

Sustainable Continuous Crop Production in a Tropical Environment

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One of the major means of increasing agricultural productivity in the tropics is through continuous cultivation. Year-round cropping is feasible where incoming solar energy, soils, and the moisture balance allow for continuous growth of plants. This condition often prevails in the humid tropics and can be created in the semi-arid tropics through irrigation. Under actual farming conditions continuous cropping is not often achieved since the high levels of solar energy receipt and heavy rainfall are associated with many problems that make cultivation difficult and reduce agricultural output considerably.

In the humid tropics the problems include infertile soils due to nutrient leaching and soil erosion, high incidence of weeds, pests and diseases, cloudiness and waterlogging. In the semi-arid tropics, constraints are shortness of the hydrologic growing season, moisture stress, soil erosion and excessive oxidation of soil organic matter. Agricultural practices to overcome these problems include continuous protection of the soil by covering it, timely planting, erosion control and irrigation works, the application of modest quantities of chemical fertilizers, and practices that reduce the risks of pests and diseases. Most practices mentioned require a great deal of know-how and they are not yet within reach of the majority of Third World farmers.

Introduction

The possibilities for increasing agricultural productivity in the tropics are often debated and many strategies have been proposed. Broadly speaking, crop production can be increased by one or more of the following methods.

1. by expanding the area for planting crops;
2. by raising the yield per unit area of individual crops; and
3. by growing more crops per year (in time and/or in space).

In the past, agricultural production mainly increased by the cultivation of more land, but now there is limited scope for that. Nowadays, cultivated land should be cropped more intensively and if possible continuously (Beets, 1982).

Continuous cultivation can only be achieved with improved (multiple) cropping patterns. Such patterns should be based on prevailing natural resources, in particular agro-climate.

Under practical farming conditions the design of improved cropping patterns can best be based on existing ones, but within the broad possibilities offered by theoretically possible patterns.

There are three situations where one could consider to try and introduce entirely new patterns, namely.

1. in new irrigation schemes where farmers did not practise irrigated agriculture before;
2. in settlement or transmigration projects;
3. where the productivity of prevailing systems is so low, or environmental degradation so severe, that drastic changes can no longer be postponed.

In most developing countries, agricultural services and extension have to be drastically improved before entirely new, sophisticated farming systems can be introduced. Thus, in most cases the aim should be to improve existing systems.

Continuous cultivation has two time dimensions, namely 1) during any one calendar year (year-round, or multiple cropping) and 2) sustained crop production for longer periods (year-by-year, as opposed to shifting cultivation with long fallow periods).

It is possible to sustain cropping over long periods, but only if use of natural resources is optimised and if no environmental degradation occurs. The latter requires that sufficient attention is given to soil conservation and ecological stability.

This paper examines agro-environmental factors and cropping systems that makes continuous cultivation possible. Socio-economic aspects are very important but are only briefly mentioned.

The agro-ecological environment

a. Climate

Four main parameters can be used to describe an agro-climatic environment: (i) solar energy receipts measured as Potential Evapo-Transpiration (PET); (ii) Precipitation (P); (iii) duration of the thermal and hydrologic growing seasons; and (iv) climatic uncertainty, measured as the coefficient of variation of the mean annual precipitation.

The main parameters of the biological environment include:

(i) flora and fauna; (ii) the incidence of pests and diseases; and (iii) the incidence of weeds. When these parameters are used, it is possible to

understand the agro-climate and relate it to the adaptation, growth and yield of crops.

The tropics receive almost twice as much solar energy as the temperate zone and the thermal growing season extends throughout the year.

In the humid tropics near the equator moisture conditions are favourable for plant growth throughout the year. Moving away from the equator towards drier areas, PET increasingly exceeds P and during large parts of the year crop production is not possible without irrigation.

b. Soils

There is great variability among soils of tropical areas. Some are deep and friable and easily tilled while others, such as the lateritic soils, are often thought quite worthless from an agricultural point of view. The warmer and more humid the climate, the speedier biological processes, the more quickly the natural fertility of the soil is used up, and the greater the effort required to maintain fertility. Chemical nutrients used up by crops and lost through leaching have to be replenished and great care should be taken to maintain the physical soil fertility by keeping the level of organic matter high.

Soil acidity tends to increase and many soils appear to be marginally supplied with zinc and sometimes manganese and iron. Erosivity as well as erodibility are high and environmental degradation due to erosion can be severe. However, with good management, including keeping the soil covered, and with erosion prevention, sustainable production is possible.

