plants (herbivores) or other animals (carnivores) or both (omnivores). This transfer of energy is not efficient. When an ant eats a leaf it gains only a fraction of the energy which was contained in the leaf. This is due to:

1. The ant not eating all the leaf
2. The ant immediately using some energy through respiration as it eats the leaf
3. The ant losing some of the energy contained in the leaf because it couldn't digest the leaf - the undigested material is passed out of the ant as faeces

These three types of energy loss - through not all of the food source being eaten, through respiration and through faeces - occur at all subsequent stages of the food chain. It is precisely because of this energy loss that the number and biomass of organisms at each feeding level (trophic level) decrease.

To summarise, energy **flows** through the TRF ecosystem (Fig 2)

Fig 2. Energy Flow



Nutrient inputs and outputs

Nutrients dissolved in rainwater represent an important input. Most rainfall contains ions such as nitrate (NO_3^-) but, in any case, rainfall penetrating the canopy may leach nutrients out of the foliage or out of algae and will wash insect deposits (frass) off leaves. It is also clear that, whilst some nutrients are removed from the foliage by rainfall, other nutrients are actually absorbed from the rainfall by leaves, aerial roots and epiphytes. The result is that the concentration of nutrients in the throughfall (water reaching the soil) is often very different from that of the original rainfall.

Decomposition of leaves, twigs, fruits, flowers, dead animals and faeces releases minerals into the soil. Such minerals may be leached or absorbed by plant roots. The top 20-30 centimetres of soil contains a dense network of fine roots which are capable of absorbing soluble nutrients extremly rapidly. Some tree species have very deep tap roots which recapture leached nutrients which would otherwise be effectively lost to the system. The pattern of nutrient input and output is summarised in Fig 3.

Nutrient cycles

Nutrients - inorganic substances such as nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca) - are found in the soil and litter. Nutrients are cycled between these three stores. Usually this is shown in the form of a flow diagram, where the size of the circles represents the amount of nutrients in a store and the width of the arrows between the circles represents the importance of each type of nutrient transfer.

The common perception is that most nutrients of a TRF are in the biomass, with the least biomass in the soil. This is an oversimplification but nevertheless this is the pattern which all candidates must be able to describe and explain (Fig 4 overleaf).

***Exam Hint** - Candidates frequently show great confusion about tropical soils. Some clearly believe that they are **all** very deep and nutrient rich, others indicate that **all** TRF soils are shallow and nutrient deficient. The truth is more complex and good candidates will show the examiners that they appreciate this (see Fig 5).*

Figure 5 shows the distribution of inorganic nutrients above and below ground in three TRF areas. Table 2 summarises the principles underlying nutrient cycling and their implications for sustainable management.

