

ADVANTAGES, DISADVANTAGES AND DESIRABLE CHARACTERISTICS
OF SHADE TREES FOR COFFEE, CACAO AND TEA

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INTRODUCTION

Agricultural systems*, which combine trees with annual crops, perennial crops and/or animal husbandry, have been empirically developed by Costa Rican farmers for a wide range of environmental conditions (9). In order to take advantage of this traditional knowledge CATIE has initiated cooperative studies, of the existing Costa Rican agro-forestry systems, with the United Nations University (UNU) and the German Agency for Technical Cooperation (GTZ). The intention is to improve these systems in situ and to promote knowledge of them in suitable areas where they are not presently known.

The initial phase of these projects involves the delimitation of research areas where the majority of the influences on the farming systems, e.g. socio-economic, can be studied as well as the individual agro-forestry combinations per se. In cooperation with the farm owners, dual purpose research-demonstration plots are then established on representative farms, while more wide spread surveys are used to gather background data. Annual measurements of the heights and diameters of the commercial tree species in these plots are used to estimate timber volume increments (per hectare) and hence the economic potential of these trees. In a few of the better managed plots data on crop yields, organic material and nutrient cycling (primarily nitrogen), and on the environmental consequences of including trees, e.g. influence upon erosion, are being recorded.

Owing to the heterogeneity of the conditions in most small farm plantations

* In this paper the word "system" is used when referring to all the components of a farm; the words "combination" or "association" are used when referring to a specific group of species, e.g. Cordia alliodora (timber tree) - Erythrina poeppigiana (shade tree) - Coffea arabica (perennial crop).

meaningful statistical studies can not be carried out. For example, the typical small farmer coffee plantation will include coffee bushes of different varieties and ages, planted at variable spacings. As a consequence results from such plots can not be simply compared with other trials nor can the results be readily extrapolated. Hence, the second phase of these projects will require the establishment of carefully managed examples of the traditional combinations where all variables are adequately controlled. Only then can recommendations on, for example optimal tree densities, be deduced.

Detailed studies of all the existing traditional agro-forestry systems are not feasible. A selection of the most promising combinations, in terms of their productive potential and/or the number of rural people who could benefit from their promotion, has to be made. In the UNU project, studies in the combinations Laurel poró - coffee (Cordia alliodora - E. poeppigiana - Coffea arabica) (6) and to a lesser degree Laurel - pasture, and Laurel - cacao (Theobroma cacao) (5) have been emphasized. Data on crop yields, as well as tree growth, from the association of Laurel with sugar cane (Saccharum officinarum) has also been collected for comparison.* Since these measurements are being taken in existing developed plantations the conclusions are limited by being applicable only to the present spatial structure of the tree-crop combination. In these cases information on the interactions during the establishment phase of the crops and the trees is almost non-existent.

The use of shade trees for tropical perennial crops

The recent tendency of agricultural extension services is to recommend the culture of coffee and cacao without shade trees in order to gain the highest possible yields. These recommendations are based on a huge amount of experimental work, carried out in many countries, which has shown that intensive management of self-shading monocultures can give 2 and 3 fold yield increases over traditional mixed systems on the most appropriate sites. (52, 54). However, there is little information on the relative long term profitability of the unshaded vs the shaded crop.

The inclusion of shade trees is less controversial in the case of small farmers since they are frequently cultivating a sub-optimal site for their crop

* Heer, J.W. "CATIE- UNU Convenio "Annual Report 1980 Turrialba, Costa Rica. CATIE 1981. 17 p. 3 Anexos"

(see Nair (39), Purseglove (42), Wrigley (54) for descriptions of the optimal conditions for coffee, cacao, tea, etc.). Purseglove (42, p. 587) summarizes some of the most important considerations in such a situation when he states "shade reduces photosynthesis, transpiration, metabolism and growth and therefore, the demand on soil nutrients and so enables a crop to be obtained on soils of lower fertility." Shade is invariably recommended for the establishment of cacao and it should be gradually removed on optimal sites as the cacao becomes self-shading. However, in cases where intensive management, in particular the regular application of fertilizers, can not be guaranteed some shade trees should be retained (24). Wrigley (54, p. 84) goes further by suggesting that "Conversely in areas of high intensity with no shade the tree will have to take up minerals at the maximum light to balance the accumulating products of photosynthesis which are otherwise toxic". Some of the many reported advantages and disadvantages of shade trees are listed in the appendices but it appears that the fundamental question, when planning the renovation or establishment of coffee and cacao plantations, is whether the owner has the sites, education and resources to maintain these crops without shade. In the case of export crops there is an additional risk, that the value of the product will temporarily fall to a level where the farmer can no longer afford the necessary inputs and therefore, will temporarily abandon his plantation. Cacao or coffee under shade will survive such a setback far better than monocultures of these crops (22, p. 88).

