Agroecology Tutorial

The documents in this tutorial describe some of the basic concepts of agroecology that apply to IPM. The first document, **"Agroecosystems"**, introduces the science of agroecology and explains the structure and function of agroecosystems. The second document, **"Communities"**, describes the characteristics of agroecological comunities. The third document, **"Energyflow"**, explains how energy moves through an agroecosystem. The fourth document, **"Populations"**, gives a brief introduction to population ecology. The fifth document, **"Interferences between organisms"**, provides a framework for thinking about how organisms in an agroecosystem interact.

Agroecosystems

Agroecology uses ecological principles to try to understand and manage agriculture. Agroecologists call agricultural operations agroecosystems. By understanding the role of pests in agroecosystems, agricultural professionals can apply ecological principles to IPM.

Ecosystems consist of living and non-living parts which interact to form a recognizable system. Forests and lakes are examples of ecosystems.

Agroecosystems are ecosystems that include agricultural parts, such as crops. Rice fields and orchards are examples of agroecosystems. We can sort the parts of agroecosystems into two categories - living and nonliving.

The living parts of an agroecosystem are organisms such as crop plants, pests, beneficials, and the farmer. The non-livings parts include the soil, air, water, nutrients, and dead and decaying organisms.

The living parts of an agroecosystem can be further subdivided into organisms, populations, and communities.

A single organism is the most basic unit of agroecology. It is important to understand how individual organisms respond physiologically to environmental factors, such as temperature, light, or chemical pesticides. Many IPM interventions exploit the physiological vulnerabilities of pests. An individual maize plant is an example of an individual organism.

A population is a number of interacting organisms of the same species. The interactions of individual organisms within populations determine the size, growth rate, etc. of a population. A field of maize is an example of a population. A community is made up of several interacting populations from different species. One population can affect another through herbivory, competition, allelopathy, or other community-level interactions. A maize crop, its pests, its beneficials, and other neutral organisms in a maize field is an example of a community.

Communities

The structure of agroecological communities varies widely. A monocultural field of maize has a quite different structure than a market garden, which is different again from a coffee plantation. Characterizing the structure of an agroecological community improves our understanding of how it functions. Three important characteristics of an agroecological community are biodiversity, dominance, and trophic structure.

Biodiversity is a measure of how many species inhabit a community. The more species in a community the higher the total biodiversity. Crop biodiversity, beneficial biodiversity, and pest biodiversity are other measures that can be taken.

Dominance is a measure of the relative effect of a species in a community. A species is usually dominant because it is abundant, large, or both. In a rice field, for example, rice is the dominant species.

The trophic structure of a community accounts for who eats whom. Producers are at the bottom of the trophic structure. These include plants and other organisms that make their own food from solar energy. Herbivores eat plants, and predators prey on herbivores. Parasites, parasitoids, and pathogens attack other organisms, and scavengers and detritivores consume dead organisms.

Energy Flow

The way energy flows through an agroecosystem reflects the trophic structure of an agricultural commuinity. Understanding agroecosystem energy flows can improve IPM.

All energy enters agroecosystems through photoynthesis of sunlight by plants. Plants store this energy in organic molecules such as sugars, starches, and cellulose that release energy when broken down. The biomass of plants in an agroecosystem is directly related to the amount of energy they have stored.

Agricultural crops are generally much more efficient than wild plants at capturing and storing solar energy. Wild plants average store about 0.1% of available solar energy as biomass, while sugar cane can approach 4% energy to biomass conversion.

Not all of the energy that plants photosynthesize goes into storage, however. About 90% is used by the plants themselves for metabolic processes. The amount of energy that is absorbed by plants from the sun is called gross primary productivity, while the amount that is stored and available to higher trophic levels is termed net primary productivity.

Herbivores consume plant biomass, converting about 10% of their consumption into herbivore biomass and using the remaining 90% for metabolism. Because the relationship between stored energy and biomass is fairly constant, the biomass of herbivores in most agroecosystems is about 10% of the plants. A lot of plant matter is never consumed by herbivores, but dies and is decomposed by detritivores.

Secondary consumers such as predators consume herbivores, converting 10% of their consumption into consumer biomass. Predator biomass is about 10% of herbivore biomass, or about 1% of plant biomass. In addition, many herbivores die without ever meeting a predator, their stored energy being consumed by detritivores.

