MAMAGEMENT OF QUICK DECLINE IN PRODUCTIVITY OF TROPICAL AGROECOSYSTEMS*

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Quick decline in productivity, a characteristic of tropical agroecosystems

Epidemiological, are powerful selection forces determining the types of vegetation of entire regions, as strong as edaphic, climatic or any other. If they condition types of vegetation, they condition types of crops and agricultural practices associated with them in the agroecosytems built in substitution of natural ecosystems.

Because of climatic conditions, parasitism should be more acute in tropical rain forest ecosystems as compared to that of ecosystems in temperate or cold regions of the world. However, natural ecosystems in the tropics do not seem to suffer devastating epidemics of the kind that put the whole systems on the verge of extinction. This is because, in the immensity of time and vastness of space, during the evolution process, these systems have arrived to what Maynard Smith and Price (4) call Evolutionary Stable Strategy (ESS), that can be defined as the best possible strategy of inherited behavior patterns at a specified systems level. Such strategy, after all, would not have become genetically encoded if it lacked survival value, and it has become the best possible strategy by the competitive elimination of all earlier, inferior strategies. When the natural ecosystem is replaced by agroecosystems they show quick decline in productivity, which is conditioned for any or all of the four following main factors: 1. Soil fertility loss, 2. Weed invasion, 3. Epidemic attack of insects (pests). 4. Epidemic attack of diseases. It is important to emphasize that one of the less studied and understood factors deals with the edaphic pathosystems. The involved parasites, whose function takes place in the soil, a dark body that do not allow for direct observation of the phenomena taking place there, makes very difficult critical evaluations of behavior patterns related with them. However, Wellman (8) considers that some soil-borne plant pathogens could very well be the reasons behind the need to abandon the land in what is known as shifting cultivation or slash and burn type of agriculture in tropical regions of the world.

The ESS (Fig. 1) to which natural ecosystems arrived under tropical conditions is characterized by high species diversity, high genetic diversity for each one of the species and high structural diversity, making possible a huge amount of diverse ecological niches among the different strata of vegetation in the jungle. All these components make possible a balanced behavior of all present pathosystems.

In the evolutionary process, natural ecosystems reach amazing levels of complexity and developed subtle mechanisms and complex species interactions, responsible of maintaining the ecosystem balance. Under tropical conditions, soils, for example, are extremely poor in contrast with the exuberant vegetation. All nutrients appear to be sequestered in the vegetation as to preclude their loss. In this way, all nutrient cycles are efficiently closed by the means of a delicate web among microorganisms and plants in which the so called mycorhizae, are responsible of the translocation of nutrients from decomposing organic debris, directly to the roots of any kind of tree, avoiding nutrients lixiviation.

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It is not surprising then that upon the transformation of the natural ecosystem to any agroecosystem, occurs a quick loss of soil fertility, as it is not surprising either that in the attempt of “transplanting” agricultural technologies developed under temperate conditions, the impact of local pathosystems turn out to be devastating. Those agricultural technologies were developed to deal with different and more benign pathosystems since, under tropical conditions, life goes on continuously, i.e., there is not break down of life cycles of the parasites, because there is not cold weather, and there is continuous presence of suitable hosts.

Holistic approach to deal with crops parasitism under tropical conditions

The evidences are overwhelming: all attempts of technology transfer of agricultural techniques developed outside of the tropical regions have had a high ecologic, economic and social cost, due to their rotund failure.

The management of the ecological limiting factors to prevent the quick decline in productivity in tropical agroecosystems must be taken under a holistic, ecological approach. Robinson (7) has proposed a simile with ESS of natural ecosystems for agroecosystems which he calls Crops Stable Strategy (CSS) which he defines as the best possible agriculturally stable strategy; it must necessarily be an artificial strategy in the sense that the inherited behavior patterns of the wild pathosystem have to be externally controlled by man. The CSS must consequently be a coherent system of both inherited and acquired behavior patterns. The acquired behavior patterns are ours; they are controlled by experience and we are the ones who must do the learning. In other words, in agroecosystems with CSS it is a human responsibility both, genetic host management and host environment management. Unfortunately, all technologies developed in temperate and cold regions that have been transferred to the tropics have proven not to be CSS.

An ecological and holistic approach to the problems of parasitism in tropical agroecosystems should begin by looking for CSS for these regions. One should keep in mind that the supreme achievement of a CSS is a sustainable agroecosystem. Such CSS do exist in the tropical regions and should be the departing point in our research efforts for regional development. Such systems, unavoidably, should contain elements from the natural ecosystem; from those with ESS.