The higher risk inherent in unshaded cacao cultivation is also illustrated by Cunningham's (13) economic analysis of cacao production in Ghana. "The extra expenditure and work associated with clear-felling and growing unshaded cacao with large amounts of fertilizers would probably be justified only when yields of 3 000 lb. dry cacao/acre (3360 kg/ha) and over are obtained" (See also Vernon, 51).

It should also be noted that the conclusion from the majority of the shade fertilizer experiments on cacao has been that any shade greatly reduces the response to fertilizer applications (e.g. 12, 37) and in such conditions they are rarely economically justifiable. A general impression, after reviewing some of the publications dealing with cacao and coffee, is that part of the world-wide research effort devoted to these crops should be reorientated, away from the achievement of maximum yields, towards the study of sustained yield systems for farmers of few resources cultivating marginal agricultural land.

Some of the consequences of including shade trees with perennial crops can be either an advantage or a disadvantage, e.g., the influence upon the water balance of the understory crop. Whether the interaction is detrimental or beneficial will largely depend upon the characteristics of the species and of the particular farming area (climate, soils, etc.). Shade trees may be recommended:

- "A") As a tool for the management of the environmental conditions in the associated crop plantation, e.g. E. poeppigiana over coffee.
- "B") As a means of diversifying crop production (including timber) from a given area, e.g. C. alliodora over coffee.
- "C") In some cases the shade tree fulfills both management (A) and production (B) functions, e.g. Leucaena leucocephala over coffee. Based on the interactions suggested in the two lists "Advantages" and "Disadvantages" the shade tree characteristics given in Appendix 3 are usually considered desirable, though which are deemed most important will depend upon the objective ('A', 'B' or 'C'). The first question is whether the shade species is indeed adapted to the zone. Finally, the acid test of the suitability of any shade tree is the long term financial yield of the combination versus the perennial crop monoculture. The attached lists are only guidelines to the choice of species for testing.

Lists of potential species are given by:

Cook (various countries, 11); Greenwood and Posnette (Gold Coast, 20); Gutiérrez and Soto (Costa Rica, 21); Haarer (various countries, 22); Holdridge (Costa Rica and Mexico, 26); Jiménez (Central and South America, 29 + 30); Letousey (Camerouns, 32); McClelland (Kenya, 33); MacMillan (various countries, 35); Murray (Trinidad, 36); Poncin (Belgian Congo = Zaire, 41); Thomas (Uganda, 49); and Urquhart (various countries, 50); Wrigley (various countries, 54).

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(see paper and subsequent transcribed discussion)
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POSSIBLE ADVANTAGES OF INCLUDING SHADE TREES
WITH PERENNIAL CROPS*

I. Consequences which facilitate crop management.

1. Prevention of overbearing (and subsequent die back) results in less variable annual yields which, over a long term, permits a more efficient utilization of labour and machinery during harvesting and processing (28).
2. Suppression of weed growth (7, 8, 28, 47, 51).
3. Product diversification, e.g. fruits, timber. Merchantable trees represent "standing capital" and hence are an insurance against crop failure (38).
4. Control of crop phenology, e.g. fruit maturation, by manipulating the environmental conditions through the careful timing of shade tree pruning or the use of an appropriate deciduous tree species (1, 15, 20, 27).

II. Beneficial influences on the hydrological cycle.

5. Reduction of evapotranspiration of the shaded crop. (16, 34, 38, 47).
6. Removal of excess soil moisture by transpiration of a heavy shade tree cover (15), e.g. in north-east Indian tea gardens (52)
7. Increased moisture input through horizontal interception of mist or clouds, e.g. Grevillea robusta over tea in Tanzania (Fordham, 16 cited by Willey, 52)

III. Protection of the crop from pathogens, insects and adverse climatic conditions.

8. Extension of the productive life of the crop (21, 42).
9. Reduction of air, soil and leaf temperature extremes, and in some cases improvements of the microclimate for the crop, e.g. higher humidity (4, 23, 24, 38, 47)
10. Reduction of damage caused by hail and heavy rain
11. Reduction of some diseases, pests and parasitic plant infestations, e.g. the cacao capsids Distantiella theobroma and Sahlbergella singularis (1, 40, 41, 48, 49).

* Principle sources: Budowski (1), Purseglove (42), Willey (52),
Wrigley (5)

12. Reduction of wind velocities in the crop strata (44)

IV. Improvement of soil fertility and/or soil protection

13. The growth (and possible die back) of the shade tree root system can improve soil drainage and aeration, e.g. by breaking up a "hard pan".

14. The provision of a soil mulch (which helps retain soil moisture during the dry season) and an increase in the soil organic material from natural leaf fall and pruning residues (1)

15. Reduction of erosion on slopes (11, 45)

16. Reduction of the decomposition rate of soil organic material (because of reduced soil temperatures)

17. Recycling of nutrients of which are not accessible to the crop. (2, 22)

18. Nitrogen fixation by shade trees root nodules (11, 24)

19. The management of unshaded perennial crop plantations involves greater use of agricultural chemicals, especially herbicides. These chemicals may have inhibiting effects upon beneficial soil organisms, e.g. organic material decomposers and free living nitrogen fixers (17). Moreover, the increased soil organic material content, created by the presence of shade trees, can promote the activity of beneficial soil organisms.