The cropping environment

The main characteristics of the humid climate that affect the cropping environment are high rainfall and overcast weather leading to reduced solar energy receipt and high relative humidity. Short growing seasons are a main characteristic of the semi-arid climate. The problems associated with farming under such conditions together with their solutions are summarized in Table 1.

Because of the long growing season, the humid tropics theoretically offer the best environment for vegetative growth and perennial crops seem best suited there. The environment can sustain plant growth throughout the year and permanent crops provide better soil cover than annual crops. Problems

associated with crop production in this climate include rapid decline of natural soil fertility caused by leaching and erosion; the high rainfall leads to considerable run-off which, in turn, results in severe loss of soil, frequently as high as 20 t/ha/yr.

Semi-arid climates have short growing seasons. Drought determines the start as well as the end of the season. This type of climate also imposes limitations in the form of dry spells. Consequently, crop growth cannot be sustained under natural conditions throughout the year and short season, drought resistant annual crops are best suited.

Farming systems for continuous cultivation

Problems of soil fertility maintenance are less with tree crops than with annuals since perennials continuously cover the soil and pump up nutrients from the subsoil. Rubber, cacao and oil palm are, therefore, highly suitable for the humid tropics

a. Humid Climates and Agroforestry Systems

Technically, it is relatively easy to design ecologically sound farming systems in which production is sustained over time by using tree crops. However, for socio-economic reasons simultaneous production of annual food crops such as upland rice, groundnuts or maize might be necessary. It is now widely accepted that growing annuals in monoculture systems is less desirable since sole crops provide sparse vegetable cover. For ecological reasons it seems therefore beneficial to use agroforestry systems that combine annual with perennial crops.

Figure 1 gives an example of such an agroforestry system designed for Palawan, Philippines, which has a bi-modal rainfall pattern. The most suitable tree crop there is a deep rooting species because it can draw up nutrients from the subsoil. Leguminous trees can also fix nitrogen. Some of this nitrogen may gradually become available to the annual crops through decomposition of leaf litter and/or roots. Between the twin rows of the tree crop, annual crops such as a mixed crop of maize and upland rice can be planted. Soon after the harvest of the maize, cassava is planted which, in turn, is relay-interplanted with first a grain legume and later a pasture legume such as a *Desmodium* species. After harvesting the cassava, cattle can graze the pasture legume, which has established itself by that time. The trees can now be browsed; they provide shade for the cattle, protect the land from air and water erosion, ameliorate stream flows and in addition, produce fuel, fence posts and timber. The trees can be harvested after 5 to 10 years. Soil fertility will then be restored and annual crops can be grown again.

Other trees which may be suitable for this type of ley systems are *Parkia speciosa* and *Parkia javanica* (African