Agroecosystems with CSS in the tropical rain forest regions

There are notable examples in the tropics of agroecosystems with high species diversity, high genetic and structural diversity. They are ubiquitous in all tropical regions of the world. Classical examples are the cacao plantations in South Eastern Mexico, in the State of Tabasco, where there exist cacao groves made out of over a hundred different species per hectare, plants and animals all growing together, all useful to the farmer. Other beautiful example is that of the so called Popal system or Marceño system of maize cultivation. Popal (Fig. 2) is the name of a *musaseae* (*Thalia geniculata*) that grows with total dominance in shallow lake areas. When the time comes for raining reduction, i.e. beginning of February, and the water level lowers down to some 10 cm deep, the farmers, (from the Chontal ethnic, Maya and Aztec confluence), chop down the popal vegetation with the machete. Some 3 to 5 days later, when the vegetation begins to dry out and the water level goes further down because of the strong sun hit, the farmer sows the maize seed. He drops 3 or 4 seeds in holes 20 cm deep made with a pointing wood stick leaving the hole open. He makes holes at a meter distance in rows kept at a meter distance as well. One week after the maize has been planted, when it begins to emerge (and so the popal plants), he sets fire to the whole system. With fire the farmer gets rid of all undesirable vegetation, insects, snakes, and surely releases nutrients from the burning vegetation. The maize tips burn a little but afterwards the maize grows surprisingly fast. The burning of the system and the flooding period between maize production cycles (8 months approximately) probably contributes to the reduction or elimination of important pathosystems, breaking life cycles o parasites. Water accumulations brings about nutrients running out of surrounding areas.

The farmers are depositaries of maize germplasm exclusively selected to be grown under these conditions of cultivation. They are short cycle (precocity) varieties for they only have 3 to 4 months of reduced rain fall during the dry season to complete their cycle, before the very rainy season gets established. In other words, they seem to have a complete "technological package" resembling those of the "green revolution". They have selected (improved) varieties, soil fertilization, weed control, and pest and diseases control. The difference is that in this system, chontal farmers have developed a sustainable agroecosystem that produce annually from 4 to 6 tons per hectare in a region where maize production has a yield average of 1.2 tons per hectare, with the additional advantage that neither agricultural machinery nor fossil fuels are used, not to mention synthetic fertilizers or pesticides. No wonder is a system still practiced in spite of being practiced in "marginal" land (land to be avoided for agricultural porpoises because it gets yearly flooded).

Another agroecosystem showing CSS, also practiced by the Chontales in Tabasco State, Mexico, is the Maize – *Mucuna deeringiana* (locally known as "Nescafe") rotation. "Nescafe" is a fast and vigorously growing tropical legume planted at the beginning of the rainy season (May). By the end of its cycle (November) it is chopped down with machete and left as mulch covering the soil surface which is immediately sown to maize. The farmer drops 3 – 4 seeds of local land races of maize in holes 20 cm deep made with a pointing wood stick leaving the hole open. He makes holes at a meter distance in rows kept at a meter distance as well. Besides to maize, the farmer also sows pumpkin seeds, at larger distances. This system was first observed in 1975 in some groves at the Chontalpa Region where the original ecosystems had been recently devastated by one of the largest government rural development plans, the so called "Plan Chontalpa". The farmers pointed out that once the legume cycle is over, the following maize crop behaves as if it was the first maize crop after the slash and burn of the jungle. The system was documented and tested at Colegio Superior de Agricultura Tropical, down in Cardenas, Tabasco (3).

In 1977 this rotation system was found in Tamulté de las Sabanas Region over an estimated area of 1000 hectares. In 1986 the land planted with Maize – Mucuna rotation covered some 4600 hectares. The average maize annual yield in this system is 5 Tons per hectare and, again, because of the CSS, the system does not require machinery, fossil fuel, chemical fertilizers or pesticides (2, 6).

It is important to point out that a very similar system used to be practiced over quite a huge (five million acres) area in Sothern continental USA, (5). Such system was abandoned by the end of World War Two, perhaps due to the abundance of synthetic nitrogen fertilizers as well as machinery and the availability of new pesticides. It was also abandoned because, at that time, there was not concern about the need of developing and preserving sustainable agroecosystems. Due to these works carried out in Tabasco, several research institutes have taken this system as an important subject of investigation as a response to the concerns for the environmental risks created by modern agriculture.

