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FARMING SYSTEMS UNDER VARIOUS ECOLOGICAL CONDITIONS OF LATIN AMERICA, AND THE IMPROVEMENT OF TRADITIONAL FARMING WITH SPECIFIC PREFERENCE TO THE SMALL HOLDERS

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APPENDIX 14

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SUMMARY

In this document an analysis is made of the present situation of the productivity of some basic and export crops in Latin America comparing it with productivity under high levels of technology. It is demonstrated that in general, the small producer is efficient in his operations and that he could be even more efficient if he had the necessary economic resources and adequate technology for his multiple and mixed crops. This is followed by information on research carried out in several countries precisely on these cultivation sistems including the results obtained so far in CATIE, which seem to prove that greater yields in products and biomass are obtained under these systems, making better use of land, fertilizers and solar energy as well as labour. The attack of diseases and pest was not as severe and the invasion of weeds not as bad.

Finally, emphasis is placed on the promising prospects of this type of research together with basic research on the tropical ecosystem. The establishment of new programmes on these lines is suggested so that man in the tropics may understand his ecosystem and learn to manage it.

INTRODUCTION

Considered collectively, the gross income of Latin American countries depends between 50 and 55% on agriculture and nearly 70 to 75% of their foreign exchange income (excluding Venezuela) is obtained from the export of some agricultural products such as bananas, coffee, sugar cane, cacao, cotton and tobacco (8,20).

Latin American countries de not produce the amount of staple foods required to support their growing population, whose average growth rate between 1962 and 1970 was of 2.9%. In 1970, Central America imported the equivalent of 20 million US$ in the form of food or semi-processed grains (18). On the other hand, general agricultural production efficiency in the period 1961-63 to 1969-71 (6) reached a yearly average of 2.9%, a rate which is still below the yearly limit established by FAO for the World Indicative Plan for Agricultural Development during the 1970-80 decade.

STRUCTURE OF AGRICULTURAL PRODUCTION IN LATIN AMERICA

In general terms, agricultural production in Latin America is represented by: (a) export crops, and (b) staple food crops.

In Central America, 68% of total agricultural production in 1970 corresponds to export products and 32% to staple foods. Although there are no comparable recent data for South America, it might be said that in general the countries within the tropical area are similar to Central America. Production of food crops is proportionally higher than exportable tropical crops in Argentina, Uruguay, Paraguay, Chile, Bolivia and Peru.

AGRICULTURAL PRODUCTION SYSTEMS

Production systems are defined as the yearly sequence or special location of one or several crops and fallows in a given production unit and their interaction with the resources and technology used.

Several of the systems used in Latin America fall under this concept, both as regards yearly food crops as well as yearly and perennial exportable crops. In general terms, it may be said that they include the following:

1. **Single crop farming.** When only one crop a year is planted, the land remains fallow the rest of year in the case of yearly crops.

2. **Inter-cropping.** When two or more crops are planted simultaneously on the same land or are planted in varying degrees of overlapping.

3. **Multiple crops.** When one tract of land is used for single cropping and inter-cropping within a year one after the other, with or without fallowing.

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PRODUCTION IN RELATION WITH CROP GROUPS, AGRICULTURAL SYSTEMS AND TECHNOLOGY USED

Staple food crops

Table 1 (18) shows average yields per hectare during the years 1967-69, of several food and export crops in Central America. It also includes average experimental yields obtained in some areas with improved and advanced technology.

Present yields are low for all crops, if compared with the experimental yields reported in all the countries for these crops and some commercial exploitations in which more complete technology has been applied. This includes the use of fertilizers, pesticides and machinery, with which in some cases production has been increased from three to five times over present Central American averages. With adequate financial resources, good technical support services and good marketing systems, it is possible to increase production to these levels in medium and large production units.