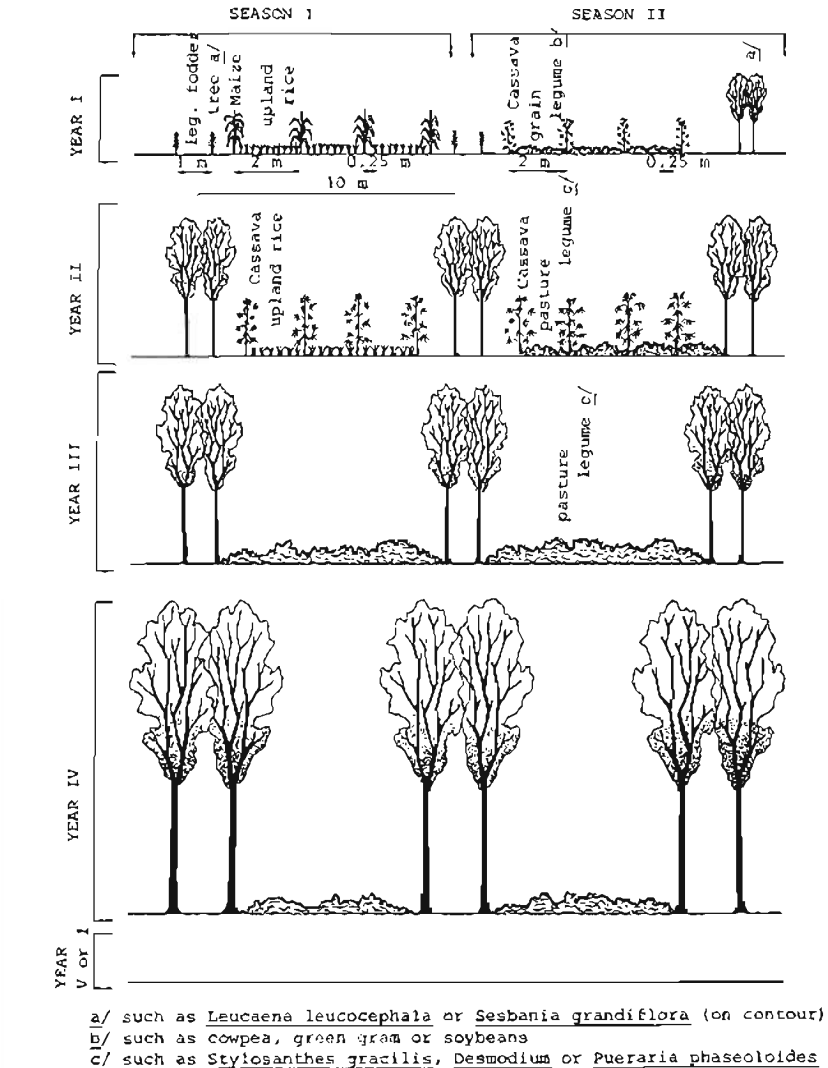


Figure 1. Example of an agroforestry system, designed for Palawan, Philippines with two rain seasons, combining annual with perennial crops.

locust bean), *Acacia* spp., *Dalbergia cochinchensis*, *Albizia* spp. and some *Eucalyptus* species.

b. Semi-arid Areas and Multiple Cropping

The problem of shortness of (moisture) season in the semi-arid tropics can be overcome by irrigation. However, in view of high irrigation development costs and institutional deficiencies, rainfed farming will remain dominant for many years. In areas dependent on a single short rainy season, it is important to design systems that make maximum use of the limited period of favourable (moisture) conditions by planting at the right time (normally as early as possible), through mulching, zero tillage, and by using drought tolerant crops with growing periods that correspond with the moisture-availability-period.

To allow detailed design of cropping systems in sub-humid and semi-arid regions, the moisture season has to be adequately described. Cochemé (1966) gives an example of describing the „moisture balance“ and „availability of water periods“ of a semi-arid area in West Africa (Figure 2A). Curves

representing P and PET are plotted together with fragments of curves representing PET/2 and PET/10. The points of intersection with P define the boundaries of periods called „humid“ and „moist“.

When periods of „water availability“ are thus described, a detailed cropping calendar (Figure 2B) can be designed. When doing so the first point to consider is the length of the period available for land preparation. The slope of the rainfall curve, and the dependability of the rainfall are important variables. The main crop (maize in the example) should be planted as soon as possible. The „onset of the moist period“ is the most suitable time. Since the „moist + reserve period“ is relatively long, a late maturing variety can be used to exploit available moisture to a maximum.

To also fully exploit available light and nutrients a mixed cropping system can be used. The first crop grown in association with the maize could be an early maturing cowpea intercrop. As soon as the cowpeas are harvested, they are replaced by late maturing relay pigeon pea (Fig. 2B).

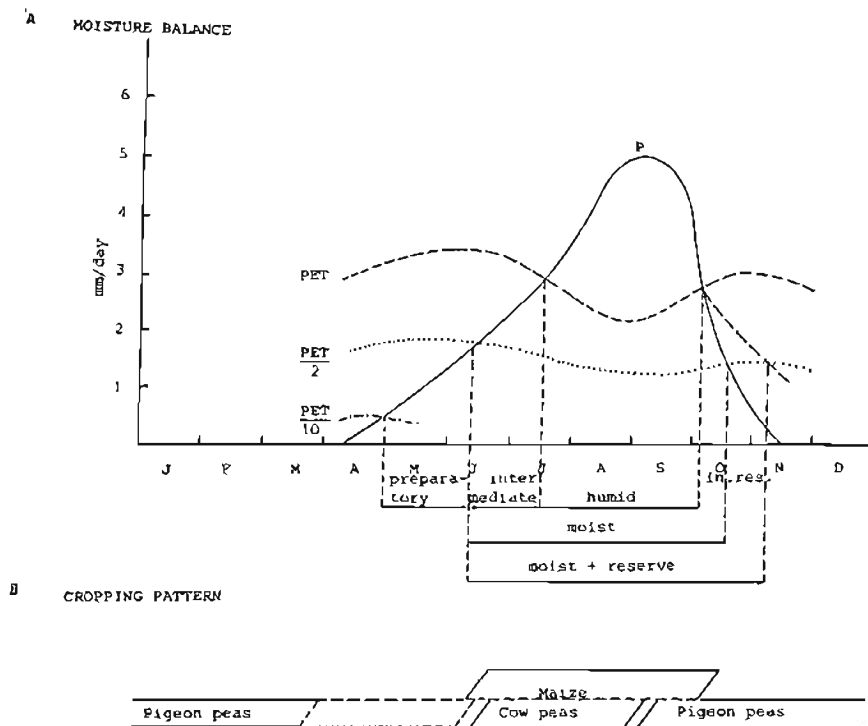


Figure 2. Example describing the moisture balance and availability of water periods of a semi-arid area in West Africa (A). When periods of water availability are thus described, a detailed cropping calendar can be designed (B).

