Food web

By Fábio dal Soglio. Source: Dictionary of Agroecology and Education.

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To correctly manage an agroecosystem, it is necessary to understand how the different species that inhabit it, whether native or introduced, get their food. All living beings need energy and materials for their growth and development, to produce the structures and compounds they need, living organic matter, and to keep their life support systems functioning. This energy and the nutrients necessary for life are obtained from food. But while some species produce their own food, using available free energy and inorganic molecules, others lack this ability and depend on food that has already been synthesised. As a result, each ecosystem establishes a relationship of dependence, at different levels (trophic levels), between species that produce their own food and those that depend on other organisms for food. This forms a chain of ecological interactions based on food, the food chain or trophic chain (from the Greek 'trophe', meaning food or nutrition).

Of course, food interactions between species don't occur linearly, with plants being consumed by herbivores, hunted by predators who, when they die, are processed by decomposers. We have, for example, predators that can attack other predators in order to feed, or fungi in the soil that are decomposers of dead organic matter, but which, if given the opportunity, become plant pathogens and become consumers. So food interactions are actually complex, forming a network of food chains, the food web, also known as a food web or trophic web, which is how the concept will be dealt with in this text. But because it is a more widespread concept, and easier to apply, the term food chain has still been used.

Trophic levels and the flow of energy in the food web

The different species found in an ecosystem can be grouped by trophic levels, which are characterised by the ability of these species to produce and/or consume food. These trophic levels are: producers, which are the species capable of synthesising their own food; consumers, which feed on other organisms, living or dead; and decomposers, which, by breaking down complex forms of dead organic matter, release nutrients back into the environment. Throughout the food web, from primary producers to decomposers, there is a transfer of energy and nutrients between trophic levels, i.e., a flow of energy and a flow of materials. A schematic representing the interactions between these different trophic levels and the flow of energy is shown in Figure 1 (see below, p. 799).

Primary producers are autotrophic organisms, i.e., they can synthesise complex organic molecules such as sugars, lipids, and amino acids from inorganic molecules and an energy source. The main inorganic molecules they use are those that serve as a source of carbon, oxygen, and hydrogen, such as carbon dioxide (CO2) and water (H2O). Autotrophic organisms that have chlorophyll, such as plants and some algae, and bacteria, carry out photosynthesis, using sunlight as a source of energy and transforming CO2 and H2O molecules into glucose, which is a sugar, releasing oxygen (O2). Other autotrophic organisms take advantage of the energy released by chemical oxidation reactions through chemosynthesis, where the result is also the synthesis of sugars. Examples of organisms that carry out chemosynthesis are: ferrobacteria, which oxidise iron compounds (Fe); sulphobacteria, or thiobacteria, which oxidise sulphur compounds, mainly hydrogen sulphide (H2S); and nitrobacteria, or nitrifying bacteria, which oxidise ammonia (NH3) or nitrite (NO2), producing nitrate (NO3), which is a source of nitrogen for plants.