Biotecnological production module for sustainable agriculture

In 1975 at Colegio Superior de Agricultura Tropical, down in Cardenas, Tabasco, a modular production system (module) began to be built inspired on elements that seemed to be responsible of the stability of natural ecosystems, i.e. high species diversity, high genetic and structural diversity. The goal of the project was to have an agrecosystem in which pests and diseases do not cause devastation. It could be considered as the first scientific effort focused on developing a sustainable agroecosystem in modern agricultural sciences (1).

The module was built over a five hectares piece of land covered with 25 years old vegetation of secondary growth, known as "acahual", the vegetation that grows once the original jungle has been removed. This particular piece of land was yearly flooded. In the area, in about a hectare the acuhal had been removed to grow maize. IN that area and because the main problem in the module was water excess, a one hundred meters long, 10 meters wide and 6 meters deep drench was built using one huge tractor (Caterpillar D8) in this central part and to help collecting excess water over a wider area, secondary drenches were connected to the main drench. All soil coming from this excavation was spread around the main drench, which turned out to be a mistake, because that was subsoil and for awhile it could not be cultivated, until it had enough organic matter content and microorganisms. Around the main drench an attempt was made to build a "chinampas" system (Fig. 3) using regular vegetables, but parasitism was so intense that it turned out to be impossible, until the regular vegetables were substituted by tropical vegetables. So, instead of potatoes, plantain (*Musa paradisiaca*) or yucca (*manihot sculenta*) or Malanga (Taro, *Colocasia esculenta*) were planted, instead of spinach, Chaya (*Nidusculus chayamansa*)the tropical spinach, and so on. The area for "chinampas" ended up covered by perennial tropical crops under such an array that could be called cells of tropical vegetables. The pathosystems damage became subtle in those cells. With few changes, after 20 years the cells could still be seen.

It is recognized that some of the natural ecosystems with the highest net productivity are swamps. In the central part of the module, in the drench, little by little a swamp was formed, although the species richness was artificially brought in. For instance, bivalves, which are the natural water filters were brought from some nearby sweet water lakes; water hyacinth was introduced to provide organic matter to be used in the chinampas; ducks and several fish species were also introduced; they were all human useful species.

Somewhere in the module even a collection of traditional medicinal plants was established with over 50 different plant species, to treat health problems as common in those areas such as snake bites.

Around the chinampas area a crop rotation was established, using alternatively Mucuna, then maize, next rice, and then again Mucuna.

Surrounding the annual crops area of rotations was the largest area of the module and was all covered with acahual. Very many of the trees were as tall as 25 meters, but the number of other shorter plant species was astonishing; making it very difficult to even walk through. Every 20 meters breaches were opened of 1.5 meters wide and an average of 100 meters long in which forest and fruit trees were planted, belonging to 26 different species. They were planted in alphabetical order, from avocado to "zapote" (*Achras zapota*), one every 3 meters. This was done to stop the spreading of parasites; if an avocado tree was parasitized, the parasite needed to move some 80 meters distance within so many species inside the "acahaul" that they should necessarily find some biological enemy to stop it, thus reducing the risks of epidemics within the system.

Time has proven the approach was right. The chinampa cells and the swamp in the middle, remained for over 20 years. The trees in some of the breaches grew fantastically, when they were 10 years old it was almost impossible to embrace them (Fig. 4) and they certainly could not be embraced when they were 20 years old. When the system was 21 years old was invaded by very poor farmers guided by unscrupulous politicians and most of it was destroyed because of the high value of the fine woods.

Parasitism under tropical rainforest conditions is really devastating but it is possible to deal with it under an ecological approach. Fortunately, the ecological reasons are beginning to be understood and accepted and there seems to be a general trend to support research and development guided by ecological principles. The works described above could become a guideline to look and search for ecological principles for they document so many valuable lessons to be learned from nature as well as from ancient cultures (such the Chontales), which are depositaries of wisdom that can help in the proper, ecological, management of agricultural production systems for the tropical rain forest regions, whose knowledge should be recognized, respected and expanded.

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Figure 1.- Growing stable strategy

Figura 2.- Popal system of corn production

Figura 3.- Chinampas system

Figure 4.- General view of one of the breaches planted to forest and fruit trees (26 different species) in alphabetical order. The trees were 10 years old. They could not be embraced when they were 20 years old. Biotechnological modular system for sustainable agriculture, established in 1975