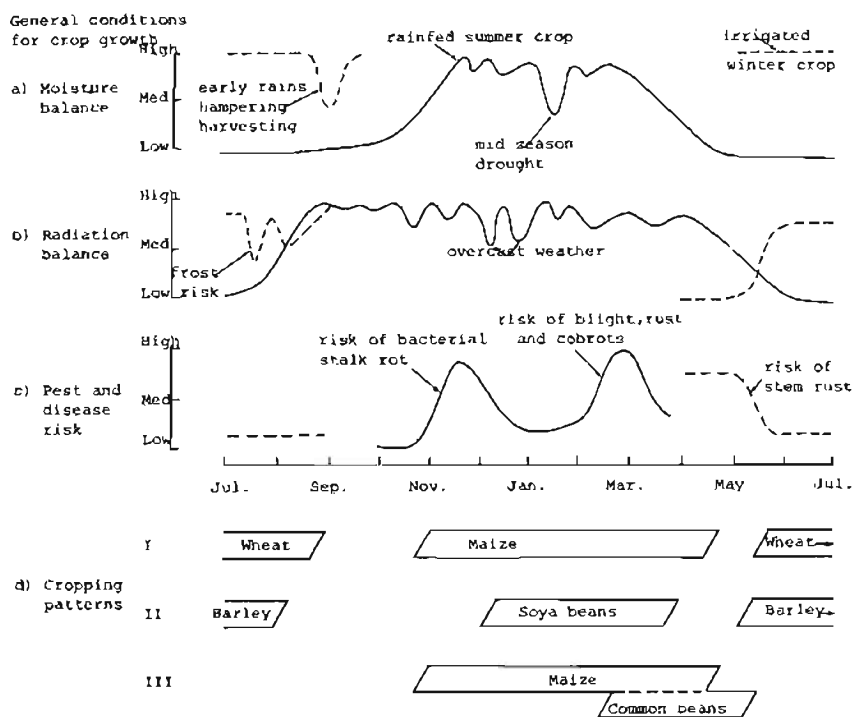


Figure 3. Example from sub-humid Zimbabwe describing continuous cultivation which can be achieved almost every year with irrigation.

The latter crop uses not only the tail-end of the moist period but can also use up all reserve moisture stored in the soil. If the rains are good and the soil has good moisture storage characteristics, the pigeon peas are able to grow well into the dry season and even up to the next rains. Continuous cultivation is then achieved in years with good rains.

c. Irrigated Cropping Systems

With irrigation, continuous cultivation can be achieved every year, or in 4 out of 5 years. This is illustrated with an example from sub-humid Zimbabwe (Figure 3). Zimbabwe is located in the subtropics and the thermal balance during „winter“ allows the cultivation of temperate crops such as wheat and potatoes. The climate imposes certain

limitations on planting dates, which can be described as „general conditions for plant growth“ (Fig. 3 a-c).

The moisture balance also poses the problem of mid-season droughts, which often occur during maize pollination. Droughts can then drastically reduce seed yields. Some aspects of the thermal balance are early morning frosts and hot periods which affect wheat pollination.

Pest and disease risk is closely related to climate. For example, maize can be attacked by stalk rot in the moist period at the beginning of the maize growing period, and the risk of stem rust for wheat is high during hot, humid days at the beginning of the wheat growing period

As shown, year-round cropping is possible in a sub-humid climate especially when irrigation is available. However, it can only be sustained if ample supplies of support energy, especially fertilizers, are available.

Some conclusions

When natural resources are carefully manipulated and fully exploited, most of the tropical areas can technically be continuously cropped, especially with the help of irrigation. Of late, population pressures in shifting cultivation type systems have often made sustainable cropping impossible as a result of environmental deterioration due to overcultivation. The main technical problems that block continuous cultivation include soil erosion and loss of soil fertility, timeliness of land preparation and shortage of water. Nevertheless, in some areas where all such problems are overcome (e.g. Zimbabwe), continuous cultivation has proven to be possible, but only after detailed analysis of the soil and climate and other natural conditions. This analysis forms the basis for establishing a more sound cropping pattern for continuous cultivation in a rational way. Finally, the cropping pattern and the symbiotic relationships among crop types should form the basis for continuous cultivation.

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