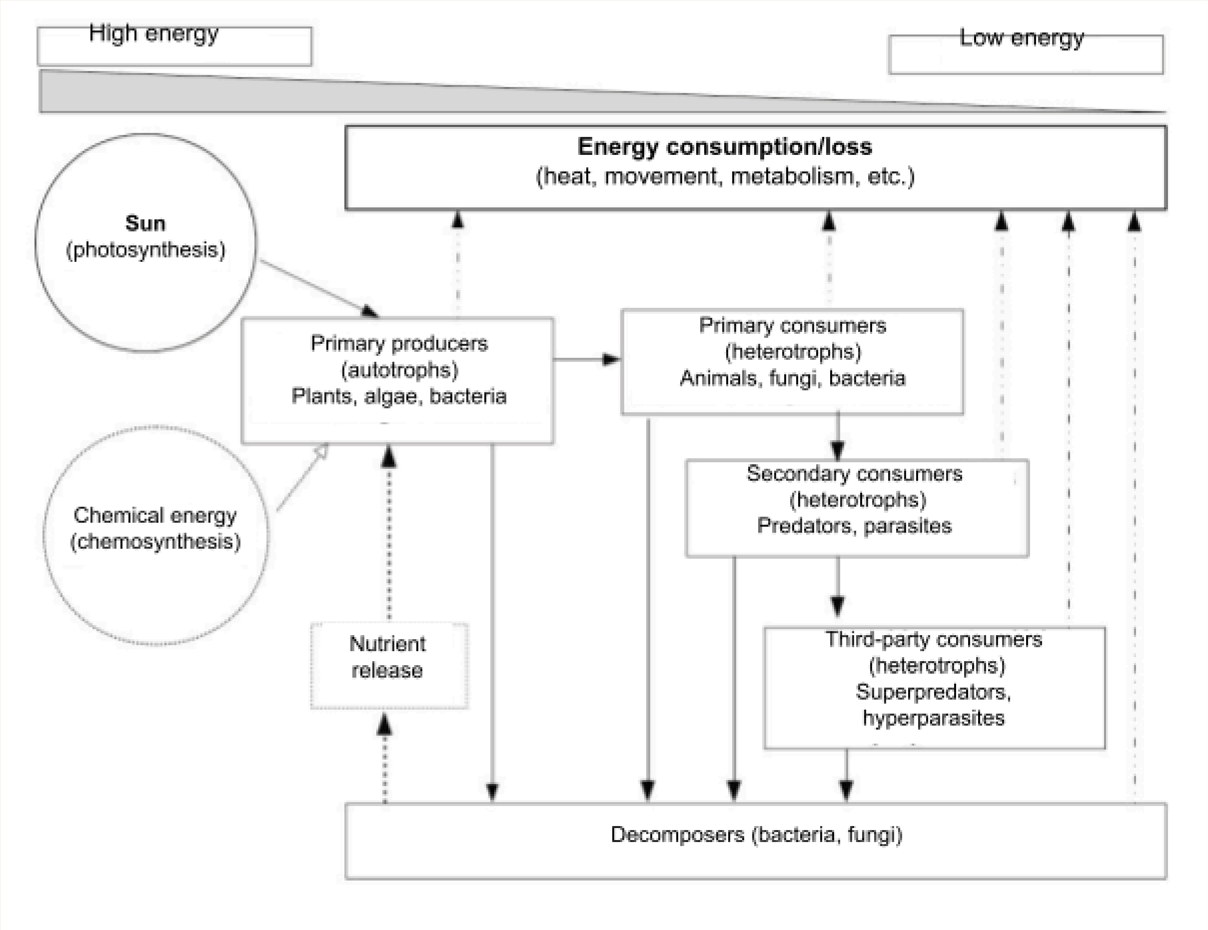

Figure 1 - General diagram of the food web, showing food interactions and energy flow in the ecosystem.

The sugars produced in photosynthesis and chemosynthesis serve as a primary reserve of energy, which, if necessary, can be released through oxidation reactions. In some organisms, aerobes or aerobes, this oxidation takes place in respiration, which occurs in the presence of oxygen (O2); the breakdown of sugars releases chemical energy, CO2, and H2O. In some organisms, the anaerobic or anaerobic, the breakdown of sugars is carried out in the absence of oxygen, by other compounds, such as some nitrogen compounds or sulphur derivatives, and through fermentation, a reaction in which the sugars are not broken down completely, producing simpler compounds such as alcohol (Lehninger; Nelson; Cox, 1993). Some organisms, such as certain fungi and bacteria, can act either aerobically or anaerobically, depending on their environment. The energy released in the breakdown of sugars allows organisms to synthesise the other organic molecules they need or to carry out work. Energy is thus transferred to the new molecules formed or lost in the form of work or heat.

Among consumer organisms, known as heterotrophs because they don't synthesise their food, there are different ways of obtaining and processing food to get the energy and nutrients they need to live. There are obligate aerobic consumers, obligate anaerobic consumers, and consumers that survive in the presence or absence of oxygen. Primary consumers feed only on primary producers or part of them. This is the case with herbivores, such as ruminant animals, which eat only plants. Other organisms feed on other consumers and can be known as secondary consumers, when they feed on primary consumers, such as ticks parasitising cattle, or small predators feeding on rabbits, or as tertiary consumers, such as superpredators, predators of other predators, such as eagles that feed on snakes, and hyperparasites, parasites of other parasites, such as fungi of the genus Trichoderma that attack fungi that parasitise plants.

