Quadrant II – Transcript and Related Materials

Programme : Bachelor of Science (Third year)

Subject : BOTANY

Course Code : BOC-110

Course Title : PLANT ECOLOGY AND PHYTOGEOGRAPHY

Unit : VIII

Module Name: Models of energy flow

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Notes:

Energy flow in ecosystem

The behaviour of energy in ecosystem can be termed as energy flow due to unidirectional flow of energy. From energetics point of view, it is essential to understand for an ecosystem:

1. The efficiency of the producer in absorption and conversion of solar energy.
2. The use of this converted chemical form of energy by the consumer.
3. The total input of energy in form of food and its efficiency of assimilation.
4. The loss through respiration, heat, excretion, etc. and the gross net production.

Single- channel energy model

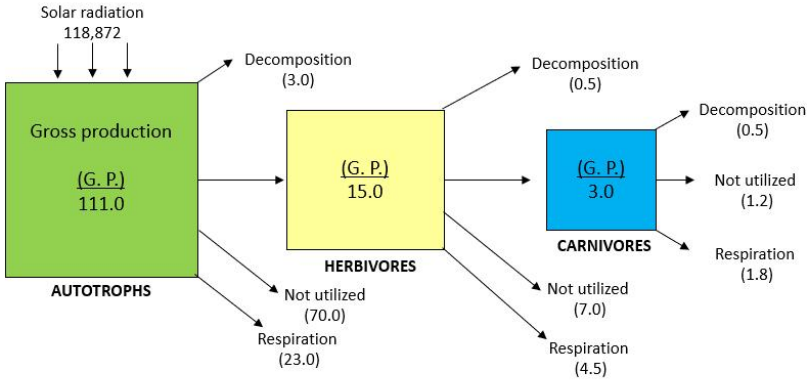
The principle of food chains and the working of the two laws of thermodynamics can be better made clear by means of Single- channel energy flow model. All biological activities need energy which they derived from the sun. The energy

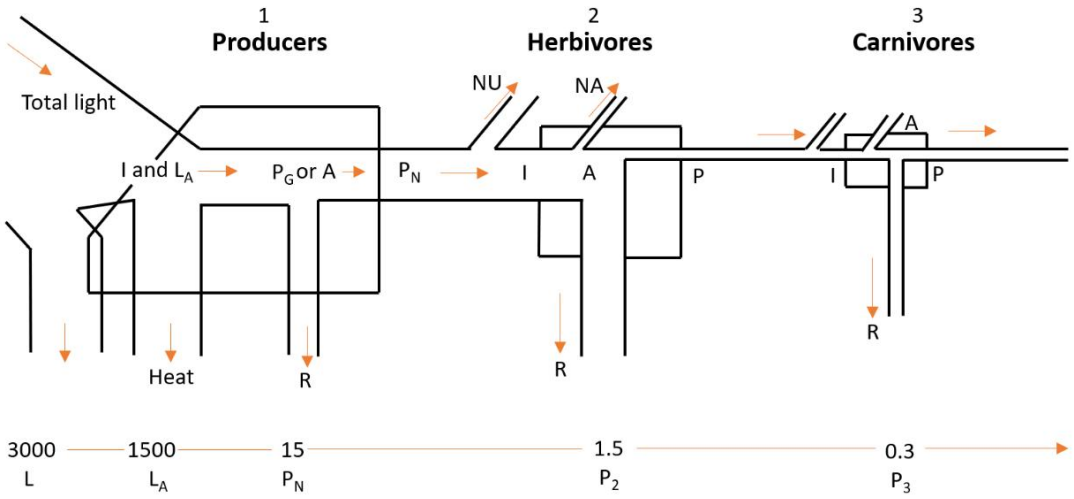
obtained from the sun is transformed into chemical energy by the process of photosynthesis. This energy is stored in plant tissue and transformed into heat energy during metabolic activities. The solar energy captured by autotrophs never revert back to sun, however, it passes to herbivores and that which passes to herbivores does not go back to autotrophs but passes to consumers. Thus, in biological system, the energy flows from the sun to plants and then to all heterotrophic organisms. The flow of energy is unidirectional and non-cyclic. Due to unidirectional flow of energy, the entire system would collapse if primary source of energy were cut off. At each tropic level there is progressive decrease in energy as heat in the metabolic reactions and also some of the energy is utilized at each tropic level.