Low food production in Latin America has been attributed in great measure to the use of agricultural systems of limited efficiency. Most of the staple foods of the area are supplied by small farmers who use traditional cultivation systems, which include single crop farming and more often inter-cropping and multiple crops. These production systems already existed in Pre-Columbian times and have probably been used for millenniums. It is known that the Mayas and the Incas since very remote times grew maize and beans together and this practice is still predominant among small farmers in Mexico, Central and South America. Among the small Central American farmers of the low tropical area, both under humid conditions as well as alternating rain regimes, inter-cropping and multiple cropping of maize with beans, manioc, sweet potato, sorghum, sesame, cucurbitaceous plants and vegetables are very common (4). In the high Andes of South America the number of crop combinations is even more varied, with a predominance of maize with beans, chick peas, potatoes (9), quinoa *(Chenopodium quinoa)*, lupin *(Lupinus mutabile)*, Oxalis *(Oxalis tuberosa)*, ulluco or melloco *(Ullucus ullucus)*, European vegetables and wheat or barley.

In North Eastern Brazil associations of maize, beans and arborescent cotton are predominant, while manioc, associated with maize and beans constitute the dominant crop in the Amazon basin and the Venezuelan and Colombian plains. Associations of maize and beans, vegetables and manioc are predominant in the mountainous areas of the state of Minas Gerais in Brazil.

Estimates made for several countries (17) show that beans produced in association with maize represent 50% of the total produced in El Salvador, 85% in Colombia, 58% in Mexico and 80% in Brazil. It could be stated without risk that over 60% of bean production in Central America is produced under inter-cropping and multiple crop systems with maize and that a greater proportion of maize production of the area is supplied through inter-cropping systems with other crops.

Production systems of small farmers normally include more than one crop of the same or different species, that are grown during the agricultural year as single crops, crop associations or rotations. As an integral part of their system some small animals should be included such as poultry, pigs and even a few cows.

Small farmers (with less than 5 hectares of land) operate 80% of Guatemala's farms, with 85% in El Salvador, 60% in Honduras, 43% in Nicaragua and 46% in Costa Rica (18). In Colombia*, 65% of productive units have less than 10 hectares. The situation in Ecuador, Peru and Bolivia appears to be similar or to have a great percentage of small owners in the Andean region.

It is estimated that in Colombia 70% of the food consumed in the country is supplied by small producers, a situation which is similar or of greater dependence in the Andean countries than in Colombia. In Central America 90% of food products consumed are produced in the area and over 75% is supplied by small producers (16).

A question that arises is why this mass of producers does not use available technology. There could be several answers to this, but the most valid appears to be that available technology is out of their reach because of its high cost. These farmers who have no resources of their own and to whom credit is not easily accesible, cannot follow the indications of extensionists, who make recommendations with available technology. The extensionists in turn, because they are not favourably received, leave this strata of producers without the assistance of their continued advice, as a result of which traditional production systems remain unimproved.

On the other hand, available technology has sometimes been developed outside of the area or following patterns for the use of resources typical of developed countries, such as the availability of large areas, use of machinery and large quantities of agro-chemicals. Wheat, rice and in a smaller scale, maize, are produced as single crops with high technology in the large or medium farms.

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* Information given personally by Mr. P. Spijkers, CIAT, Colombia.

Little research has been carried out in tropical countries to develop production systems adjusted to the ecologic conditions of the region and the social, economic and working conditions of small farmers. The characteristics of this group of producers are the high availability of labour (large families), lack of capital resources, small extensions of land, high incidence of radiant energy during the entire year and adequate season for planting. Little research has been done on traditional agricultural systems used in Latin America.

Table No. 1. Central America: Production Margins for Technologic Development in Selected Crops and Livestock, 1969, kilograms per hectare and per hundred head of cattle. (taken from SIECA) (18)

Product	Average Central American yield 1/	Modal Commercial yield with improved technology 2/	Experimental yield with advanced technology 3/
Export product			
Coffee	604	960	1,900
Cotton	2,093	2,570	3,800
Sugar cane	48,142	90,160	100,000
Products for external Consumption			
Maize	1,035	3,800	8,000
Sorghum	1,117	4,500	7,600
Beans	652	1,280	2,300
Rice	2,046	5,150	10,000
Livestock			
Meat 4/	2,500	3,400	5,000
Milk (per hundred head) 4/	13,000	16,000	75,000

Source: GRAFICA. production sheets utilization of agricultural products in Central America (unpublished)
SIECA, Agricultural Development Branch; compilation on the basis of technical publications of Central American countries.

