ENERGY FLOW AND MATERIAL CYCLES IN TROPICAL FORESTS

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1. GLOBAL RADIATION BALANCE

Two types of energy acting as input in the forest ecosystem may be identified : gravitation and solar energy. Figure 48 shows a schematic diagram of the global radiation balance.

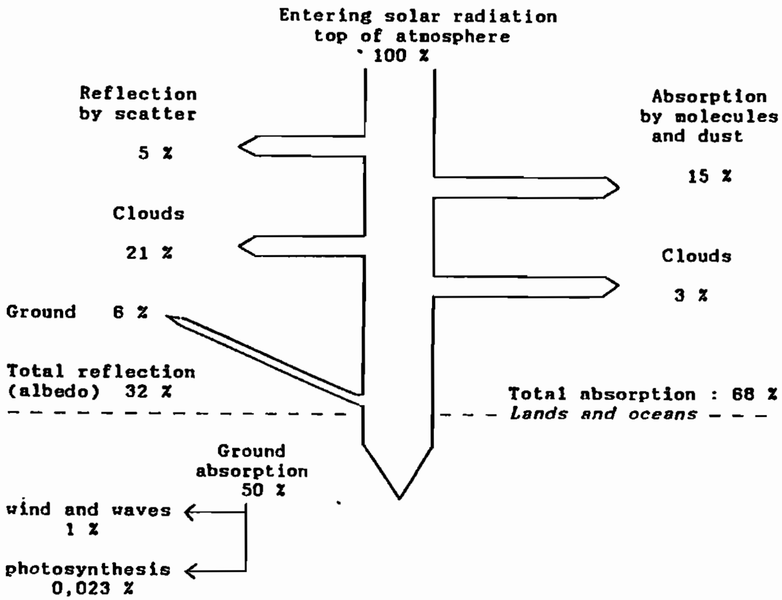


Figure 48 The global radiation balance

2. THE ROLE OF PLANTS IN ENERGY FLOW AND MATERIAL CYCLES

Vegetation lies at the interface between the ground and the atmosphere. Plants are the first component of the terrestrial ecosystem to receive solar radiation composed of shortwave radiation (ultra violet and visible).

Lecture notes

i) Plants use the shortwaves of solar energy for the photosynthesis of carbon hydrate molecules which are used for cell respiration and for the building of vegetal tissues. Only 0,023 % of the total solar energy radiation entering the atmosphere is used for photosynthesis (figure 48).

ii) Plants absorb infra-red radiation (longwave) which increases the temperature of their tissue surface. Without regulation this temperature increase could destroy the leaves. Plant transpiration is the thermal regulation which avoids this threat.

Figure 49 shows plants as a "black box" system where :

i) inputs are solar shortwave radiation, longwave radiation and air oxygen,
ii) outputs are carbon material coming from photosynthesis,
iii) transpiration acts as a feed back regulation of the system to avoid disturbance caused by temperature increase and allow a maximum of efficiency to photosynthesis.