Out of the total incoming solar radiation (118, 872 gcal/cm^2/yr), 118,761 gcal/cm^2/yr remain unutilised, and thus gross production (net production + respiration) by autotrophs is 111 gcal/cm^2/yr with an efficiency of energy capture of 0.10 %. It may also be noted that 21% of this energy, or 23 gcal/cm^2/yr is consumed in metabolic reaction of the autotrophs for their growth, development, maintenance and reproduction. It may be seen further that 15 gcal/cm^2/yr are consumed by herbivores that graze or feed on autotrophs.

This amounts to 70% of net autotroph production. Decomposition (3 gcal/cm^2/yr) accounts for about 3.4% net production. The remainder of plant material, 70 gcal/cm^2/yr or 79.5% of net production, is not utilised at all but become part of the accumulating sediments. It is obvious then that much more energy is available for herbivores than is consumed. It may also be noted that various pathways of loss are equivalent to and account for total energy capture of autotrophs, example Gross production.

Also, collectively the 3 upper 'fates' (decomposition, herbivores and not utilised) are equivalent to net production. Of the total energy incorporated at the herbivorous level, example 15 gcal/cm^2/yr, 30% or 4.5 gcal/cm^2/yr is used in metabolic reaction, thus, there is considerably more energy most via respiration by herbivores (30%) then by autotrophs (21%). Again there is considerable enrgy available for the carnivores, namely 10.5 gcal/cm^2/yr or 70% which is not entirely utilised; in fact only 3.0 gcal/cm^2/yr or 28.6% of net production passes to carnivores. This is more efficient utilisation of resource then occur at autotrophs to herbivores transfer level. At the carnivores' level about 60% of the carnivore's energy intake is consumed in metabolic activity and the remainder becomes part of the not utilised sediments.; only insignificant amount is subjected to decomposition yearly. This high respiratory loss comprise with 30% herbivores and 21% by autotrophs in this ecosystem.





From the energy flow diagram shown in figure, two things become clear.

1. There is no way straight along which energy moves (unidirectional flow of energy), the energy that is captured by the autotrophs does not revert back to solar input; that which passes to the herbivores does not pass back to the autotrophs. As it moves progressively through the various trophic level it is no larger available to the previous level. Thus, due to one way flow of energy, the system would collapse if the primary source, the sun, where cut off.
2. There occurs a progressive decrease in energy level at each trophic level. This is accounted largely by the energy dissipated as heat in metabolic activities and measured here as respiration coupled with unutilised energy.

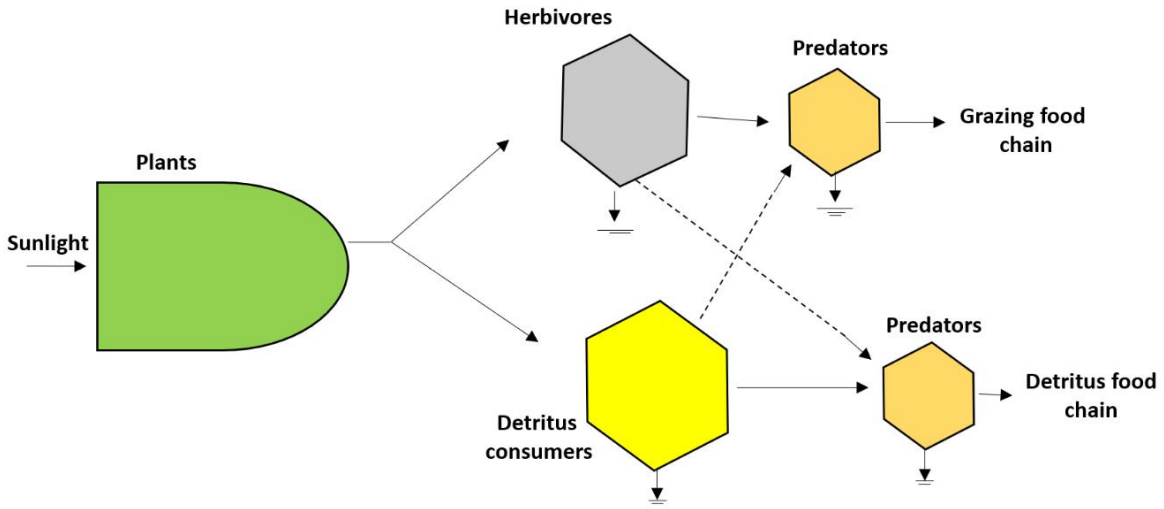
It becomes evident that, there is successive reduction in energy flow at successive trophic levels. Thus, shorter the food chain, greater would be the available food energy as with an increase in the length of food chain, there is corresponding more loss in energy.