1/ Weighted average of mean national yields of the five Central American countries in the 1967-69 period.
2/ Modal yields currently existing in commercial operations.
3/ Yields obtained experimentally in experimental stations in Central America, although some commercial operations have reported these yields.
4/ Meat and milk production per hundred head in the regional herd.

Table 2 (12) includes data on maize and bean yields, their harvest indexes and economic product in an inter-cropping trial of maize and beans and of each one as a single crop, carried out in Chapingo, Mexico, during three consecutive years, using a single fertilizer level for all treatments (80-40-0) and different population densities for each crop, including the density of the traditional system of the small farmers (20,000 plants of maize, 20,000 plants of beans per hectare). Harvest indexes show that inter-cropping of various seeding densities, including the traditional ones, produced yields in weight and money superior to those of the respective single crops, whose optimum densities were in line with technical recommendations. Mancini and Castillo (14) in Colombia, also reported similar results in an inter-cropping trial with beans and maize, obtaining a bean production between 859 to 3,937 kg/ha and maize production between 4,522 to 8,133 kg/ha.

Table 2. Maize and bean yields (kg/ha), harvest indexes and economic product (Mexican Pesos) of an inter-cropping trial with maize and beans in CIAMEC-Chapingo, Mexico, 1969. Taken and adapted from Lépiz (12).

Treatment Code	Treatment	Yields kg/ha Maize	beans	Harvest index %	Yields Mex. Pesos/ha
6	30*M + 90*FG	1,867	1,266	163	2,365
5	30 M + 60 FG	1,901	1,122	154	2,098
3	20 M + 90 FG	1,405	1,296	146	1,970
2	20 M + 60 FG	1,471	1,196	142	1,865
12	30 M + 90 FM	2,413	629	152	1,740
4	30 M + 20 FG	2,109	764	138	1,704
11	20 M + 20 FG(t)	1,676	947	133	1,550
9	20 M + 90 FM	1,851	709	136	1,402
11	30 M + 60 FM	1,899	563	125	1,152
8	10 M + 60 FM	1,862	552	123	1,139
14	110 FG(t)	--	1,459	100 FG(t)	1,125
13	40 M (t)	2,454	--	100 M (t)	927
10	30 M + 20 FM	2,045	303	109	913
7	10 M + 20 FM	1,687	353	99	683
15	160 FM (t)	--	1,169	100 FM (t)	661

FG = Black beans 150

FM = Canary Beans 107

M = Maize H-28

* = Numbers indicate sowing density in thousands.

(t) = Check plots

The Colombian Agricultural Institute (10) has made technical recommendations regarding some species, varieties, seasons, sequences and technology for various inter-cropping and multiple crop systems practiced in the high zones of the Colombian Andes.

Taking traditional bean and maize crops as a basis, (Hildebrand and French (9), some multiple crop systems have been tried with agricultural and economic success in low areas in El Salvador. Maize is used as the central crop and crops such as beans, radishes, tomatoes, cucumbers or vegetables are planted between the line of maize in varying degrees of overlapping, obtaining several harvests a year with the help of irrigation and high technology. The authors give a detailed description of management methodologies and sowing seasons for the different crops.

In 1973, the CATIE (Tropical Agriculture Research and Training Centre) in Turrialba, Costa Rica, started an investigation through field trials to try production systems which took into account small farmers' resources. Following is a summary of the results submitted to the XXI Yearly Meeting of the PCCMCA (5) held from 7 to 11 April this year

"In a central experiment of approximately five hectares, 54 of these systems were tried with four variations in each case laid out in a pseudo-aleatory block design with two repetitions. In all the systems, sowing density per crop was maintained uniform, independently of the inter-cropping established, while sowing modes and distances were changed according to the degree of technology employed.