Although many species specialise in a particular trophic level, some species are more generalist, occupying different trophic levels depending on the environment or life stage they are in. In sirphids, which are small flies, for example, the adults consume nectar and pollen, making them primary consumers, while the larvae are predators of aphids on plants, i.e. secondary consumers (Silva et al., 2013).

In some ecological interactions, such as symbiosis and mutualism, we find associations of species that, even though they are at different trophic levels, benefit each other. Examples cited by Moreira and Siqueira (2006) include nitrogen-fixing bacteria of the genera Rhizobium and Bradyrhizobium, which form symbiotic associations with leguminous plants, and mycorrhizal fungi, which live in mutualism (obligatory symbiosis) with most plants. In both cases, the microorganisms supply the plants with nutrients and receive sugars from them. Odum (1983) also cites as an example the case of lichens, symbioses between fungi and algae or cyanophyceae (photosynthesising bacteria), often known to be primary colonisers, inhabiting poorly weathered environments, in which the beneficial association between the organisms involved is such that they always reproduce together. In this case, the algae or cyanophyceae carry out photosynthesis and are therefore the primary producers, while the fungi provide them with water and protection, receiving synthesised food in return.

Some organisms, the mixotrophs, are both producers and consumers. This is the case with carnivorous plants, which, although they photosynthesize, also feed on insects that get caught in their traps, and some algae, such as those of the genus Euglena, which can both photosynthesize and feed on different organic compounds through phagocytosis (Schmidt; Raven; Paungfoo-Lonhienne, 2013).

At the end of the food web are decomposer organisms, which recycle dead organic matter. Decomposers, usually microorganisms, acquire energy by breaking down more complex organic compounds, such as sugars, proteins, nucleic acids, and lipids, and releasing nutrients in the form of simpler compounds that are then available to primary producers, restarting the food web. In the process of decomposition, various organisms can succeed each other, each being more adapted to different ecological conditions or specialised in breaking down certain organic compounds. Some organisms can act as decomposers of organic matter under certain environmental conditions, becoming consumers if these conditions change. This is the case with various microorganisms that are normally found as decomposers of organic matter in the soil, and which can become pathogens if the opportunity arises.

Some organisms can feed on a greater diversity of food sources, both producers and consumers, and even decomposers, and are called polyphagous or omnivorous. This is the case with humans, who can process a wide range of foods and have an adapted digestive system. On the other hand, like humans, many organisms do not only feed on carbon and mineral sources, but also require sources of some complex compounds that they cannot synthesise, such as vitamins or amino acids, which need to be obtained through food. Thus, even an omnivorous organism, which can utilise a wide range of foods, may require some specific nutritional source to complete its development satisfactorily.

According to Odum (1983), the flow of energy occurs in a single direction and, along the food chain, this energy is consumed and lost. Thus, primary producers acquire energy from a high-energy source, such as sunlight, and accumulate it in the food they synthesise, which will form the basis of the food web. This food is used in part by the producers, and then by the consumers and decomposers, and the initial energy is consumed to produce work or lost in the form of heat to a final sink. Through the food web, energy losses at each trophic level are considerable and can reach 90 per cent (Odum, 1983). Thus, the producers accumulate more energy per mass than the primary consumers, who in turn accumulate more energy than the secondary consumers, and so on. This explains why we can consider plant production to be more energy efficient than animal production, and why we don't have carnivorous animal farms.

The food web and agro-ecosystem management

As you can see, food webs are connected to the flow of energy and the productivity, in terms of biomass, of an ecosystem. This means that the correct management of an agroecosystem directs the flow of energy towards desired ecological functions, benefiting priority species and interactions for agriculture. Although general rules can be useful, establishing the conservation of soil, water, and biodiversity for the correct management of agroecosystems, it is necessary to understand the natural trends of trophic networks, considering local ecological conditions and how different practices affect them.