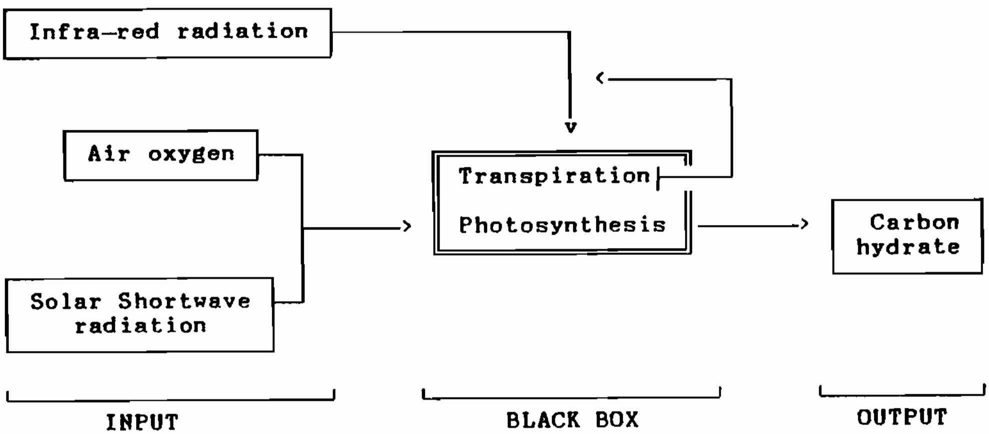


Figure 49 - Solar energy flow in the Plant system

If by photosynthesis, the plants change the solar energy flux reaching the ground, plants also play a key role in the water cycle and nutrients cycle in the soil through the hydric flux caused by transpiration. With their roots, plants pump water and soluble nutrients into the soil by osmotic pressure. Under the form of sap, water moves in the plants from the roots to the leaves where under the form of water vapour it evaporates into the atmosphere by transpiration.

Plant Tissues are composed of water, minerals, carbon and energy. Energy is stored in the joints between small molecules. The more complex the molecules are, the richer in energy they are.

Each year, each square kilometre of tropical forest produces an abundant biomass of living organic matter and an abundant waste composed of dead organic matter. With this waste, vegetation plays a key role in pedogenesis and soil fertility. Dead leaves are mainly composed of glucides (starch, hemicelluloses, celluloses); lignite (10 to 30%) and small quantities of proteins. The decomposition of this dead organic matter is the result of decomposers. Decomposers are microconsumers such as bacteria, fungi, insects and worms, which break down complex molecules to obtain energy. There are two methods of waste decomposition.

a) The first one is a mechanical decomposition. Eaten by a multitude of small animals such as slugs, snails, ants, arthropods and worms, plant tissues are transformed into small pellets of faeces, dead animals, shells,.

b) The second one is a chemical decomposition of plant tissues, mainly membranes and parenchymes. Sugar, starch, hemicelluloses and proteins are easily decomposed by bacteria and fungi. Pectines and celluloses are not so easily decomposed. Decomposition of lignine is very slow and difficult to accomplish. All these products are transformed into simpler chemicals to be finally evaporized into carbonic gas (CO_2), hydrogen (H_2) and methan (CH_4) or mineralised into nitrogen (N), phosphorus (P) and potassium (K).

Decomposition of litter produces humus (organic material) and minerals whose migration by leaching in the soil cause horizonation. The formation of humus and horizonation are the main components of pedogenesis.

Figure 50 shows the organic matter cycle in a tropical forest.

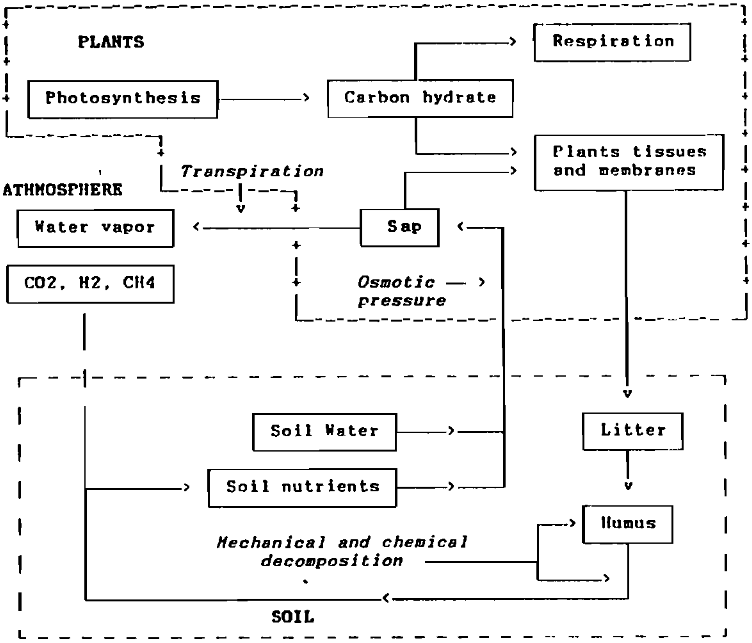


Fig. 50. The organic matter cycle in a tropical forest.