In the systems presented for this work (Figure 1) a gradient in soil use is observed which is determined by the type of crop and its spatial and chronologic distribution.

The results of the trial were evaluated taking into account agronomic and socio-economic aspects.

In general, the number of plants established was low due to the soil's physical conditions (compaction and puddling), competition between crops and sanitary aspects.

FIGURE 1

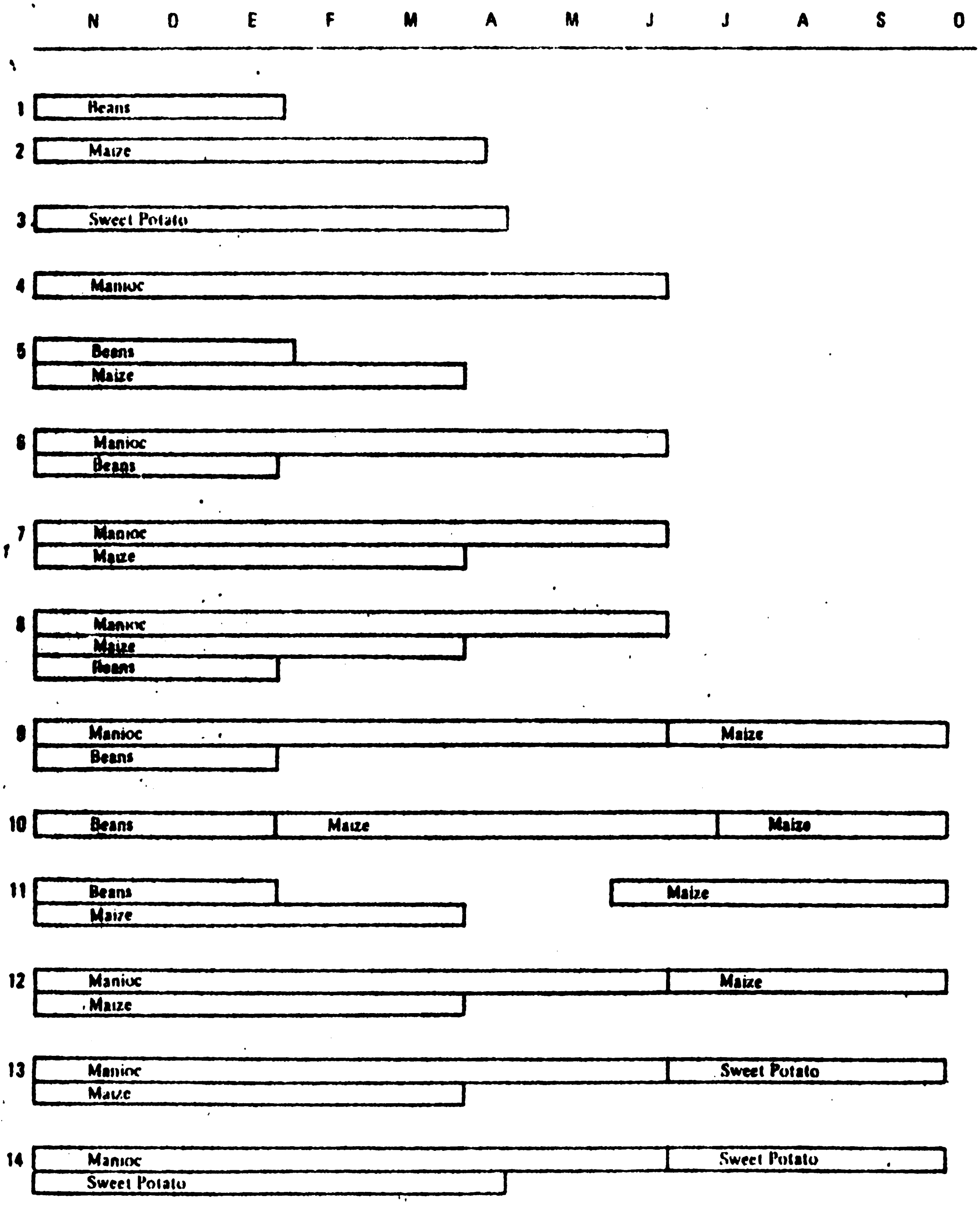
N D E F M A M J J A S O
1 Beans
2 Maize
3 Sweet Potato
4 Manioc
5 Beans
Maize
6 Manioc
Beans
7 Manioc
Maize
8 Manioc
Maize
Beans
9 Manioc
Maize
Beans
10 Beans
Maize
Maize
11 Beans
Maize
Maize
12 Manioc
Maize
Maize
13 Manioc
Sweet Potato
Maize
14 Manioc
Sweet Potato
Sweet Potato