POSSIBLE DISADVANTAGES OF INCLUDING SHADE
TREES WITH PERENNIAL CROPS

I. Consequences which hinder crop management.

1. Natural fall of branches and trees, or the harvest of mature trees, will damage the understory crop. (5)
2. Sudden defoliation of the shade trees, by insects or disease, can cause severe shock to a shade adapted crop and consequent die back (Hence a mixed shade is preferable to 1 species). (15)
3. Additional manual labour, is necessary for combinations where the trees are regularly pruned.
4. Mechanization of the underlying crop is hampered
5. Establishment of erosion control structures is hampered, e.g. terracing.
6. New crop varieties are invariably bred for monocultural conditions and may not be suitable under shade (23)

II. Detrimental influences on the hydrological cycle.

7. Shade tree root competition for moisture during the dry season and oxygen during the wet season (1, 18, 31, 51)
8. The interception of precipitation by the shade tree foliage, and the subsequent reevaporation, reduces available moisture for the crop (24)

III. Promotion of adverse influences such as pathogens, insects and detrimental environmental conditions

9. Reduced air movement and increased humidity may favour fungal diseases (11, 14)
10. Insect attack may be greater when the crop is shaded.
11. Alleleopathic effects, e.g. the combination of Noga (Juglans spp.) with coffee is potentially hazardous (43)
12. Shade trees can act as alternative hosts for pests and diseases, e.g. Albizzia falcata is a host for the coffee shoot-hole borer (Xyleborus spp) in Africa (1, 7)
13. Heavy shading can reduce the quality of a crop, e.g. tea (11, 25, 34)
14. In addition to reducing the quantity of available light shade trees reduce the quality of transmitted radiation since there is a preferential absorption of photosynthetically useful radiation (3, 38)

IV. Reduction in soil fertility (with respect to the associated crop) and increased erosion.

15. Shade tree root competition for nutrients (19, 51)

16. Stemflow, and the drip of rain drops which coalesce on shade leaves, can adversely redistribute rainfall into a form which will increase erosion, crop damage, and reduce moisture absorption by the soil (6, 35, 46)

17. Harvesting of fruit and/or wood from the shade tree constitutes an additional drain of nutrients from the site.



DESIRABLE CHARACTERISTICS FOR PERENNIAL CROP SHADETREES*

1. Compatibility with the crop, which means minimal competition for water, nutrients and growing space, e.g. does not produce suckers; the crown branches above the crops; deep rooting minimum overlapping of understory and overstory spp. root zones.
2. Strong rooting systems (not susceptible to wind throw). Note that shade trees are more exposed to adverse climatic conditions than are trees in a forest or a plantation and should be capable of adaptation to open grown conditions.
3. Rooting ability of stakes to permit rapid shade establishment by vegetative propagation
4. Ability to extract soil nutrients which are not trapped by the crop**
5. Ability to fix nitrogen
6. A light crown that provides a regular mottled shade pattern rather than uniform shadow of photosynthetically poor quality light.
7. In the case of objective B (timber producing species)
A small diameter light crown to: a- reduce the wind resistance of the foliage and hence the risk of wind throw, b- permit relatively high shade tree densities without reducing light levels below critical values for the crop and , c- minimize crop damage when individual trees (sustained timber yield system) are harvested
8. Non-brittle branches and stem
9. Thornless stem and branches to facilitate management
10. Rapid apical growth (Obj. "B"; timber species only)
11. Self-pruning and the ability to form a straight unforked stem in open grown conditions (Obj. "B" timber species only)
12. Tolerance of repeated heavy pruning or pollarding (Obj. "A" only)
13. High biomass productivity of material that is recycled, through leaf-fall and/or pruning. Readily decomposed leaves and woody material
14. If deciduous, rapid flushing of new leaves to regenerate the shade cover
15. Absence of major disease or insect problems which could lead to sudden defoliation
16. Small leaves to minimize rain drop coalescence and subsequent drip damage
17. No allelopathic properties
18. Smooth bark that does not harbor epiphytes
19. Valuable wood, fruit or other product, e.g. rubber from Hevea spp.

20. Not an alternative host for insects and pathogens which are major enemies of the crop
21. Shade tree species should not have the capacity to become a weed e.g. Ricinus communis and Leucaena leucocephala (certain areas)

* See also Haarer (22), Macmillan (35), Thomas (49), Urquhart (50) and Wright (53).

** This is a contentious point since many authors describe trees as nutrient pumps bringing up elements from soil levels below the crop roots. However, Budowski gives as an advantageous characteristic "superficial" long horizontal roots" since few nutrients then escape the combined crop-tree root system (10). In fact with the exception of sandy soils there is little evidence in the humid tropics to show that crop and tree root systems occupy different levels. In areas of high rainfall most feeding roots of all plants are near the soil surface.