Fig 3. Nutrient cycling in rainforests

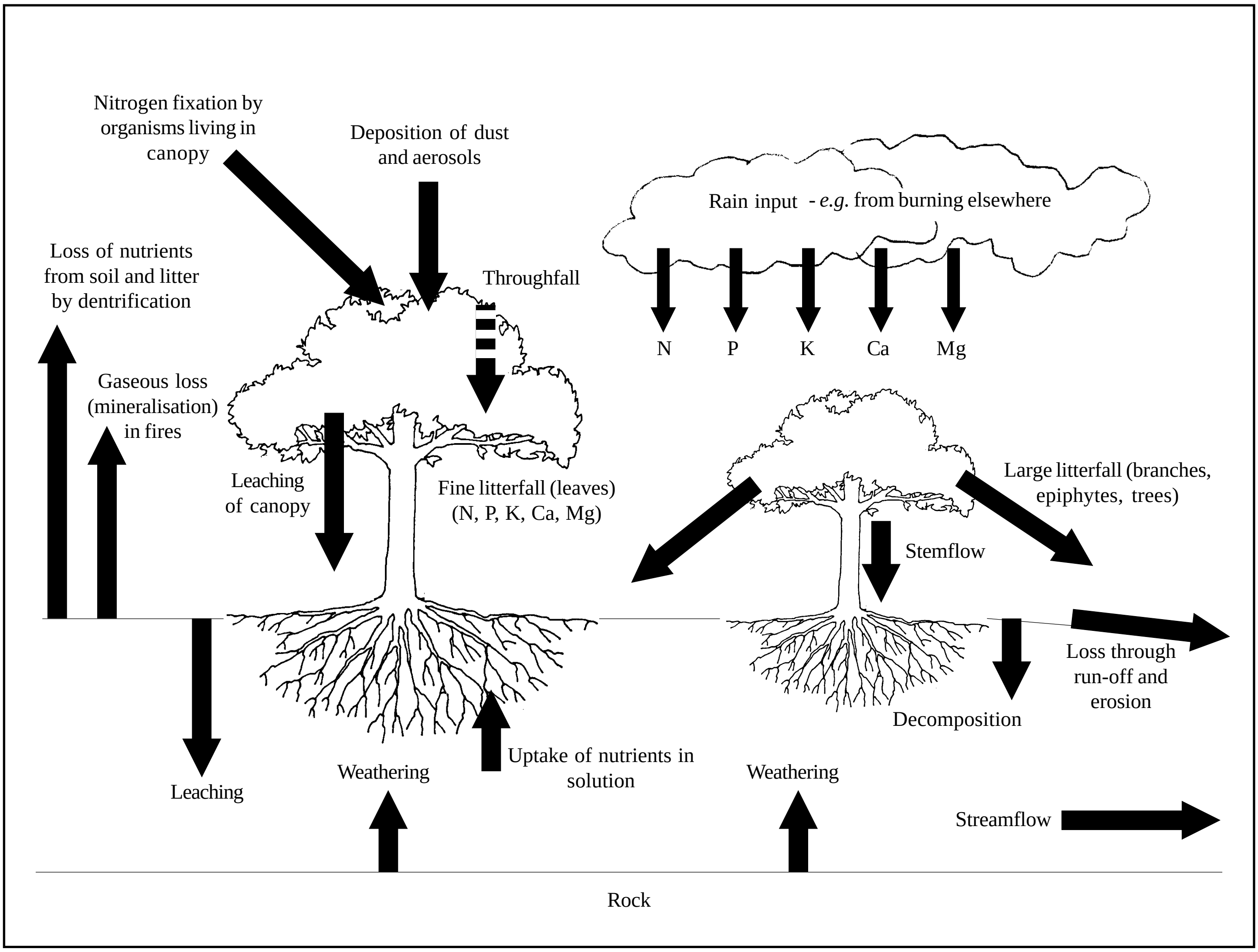


Fig 4. Nutrient stores and cycles - *This is the classical picture presented in almost all textbooks and examined on almost all syllabuses. However,* ***nutrient assays*** *(measurements) in many different areas of TRF suggest that this distribution is not always, or even often correct. The overall picture is more complex (see also Fig 5).*

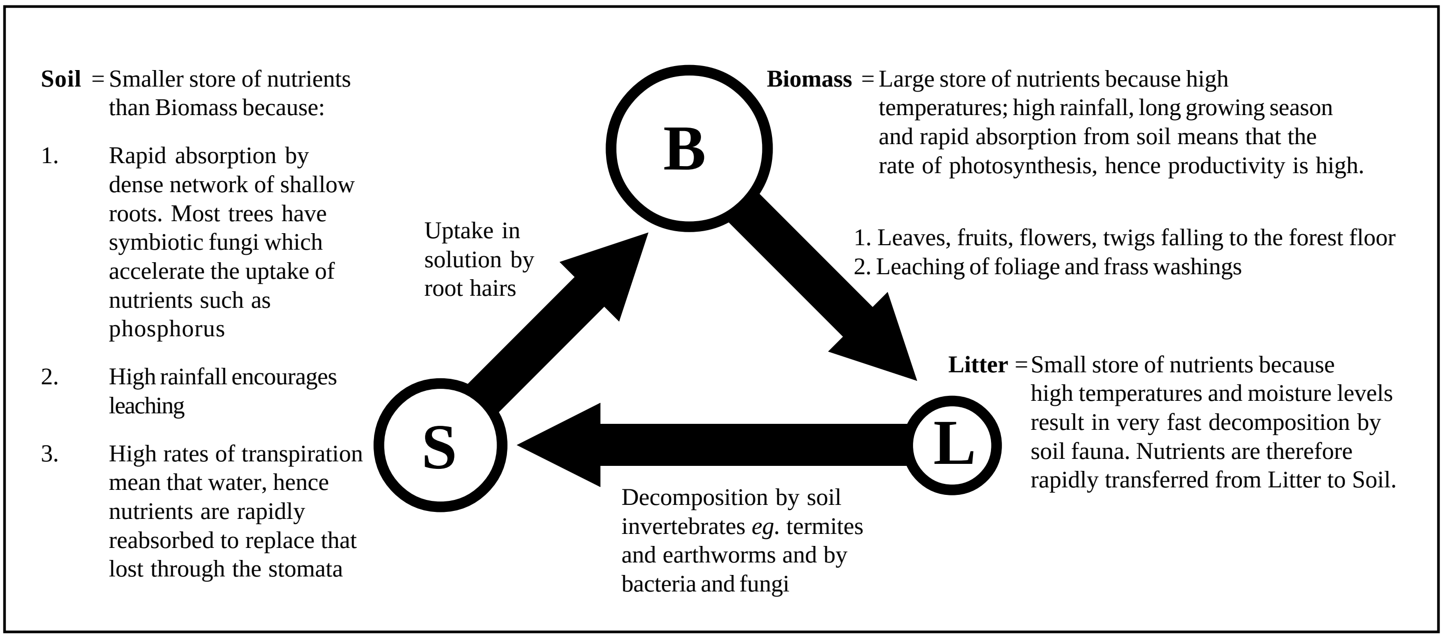
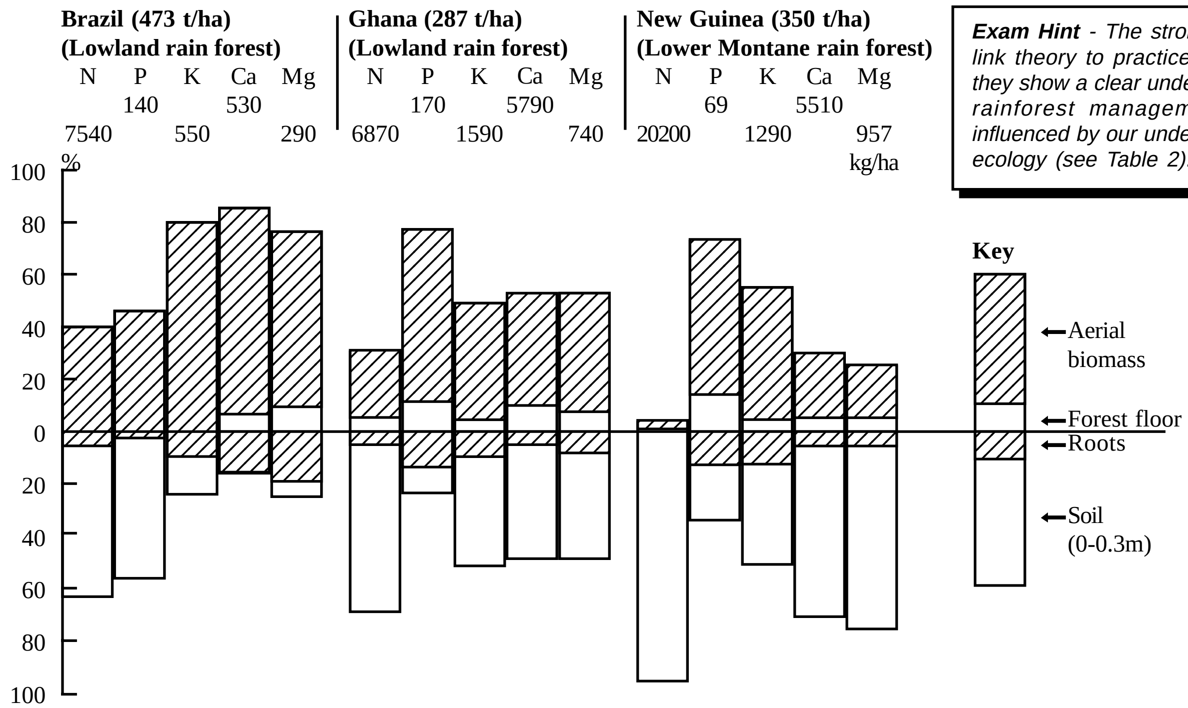