Table 3. Food production, biomass, land equivalent ratios and length of time in the sod, of 25 agricultural systems with two levels of technology.

Code	System: Crops[1] & distribution order[2] 1 2 3	System: Level of Technology[3]	Production (MT/Ha) per crop, according to distribution order: 1	2	3	Length of time in the field (days)[4]	LER[5] (%) with reference to: Monoculture in B	Monoculture in A	Biomass: Absolute Production MT/Ha: 1	2	3	Biomass: Relative Production: 1	2	3	LER
01	F	B	0.35			04	100		1.32			100			
02	F	A	1.08			84		100	1.40			100			
03	$M_1/M_2/M_3$	B	0.72/	0.49/	0.20	160	100		3.80	4.92	3.07	100	100	100	
04	$M_1/M_2/M_3$	A	2.51/	1.95/	1.36	166		100	3.26	13.26	8.55	100	100	100	
05	C_1/C_2	B	15.82/	0.51		171	100		9.00	2.40		100	100		
06	C_1/C_2	A	12.16/	0.60		171		100	10.87	5.70		100	100		
07	Y	B	7.86			240	100		10.82			100			
08	Y	A	14.71			240		100	16.40			100			
09	F+M_1	A	0.60+	2.92		166	577	172	0.87	10.89		62	132		194
10	F+Y	B	0.17+	12.52		240	208	101	0.70	13.70		53	127		180
11	F+Y	A	1.04+	19.13		240	540	226	1.59	13.56		120	32		202
12	M_1+Y	B	1.23+	8.41		240	278	106	1.85	8.05		46	74		122
13	M_1+Y	A	3.05+	8.30		240	530	178	11.64	11.59		141	70		211
14	F+M_1+Y	B	0.06+	0.69+	8.41	240	220	91	0.31	5.91	8.91	23	152	82	257
15	F+M_1+Y	A	0.37+	1.61+	12.18	240	485	181	1.12	11.97	15.88	80	145	96	321
16	F+Y −M_3	B	0.15+	13.94-	0.51	407	402	141	0.59	12.95	6.61	45	119	170	334
17	F+Y -M_3	A	1.03+	18.59-	0.93	407	863	289	1.11	14.55	5.85	79	88	68	235
18	F-M_2-M_3	A	1.36+	1.57-	1.57	417	1180	322	1.57	7.87	10.07	112	59	117	200
19	F+M_1-M_3	A	0.63+	2.35-	1.49	333	1030	262	0.72	7.89	4.01	51	95	56	203
20	M_1+Y-M_3	B	0.20+	5.70-	0.33	407	219	71	0.46	5.03	4.44	12	46	115	173
21	M_1+Y-M_3	A	2.63+	9.79-	0.31	407	779	232	8.05	11.17	7.28	97	68	85	250
22	M_1+Y-C_2	B	1.85+	10.68-	2.15	412	815	463	1.37	8.27	9.93	35	76	413	524
23	M_1+Y-C_2	A	3.00+	7.32-	0.35	412	585	226	9.71	12.77	8.94	117	77	154	348
24	C_1+Y-C_2	B	6.90+	4.99-	1.86	412	573	365	6.20	8.21	3.90	60	76	162	306
25	C_1+Y-C_2	A	1.44+	15.84-	1.21	412	440	298	8.34	13,22	9.14	76	80	160	316

1/ Symbols. F = Beans; M = maize; C = Sweet Potato; Y = Cassava

2/ Symbols M_1, M_2, M_3, C_1 and C_2 = maize or sweet potato in the first, second or third period, according to the corresponding index. The signs = (/) separation of the monoculture; (+): associated crops; and (-) = rotating crops.