3. THE WATER CYCLE

3.1. GENERAL OVERVIEW

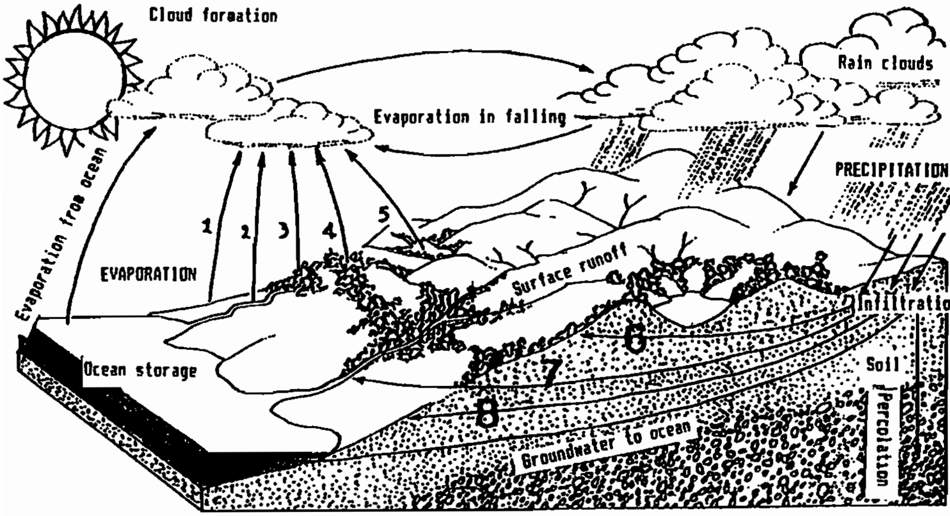
Figure 51 shows an overview of the water cycle mainly based on seven processes:

i) precipitations (rainfalls and mist in tropical countries)
ii) evaporation from soil, from vegetation, from streams and ponds;
iii) transpiration;
iv) surface run off;
v) infiltration;
vi) lateral movement of water in soil;
vii) percolation.

The complete water cycle may be briefly summarised in the following equation:

$$P = E + G + R$$ Where

P: precipitation,
R: water surplus, E: evapotranspiration, G: change in soil water storage



1 : Evaporation from soil
2 : Evaporation from streams
3 : Evaporation from vegetation
4 : Transpiration
5 : Evaporation from ponds
6 : Groundwater to vegetation
7 : Groundwater to streams
8 : Groundwater to soil

Figure 52 - The water cycle (After Tyller Miller, 1988)

In evapotranspiration two processes are combined: the transpiration of plant tissues, the evaporation of water on plant leaves and in the soil.

3.2. THE RAINFALL

Rainfall play a key role in soil erosion by the impact of raindrops. This impact is caused by the kinetic energy of raindrops. Kinetic energy of raindrops is a function of three parameters:

i) the distance between the clouds and the soil, the further the distance is, the more energetic and destructive is the impact of the drop on the soil;
ii) the air resistance, a big air resistance reduces the kinetic energy of drops;
iii) the size and the mass of drops.

When a raindrop reaches the soil, it causes a geyserlike splashing. Soil particles are lifted and then dropped into new positions. This process is called splash erosion. Particles shifted by raindrop splash tend to seal the natural soil opening, reducing the infiltration of rainwater in the soil and increasing the sheet wash and soil removal.

Lecture notes

On bare ground, splash erosion is a function of three parameters:

i) the kinetic energy of raindrops;
ii) the duration of the shower;
iii) the soil resistance to erosion which heavily depends on the texture and the structure of the soil.

Lying at the interface between atmosphere and ground, vegetation plays a key role in reducing splash erosion. The main effect is the interception of raindrops by tree canopy. The kinetic energy of raindrops acts on leaves and branches without direct effect on the ground surface.

i) In total, 35% of the rainfall reaching the canopy will evaporate and will never reach the soil.
ii) The rain water washes along the branch any removing obstacles and causing a concentration of running water which flows down into gutters, to the next branch or to the leaves underneath.
iii) By guttering from 5% to 10% of the total rainfall reaching the canopy runs along the branches to the trunk. The water washes along the trunk and disappear at its base by infiltration.
iv) By guttering from 55% to 60% of the total rainfall reaching the canopy runs along the branch to the apex of the leaves and reaches the soil after a fall of several meters during which drops concentrate kinetic energy.
v) The size and the mass of these guttering drops is bigger than the raindrop size. However their kinetic energy is less, the distance of impact being incomparably smaller.