Many management practices common in conventional agriculture, such as ploughing, incorporating crop remains into the soil, applying pesticides, and monocultures, jeopardise the flow of energy and organic matter in the system. In a tropical soil, ploughing, which causes compaction and the deep incorporation of undecomposed organic matter, for example, increases anaerobic activity in the soil and, instead of releasing CO_2, releases methane (CH_4), which is toxic (Primavesi, 2012). Methane also has proportionally greater potential than CO_2 as a cause of the greenhouse effect (Forster, 2007). Monocultures reduce the availability of food for the maintenance of different functional groups, such as biological control agents, increasing the population of unwanted organisms (Nichols, 2006). Pesticides, whether chemical or biological, affect food webs because they alter functional biodiversity, sometimes unintentionally, both directly, in species susceptible to the active ingredients, and indirectly, when they eliminate a species from the food web that is key to the survival of other species.

On the other hand, there are practices that are beneficial to agroecosystems, favouring the capture of energy in the system and the accumulation of biomass. This is the case with agroforestry systems, where trees not only increase functional biodiversity, providing food and protection for various species, but also increase light interception in the system and biomass accumulation, with positive effects on soil structure and fertility (Coelho, 2012). The use of vegetated barriers and windbreaks, which alter the microclimate in the agroecosystem, also interfere with the distribution of specialised insects or pathogens, i.e., those that attack only certain plants, and also contribute to biotic regulation by serving as a reservoir for biological control agents such as predators, for example spiders and wasps, or parasites, such as microorganisms that attack other microorganisms or cause diseases in harmful insects.

Conclusion

There are many possibilities for managing food webs in agroecosystems and thereby achieving higher levels of productivity in agriculture. However, to develop more sustainable agroecosystems, in addition to productivity, we must take into account their other properties, such as environmental sustainability, autonomy, equity, and stability. As the network of food interactions in each ecosystem has its own specificities, being conditioned by physical and ecological characteristics that vary considerably over time, throughout the days and seasons, and according to climatic conditions, for each environment and each situation, there are different responses to the behaviour of food networks. General rules for managing soil, water, and biodiversity, and how we can improve the flow of energy and biomass by managing food webs, can be used, but the experience and knowledge accumulated in each ecosystem need to be taken into account, adapting management to local contexts. In addition, as a result of the ecological interactions between species, which are generally more efficient at conserving energy and producing biomass, there is a long period of coevolution, in which priority should be given to management that benefits native species, both of the biodiversity being managed and associated biodiversity, which generally results in the establishment of food webs that are more efficient at accumulating energy and producing biomass.

References

COELHO, G. C. Sistemas Agroflorestais. São Carlos: Rima, 2012. 206p.

FORSTER , P. et al. Changes in Atmospheric Constituents and in Radiative Forcing. In: Solomon, S. et al. (eds). Climate Change 2007: The Physical Science Basis. Cambridge: Cambridge University Press. 2007.

LEHNINGER, A. L.; NELSON, D. L.; COX, M. M. Principles of Biochemistry. 2. ed. New York: Wortth, 1993. 1.013p.

MOREIR A, F. M. S.; SIQUEIR A, J. O. Microbiologia e Bioquímica do Solo. 2. ed. atual. Ed. ampl. Lavras: Editora UFLA, 2006.

NICHOLS, C. I. Bases agroecológicas para diseñar e implementar una estrategia de manejo de hábitat para control biológico de plagas. Agroecología, n. 1, 2006, p 37-48, 2006.

ODUM, E. P. Ecologia. Rio de Janeiro: Ed. Guanabara, 1983. 434 p.

PRIMAVESI, A. O solo: a base da vida em nosso globo. São Paulo: Unesp, 2012. 13p. Disponível em: https://www.fca.unesp.br/Home/Extensao/GrupoTimbo/Osolo-AnaPrimavesi. Acesso: 5 abr. 2021.

SCHMIDT , S.; RAVEN , J.A.; PAUN GFOO -LON HIENNE , C. The mixotrophic nature of photosynthetic plants. Functional Plant Biology, n. 40, p. 425-438, 2013.

SILVA, A. C. et al. Guia para o reconhecimento de inimigos naturais de pragas agrícolas. Brasília: Embrapa, 2013.

Further information

GONÇALVES, P. A. S.; SILVA, C. R. S. Efeito de espécies vegetais em bordadura em cebola sobre a densidade populacional de tripes e sirfídeos predadores. Horticultura Brasileira, v. 21, n. 4, p. 731-734, 2003.