3/ Symbol A = high level technology; B = low level technology

4/ Excluding fallow period.

5/ LER = Land equivalent ratio

Yields and biomass production, both in the case of single crops as well as multiple crops, were greater with higher technology. At the same time, within each technology level, multiple crops yield more than single crops both as regards total useful product and biomass (Table 3). In fact, land equivalent ratio indexes (LER), with reference to high and low technology levels, show that multicrop systems are agriculturally efficient, the most important being the F+Y-M, F-M-M, F+M-M and M+Y-C systems. The results of some forms of multicrops with low technology were similar in efficiency in comparison with the respective high technology single crops.

Within high technology, fertilizer use was one of the most important factors determining the yields obtained. Apparently multicrop systems make a more efficient use of fertilizers considering that the quantities applied are lower to the sum of individual requirements of the component species of the system. In a decreasing order, the efficiency of fertilizing elements as producers of useful product was the following: K >N>S>P.

Airborne diseases were more evident and their consequences more serious in single crops than in multiple crops. In the latter, some species act as natural barriers hindering the free dissemination of the inoculant. On the contrary, some multicrops, because of the creation of micro-environments with high relative humidity and shade, favour the development of other types of diseases. All crops, between June and July, were attacked by *Phyllophaga* sp. which affected yields negatively.

The number of weeds was less in multicrop systems with low technology than in single crop systems with high technology.

The biomass (kg/ha) produced by Kcal of photosinthetically active solar energy received during the duration of the system, was 36% higher in bicultural systems and 40% higher in tricultural systems as compared with single crop systems.

Although the energetic contribution in most of the systems is fundamentally supplied by carbohydrates and fats, multicrop systems appear to be more productive from the nutritional viewpoint.

Single and double crop systems with similar components in the vegetative cycle, such as beans and maize, present a more uniform distribution in the use of labour than certain multicrop systems with crops whose vegetative cycles are very different, such as those including manioc.

In three crop systems, the total amount of labour required for weeding was greater than in single crops, due to the difficulty involved in moving within an area which is almost entirely covered by vegetation.

Multicrop systems, among which the most important are F+Y, F+M+Y and F+Y-M, provide the greatest returns per day, per cycle and per year, make the best use of labour and contribute nutrients that are better suited to balance a diet.

Preliminary results obtained in this work show the following:

1. Systems including multiple crops, inter-cropping or mixed crops in general were more efficient in food and biomass production than single crops even if high technology was used in the latter.

2. It is possible to produce technology for the purpose of improving traditional systems of the small farmers, making it possible for them to make better use of land and labour resources, and at the same time provide them with greater income to improve their level of living."

Narváez (15), in Colombia, studying the productivity of socio-economic factors intervening in maize production in association with chick peas and beans at the farmer level, found that none of the factors, land, seeds, fertilizers, pesticides, labour and other inputs, were used efficiently. Factors requiring capital appear to be underemployed and were the most costly in the operation, particularly pesticides. Labour exchange practices and payment in kind were efficient. The net income, including estimated cost of the land, was positive in the case of inter-cropping of maize with chick peas and beans; inter-cropping of maize and beans did not show profits nor losses but the result was negative in the case of maize and chick pea inter-cropping. As a conclusion, the author says that traditional producers are efficient but poor and that the shortage of capital restricts a more efficient use of available resources.

