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Combination of cacao with other plantation crops: an agroforestry system in Southeast Bahia, Brazil

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Abstract. Brazil accounts for about 20% of the world production of cocoa, and about 95% of cocoa produced in Brazil is from the southeastern part of Bahia State. Traditionally, cacao is grown in monoculture (though under the shade of various other species). But various crop combinations involving cacao have recently been undertaken by the farmers with encouragement from Brazilian government.

As a part of the crop diversification programme in the traditional cacao growing areas and their surroundings, extensive areas are being planted to other plantation crops, mainly clove and rubber and, to some extent, coconut too. Crop combinations have been adopted in some of these new plantings and cacao is an important component of most of such combinations. Whereas several other crops are combined with clove trees, cacao is usually the only species grown with mature rubber trees. Young rubber trees are, however, interplanted with a number of other species. Productive coconut areas are found mostly in sandy soils along the coast so that there is little intercropping. However, scattered farms are found where coconuts are underplanted with guarana, black pepper, cacao, cashew, etc. as done commonly in other parts of Northeast Brazil.

The paper presents some data on the performance of some of the combinations involving cacao and other plantation crops based on field survey, and discusses the potentials and constraints of extending the system to more areas in the region.

Introduction

Bahia State, situated on the southeastern part of the Northeast Region of Brazil, has an area of about 570 000 sq.km. and a population of 10.28 million (1980). The major economic activity in the State is cacao production, which extends over 650,000 ha and involves about 2 million inhabitants in Southeast Bahia. The total annual production is 350,000 tonnes of dry cocoa, which contributes an estimated US$ 700 million annually to the national economy. Brazil accounts for nearly 20% of the world production of cocoa, and about

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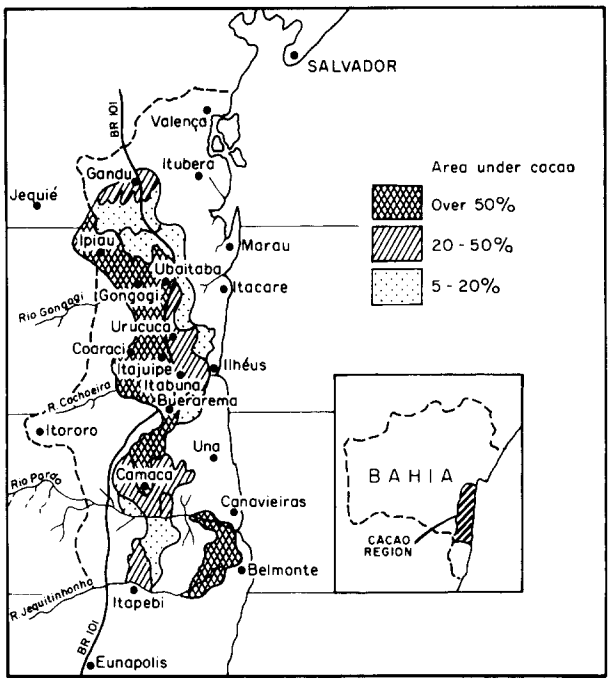
95% cacao produced in Brazil is from Southeast Bahia. Cacao crop is now being extended to other parts of Brazil also, especially Amazonia (see Figure 1).

Traditionally cultivation of cacao presents a good example of the agroforestry approach. Being a shade tolerant plant, cacao is grown in association with other species, either in selectively cleared secondary forest, or, more commonly, along with food crops that provide early shade until the shade trees planted along with cacao take over as the overstorey (shade) species. Thus, the eventual combination of cacao with shade/forest species provides an excellent illustration of compatibility and complementarity of various species with one another and at the same time the sustainability of such multistoreyed production systems. This paper describes some such crop combination systems existing in Southeast Bahia. Owing to the long tradition of cacao cultivation in the region, cacao is an important component in all cropping systems of the region, and it will inevitably, be suggested as a component of any potential (new) system.

2. General description of the area

The area, located between latitudes 13 °S and 18 °S, and longitudes 39 °W and 40 °W, has a humid tropical climate. Total annual rainfall ranges from 1200 mm to 2200 mm with a dry season (when evapotranspiration exceeds precipitation) not exceeding three months a year. The annual temperature varies from 23 °C to 24 °C, with a difference of 8–10 °C between the average maximum and minimum temperatures. The soils of the main cacao growing area are deep, reddish-brown to red, well-structured Alfisols (ferric luvisols and eutric nitosols). They are acidic but only moderately to strongly leached with a base saturation of over 50%, well-structured and permeable, and fairly fertile. Although they, particularly nitosols, possess good aggregation, there is a fairly high erosion hazard owing to rainfall aggressivity and moderate slopes. However, the major soil type of the area where other plantation crops such as rubber and clove are planted are leached and weathered Oxisols. Cacao is also planted as a mixed crop in these areas.