Y- shaped energy flow model

Energy flow models for different kind of ecosystem have been describes by several authors. For instance Teal (1957) prepared an energy flow diagram of root spring in U.S.A. similarly H. T. Odum (1957) prepared energy flow model for silver springs, Florida, U.S. A. In silver spring there is 410,000 Kcal/m^2/y effective solar radiation falling on green plants for photosynthesis. Of this 389,190 Kcal/m^2/y was lost as heat; only 20,810 Kcal/m^2/y could be used in gross primary production. Again, out of this 11,977 Kcal/m^2/y was lost by way of respiration and only 8,833 Kcal/m^2/y remained for net production.

In the model given by Teal (1957) for root spring, most of the energy rich material eaten by heterotrophs enter the system as plant debris (detritus), whereas in that given by H.T. Odum (1957) for silver spring, most of the heterotrophs food in food chain was produced by green autotrophic plants. E. P. Odum (1962) noted this basic future that to begin within some system heterotrophs consume living plants while in others they feed on dead plants (detritus) thus in this case in root spring, the chain begin with dead plant part, whereas in sliver spring with live plant parts E.P. Odum pointed out thus in nature that there are present two basic food chain in any system. We have already consider this two kind of food chains:

1. Grazing food chain beginning with green plant base going to herbivores and then to carnivores.
2. The detritus food chain beginning with dead organic matter acted by microbes, then passing to detritivores and their consumers (predators).



Y-shaped energy flow model shows a common boundary, and in addition to light and heat flows, the import, the export and storage of organic matter are also included. Decomposers are placed in a separate box as a means of partially separating the grazing and detritus food chain. Decomposers are in fact a mixed group in term of energy level.

In each Y-shaped energy flow model one arm represent the herbivore food chain and the other, the decomposer (detritus) food chain. The two arms differ fundamentally in the way in which they can influence primary producer. In each model the grazing and detritus food chains are sharply separated. This figure contrasts the biomass energy flow relationship in the sea and the forest. In the marine bay the energy flow via the grazing food chain is shown to be larger then via the detritus pathway (forest), whereas the reverse is shown for the forest in which 90% or more of the net primary production is normally utilised in detritus food chain. Thus, in marine ecosystem the grazing food chain is the major pathway of energy flows whereas in in the forest ecosystem the detritus food chain is more important.

In grazing chain herbivores feed on living plant and, therefore, directly affected the plant population. What they do not eat is available, after death to the decomposers. As a result, decomposers are not able to directly influence the rate of supply of their food. But such a difference is not necessarily inherent in aquatic and terrestrial system. In a heavily grazed pasture or grassland 50% or more of the net production may pass down the grazing path. Whereas there are many aquatic ecosystem especially shallow water, one that, mature forest, operate largely has detritus system. Since not all food eaten by grazer is actually assimilated, some (undigested material in feces for example) is diverted to the detritus root; thus impact of the grazer on then community depends on the rate of removal living plant material as well as on the amount of energy in the food that is assimilated. Marine zooplankton, commonly graze more on phytoplankton then they can assimilate, the access been egested to the detritus food chain. Thus, energy flow along different path is depend on the rate of removal of the living plant material by herbivores as well as on the rate of assimilation in their bodies. The Y-shaped energy flow model further indicated that the two food chains are in fact, under natural conditions, not completely isolated from one another. For instance dead bodies of small animals that where once part of the grazing food chains become incorporated in the detritus food chain as do the feces of grazing food animals. Functionally, the distinction between two is of time lag between the direct consumption of living pants and ultimate utilization of dead organic matter. The importance of the two food chains may differ in different ecosystem, in some grazing is more important, in others detritus is major pathway.

The important point in Y-shaped energy flow model is that the 2 food chains are not isolated from each other. This Y-shaped energy flow model is more realistic and practical working model then the single- channel model because:

a. It confirms to the basic stratified structure of ecosystem.
b. It separates the grazing and detritus food chain (direct consumption of living plant and utilization of dead organic matter respectively) in both time and space.
c. The microconsumers (absorptive bacteria, fungi) and the macroconsumers (phagotrophic animals) differ greatly in size metabolic relations.

Universal energy flow model

E. P. Odum (1983) gave a generalised model of y shaped or 2- channel energy flow model., applicable to both terrestrial and aquatic ecosystem. Present what might be called universal mode one that is applicable to any living component whether a plant, animal, microorganism or individual, population or topic group (Odum., E. P., 1968).