In agroecosystems, the main 'herbivores' are human beings, who will hopefully harvest and consume the majority of the crop biomass. Humans are in direct competition with other herbivores in most agroecosystems, and they remove the biomass that they consume from the agroecosystem. Because there are fewer herbivores in the system, there are also fewer predators. When humans fail to exclude other herbiores from their food source, their populations can increase quickly, helped by the fact that there are fewer predators than would be expected in a natural ecosystem. Energy imbalances between different trophic levels is one of the main reasons why pest outbreaks are more frequent in agroecosystems than in natural systems.

This imbalance can be compensated for by artificially augmenting the predator population.

Populations

Population demography is regulated by the behaviour of individual organisms in a population, by other populations in the community, and by the environment. We can better manage the size and structure of pest populations if we understand the factors that influence population demography.

Birth, death, and migration

Populations increase through birth and immigration. They decrease when individuals die or emigrate. The growth rate of a population is the net effect of birth, death, immigration, and emigration. In a newly colonized environment, birth and immigration are much higher than death and emigration. As population size increases, competition for resources between individuals causes the growth rate to decrease. At some point, the growth rate approaches zero and the population reaches the carrying capacity of the environment. This pattern of growth is usually shown as a sigmoidal (S-shaped) curve.

The growth of populations can be represented mathematically. For more details visit this quantitave population ecology course taught by Alexei Sharov of the Department of Entomology at Virginia Tech, Blacksburg, VA.

Density-dependent and density-independent factors

Growth factors that are influenced by the population density are density dependent factors. Competition for a limited supply of food is an example of a density-dependent factor. Density-independent factors affect populations regardless of their size. A killing frost is an example of a density-independent factor.

In agroecosystems, farmers try to manage the environment so that the carrying capacity of the crop is high. This involves mitigating density-dependent factors and protecting the crop from density-independent factors. For example, fertilization reduces density-dependent competition between individual crop plants for nutrients, and mulching can protect plants from density-independent temperature fluctuations.

r- and K-selected species

Organisms allocate their energy between growth and reproduction. Species that are mainly limited by density-independent factors tend to have high rates of reproduction relative to growth. This type of species is called and r-strategist because it grows at a high rate(r) when density-independent limiting factors are removed. Species that are mainly limited by density-dependent factors tend have low rates of reproduction relative to growth. This type of species is called Kstrategist because its population size is maintained near the carrying capacity (K) of the environment.

r-strategist species are opportunistic, reproducing rapidly when given the chance. r-strategists are common in agroecosystems - most pests are r-strategists, as are most crops. r-strategist populations increase quickly after a disturbance such as tillage. K-strategists tend to form long-term stable populations. Mature forests consist mainly of K-strategists. K-strategists are rarely found in agroecosystems.

Interferences between organisms

Populations in an agroecosystem effect each other in a variety of ways. These effects, whether direct or indirect, can be understood in terms of interferences. A removal interference occurs when an organism removes something from the environment, reducing its availability for other organisms. An addition interference occurs when an organism adds something to the environment, making it available for other organisms.

Interferences are a useful way to conceptualize the interactions which occur between organisms in an agroecosystem. Some examples of removal and addition interferences are listed below.

Removal interferences

Competition

When two organisms require the same resource, competition occurs. Each organism removes that resource for the environment, reducing its availability for other organisms. A large plant that shade a smaller plant is removing sunlight availability, reducing the ability of the smaller plant to grow.

Herbivory

When a herbivore consumes plant tissue, it is removing this tissue from the plant. This can reduce photosynthetic surface and plant health. If the herbivore leaves the agroecosystem, then nutrients that would have been recycled when the plant died are removed as well. Crop harvesting is a massive removal of nutrients that is usually compensated for by the addition of manure or fertiliser.

Predation

Predators remove biomass from the herbivore population by directly consuming them. This benefits plant populations by reducing herbivory, and increases predator biomass.

Parasitism

Parasites remove nourishment from a host's body, weakening the host and exposing it to further diseases. Parasitism is detrimental when crop plants or beneficial organisms are attacked. Beneficials which parasitize pests are highly useful in IPM.

Addition interferences

Symbiosis

Symbiosis occurs when two organisms add things to the environment which benefit each other. For example, flowers provide nectar for bees in exchange for pollination, and *Rhizobium* bacteria fix atmospheric nitrogen and provide it to legumes in exchange for sugars from the plant. In many cases, symbioses benefit farmers and should be identifyied and promoted whenever possible.

Allelopathy

Allelopahty occurs when plants release compounds into the environment which affect other plants. Usually, this effect is negative, but sometimes plant growth can be positively affected by allelopathic chemicals. Allelopathy by weeds can be detrimental to crop growth, but allelopathy is becoming an important tool for IPM as it is further understood.