Export Crops

The main export crops, such as coffee, sugar cane, bananas and cacao are important as single crops. Production efficiency of these crops is higher than that of grain crops, due to the fact that they are in the hands of large or medium owners, who have easy access to financing sources to pay for available technology. On the other hand, as these products are a source of foreign exchange for the countries, the countries themselves or the private enterprises have spent more resources on research, which has resulted in better technical recommendations, greater financial support and better processing and marketing mechanisms for their products.

THE EFFICIENCY OF AGRICULTURAL SYSTEMS IN RELATION WITH ECOLOGY IN THE TROPICS

From the ecologic viewpoint, yearly crops are less adequate and suitable than perennial crops for a sustained production in the low tropics, both because of their high demand of nutrients due to their rapid growth cycle and low recycling of nutrients, and also because they favour the presence of a greater number of diseases and pests. In addition, they cause greater disturbances among the soil's flora and fauna and its chemical and physical characteristics. Single crops are more vulnerable and less suitable for sustained production than mixed crop, inter-cropping or multiple crop systems with rotations.

A rapid loss of fertility of the soils when annual crops are used may be the main cause for migratory agriculture. Continued single crops on the same area of land allow pests and diseases to last and multiply rapidly and excessively. Although there are no concrete data, it is suspected that the effect of pests and diseases are not as bad in the case of multiple crops or inter-cropping of different species.

According to Bradfield (2, 3) inter-cropping and multiple crop systems make it possible to keep soil covered with leaves during most of the year using the continuous availability of sunlight and high temperatures in the tropics more efficiently, while at the same time producing a greater quantity of biomass and useful food product.

The success of the best tropical agricultural systems with yearly crops will depend on: (a) the possibility of maintaining optimum fertility levels and good physical soil conditions economically; (b) economic control of pests and diseases, either through chemical or preferably biological or variety resistant means; and (c) good research and technical assistance services to the farmer.

Perennial crops produced in the form of single crops are more efficient than annual crops in the use of the tropical ecosystem, although they do not equal the efficiency of the tropical forest, unless the declination of soil fertility and the incidence of pests and diseases are corrected. However, cacao and coffee crops grown under shade in many zones of tropical America have survived dozens of years, with medium yields, without using fertilizers and scanty disease and pest control (19). In this case, the cycling of nutrients is implanted in the soil of the established perennial plantation, produced by the residues of leaves and other tree parts. In studies on mineralization of the organic matter carried out in cacao plantations in Turrialba, Martínez (13) working with nitrogen and Granados (7) with sulphur, showed that cacao produced from 5 to 9 tons of biomass a year and that there was a high recycling of said nutrients. In general, the difference between the quantity of nutrients that return to the soil and that extracted in the harvest varies according to the natural richness of the soil and the volume of the harvest. However, nutrients recycle in sufficient quantities to maintain slow growth and moderate production of the crops.

On the other hand, perennial crops cover the soil with foliage, producing a closer imitation of the function of the tropical forest. There is a more efficient interception of light for photosynthesis, the soil is protected from the erosive action of the direct downpour of rain and its runoff is slower while at the same time maintenance of the soil's humidity is improved. Shading of the soil also makes it possible to maintain more uniform temperatures, a more stable microbial life and an inferior drying and sterilizing effect than under direct sun, as in the case of yearly crops which keep the soil fully exposed during varying periods of time.

Improved varieties of yearly crops, such as the so called "miracle grains", need large quantities of fertilizers and pesticides to produce their high yields and show all their potentialities. But the use of large quantities of pesticides, especially without sufficient experimental support, may create more problems than solutions. Contrary to temperate zones, tropical conditions make it possible for pests and diseases to rapidly. The speed with which new crop varieties resistant to pest and diseases can be obtained, especially of perennial plants, is much lower than the speed with which pathogenic variations are produced. A great deal of basic and applied research on the tropical ecosystem is required in order to supply the means to "develop a tropical agro-ecosystem for sustained production". It is suggested that it is first necessary to educate the tropical inhabitant to understand the surrounding ecosystem so that he may manage it. Emphasis is placed on the need to establish new research programmes exclusively devoted to study the development of agricultural systems adapted to tropical ecologic conditions.

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