As in the case of raindrops, the effect of guttering drops on the soil is heavily influenced by the soil resistance to erosion. In tropical forests this resistance is very high. A layer of dead leaves of several centimenters thick covers the soil, breaking the kinetic energy of guttering drops and avoiding splash erosion. The decomposition of this layer and humification is the first step of pedogenesis. So waste has a direct influence on the texture and the structure of the soil. In fact, the resistance of soil to erosion is a direct function of the status of the neighbouring vegetation and the agricultural practice when logged areas in the forest are used for shifting cultivation or cash crops.

A good example of the importance of agricultural practice to avoid splash erosion is given by coffee plantations. Soil resistance to erosion in coffee plantations depends on the density of the tree cover. Because of the shape of their leaves, coffee shrubs have heavy guttering. This is the reason why the soil underneath and in the surroundings is sensitive to splash erosion and needs tree cover, also useful for the coffee which likes shady areas.

Forest trees which provide an abundant litter of leaves seem better able to grow coffee underneath than coconut trees which give poor protection against splash erosion. A good litter means also a better soil permeability and a better nitrification, in fact a better soil fertility and indirectly better yield.

4. CONCLUSION

To conclude figure 53 shows a synthesis on the function of climate in the environmental processes of the life layer.

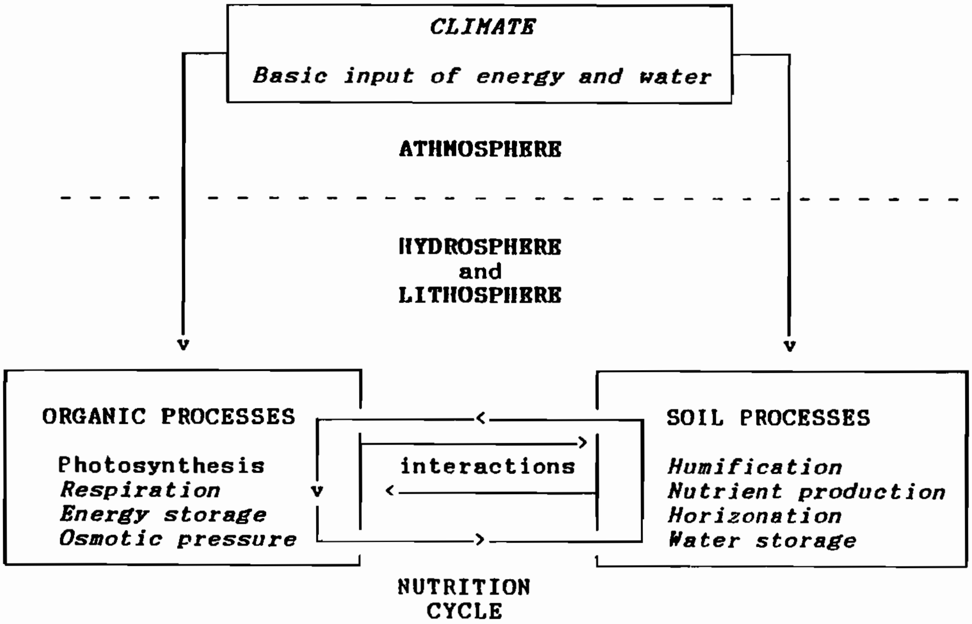


Figure 53 - Climate, plant organic processes and soil processes

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RAS/86/036
Field Document 10
February 1993

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REPORT OF THE TRAINING COURSE ON REMOTE SENSING

22 - 27 JULY 1990 NOUMEA, NEW CALEDONIA

Editors
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