Fig 5. The distribution of inorganic nutrients above and below ground in three TRF areas



> ***Exam Hint** - The strongest candidates link theory to practice. In other words they show a clear understanding of how rainforest management should be influenced by our understanding of their ecology (see Table 2).*

All three areas show that many nutrients are in the above-ground biomass and that usually, very few nutrients are found as litter on the forest floor. However, it is also apparent that the nutrient content of TRF soils varies dramatically. A large proportion of nitrogen (N) is often found in the soil whilst nutrients such as potassium (K) mostly exist in the above-ground biomass. In young, shallow soils the weathering parent material will add to the nutrient content of the soil and nutrient concentrations may therefore be high. In contrast, old, deep (e.g. 20-30m) soils in parts of Amazonia effectively receive no new nutrients from weathering of the original parent material. Nutrient concentrations in these soils may be very low.

Table 2. Implications for TRF management

Feature	Implication	Mangement Technique
A large proportion of nutrients are found in the above-ground biomass. Many of these nutrients are in the leaves, twigs and small branches.	Deforestation and removal of whole trees will permanently remove nutrients, breaking the nutrient cycles.	Selective felling, where some of the trees in an area are left behind will help to maintain the nutrient cycles. Debranching on site, leaving the leaves, twigs and branches behind, will effectively allow the return of many nutrients to the soil.
Rainforests intercept a very high proportion of rainfall and, in all areas, total rainfall is high and is often intense.	Deforestation will dramatically reduce interception. Consequently the impact velocity and therefore erosivity of rainfall will increase. Nutrient leaching will dramatically increase.	Low intensity, selective logging will help to reduce these impacts.
Deep rainforest soils may recieve virtually no input of nutrients from weathering bedrock. Nutrient input is dependant upon decomposition of vegetation, atmospheric inputs via rainfall and deep nutrient capture by the long tap roots of dominant trees.	Conversion of rainforest to arable crops completely disrupts nutrient cycles. Continuous cultivation of arable crops is impossible without sustained use of artificial fertilisers and careful rotation.	Agroforestry (the subject of a future Factsheet) - where trees and crops are grown together - may be more sustainable.
Most roots, suckers, decomposition and seed germination occur close to the soil surface.	Soil compaction caused by heavy machinery during logging may kill roots, rapidly reducing nutrient absorption and prevent regrowth.	Low mechanisation harvesting techniques may be more appropriate.

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