In most parts of the region, cacao is grown in monoculture (but under the shade of various timber species). However, the year-round production potential offered by the favourable climatic conditions of the region has encouraged the local farmers and the Brazilian Government to adopt crop diversification in order to counterbalance the socioeconomic and ecological risks of cacao monocropping. The additional crops chosen to expand regional agriculture over the past 20–30 years include rubber, oil palm, coconut, piacava or Bahia piassava palm (*Attalea funifera*), black pepper (*Piper nigrum*), clove (*Syzigium aromaticum*), and more recently, coffee and guarana (*Paullinia cupana*). In some places, small areas have also been planted with papaya (*Carica papaya*), vanilla (*Vanilla planifolia*), cardamom (*Elettaria cardamomum*),



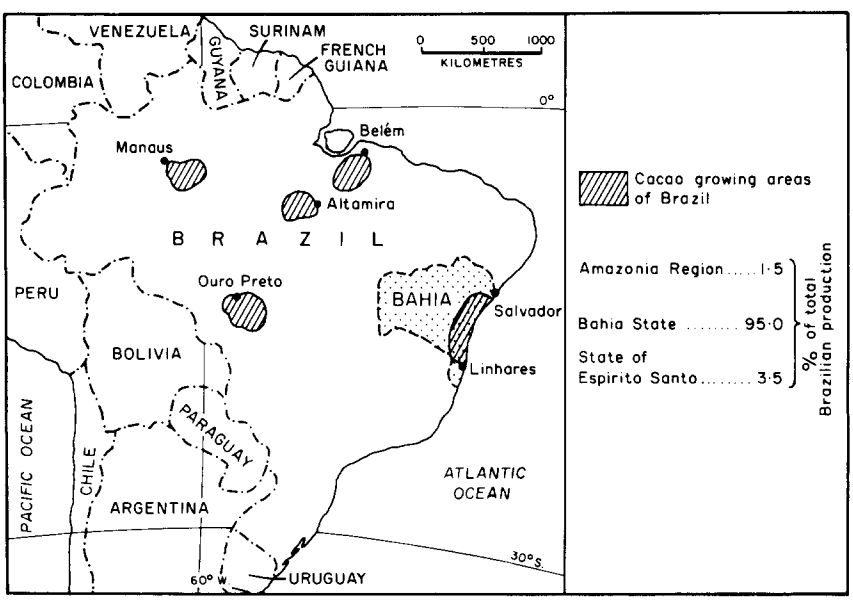


Figure 1. Cacao growing areas of Brazil.

nutmeg (*Myristica fragrans*), patchouli (*Pogostemon cablin*), passion fruit (*Passiflora edulia*), peach palm (*Bactris gasipaes*), allspice (*Pimenta dioica*) and mangosteen (*Garcinia mangostana*). Although most of the areas planted with major plantation crops such as rubber, oil palm and coconuts are in monoculture, crop combinations have been adopted in some instances. The factors that favour such crop combinations are:

- ecological requirements of some species like clove, cardamom, vanilla, nutmeg, etc. necessitate provision of shade at least during their early stages of growth; and
- the advantages of crop combinations and multiple land use are clear to th local farmers from the experience of cacao cultivation (under shade).

Combinations of these different crops, with cacao as one of the components in most, if not all, of them, present a multilayer pattern of canopy admixture, and it is often difficult to distinguish them according to their species composition. However, based on the predominant cash crop component involved, three different sub-systems can be identified, viz. multiple cropping systems with clove, rubber and coconut as the major components.

3. Multiple cropping with clove

The clove tree (*Syzygium aromaticum*) is being established on a large scale in the region; over 5,000 ha have already been planted with clove in the past 25 years, 50% of which are already bearing. Clove is usually established under the shade of food crops, most commonly cassava or in combination with black pepper (*Piper nigrum*).

3.1 Clove with black pepper

Clove is planted at 8 x 8 m or 10 x 10 m spacing in an already established stand of black pepper at 2 x 2 m or 2.5 x 2.5 m. The pepper vines, trailed on to wooden posts, provide lateral shade to young clove trees and protects them against wind. The pepper plant is usually affected by a disease supposedly caused by nematodes and fungi, so that they die in about 4–6 years after planting. However, within this short duration, it yields heavily providing cash benefits to the farmers when cloves are still not yielding. The cloves are benefited by the heavy fertilization given to pepper, and they start bearing from the 6th year so that continuity of cash income is maintained after the decline of pepper.

Three main problems are encountered in this crop combination:

- under the usual management given to pepper, which involves frequent weeding, the soil is greatly exposed to erosion problems;
- the large number of wooden (dead) posts required to support pepper makes pepper cultivation very expensive;
- following the removal of the dead pepper and posts, weeding of inter-row spaces becomes necessary, which exposes the soil under cloves.

Leguminous live posts have been tried as support for pepper so as to offer better soil protection, improve soil fertility and reduce establishment and weeding costs. *Erythrina fusca, Gliricidia sepium,* and *Leucaena leucocephala* have been found very successful. These woody species are lopped periodically to offer more light to pepper, and the loppings applied as mulch to pepper. Experiments are in progress in which herbaceous crops such as cowpea and pineapple are also being tried successfully in between rows of these leguminous live posts (Figure 2).

Figure 2. Experimental plot of crop diversification and mixed cropping in Southeast Bahia. Picture shows combination of *Leucaena leucocephala* and Pejibaye palm as the woody components with various agricultural species. (Photo: P.K.R. Nair)

3.2 Cacao after peper in clove stands

Some farmers plant cacao after the removal of pepper in order to avoid erosion-prone bare interspaces between cloves. But this would necessitate frequent pruning of cacao branches so as to minimize overlapping of cacao and clove canopies (that can lead to inflorescence deformation in cloves). Another possible component in this scheme would be cinnamon (*Cinnamon zeylanicum*), the stems of which need to be periodically removed to obtain the bark, which is its main economic produce.

3.3 Some production data from farmers' plots

In 'Sitio Jurema', located near Ubaitaba, clove was planted 8 m apart in a 5 ha plot in 1973, initially under the shade of cassava. After two years, cassava was replaced by oranges, and when cloves started giving too much shade for oranges, oranges were removed and cacao was established irregularly in clove inter-rows. Figure 3 is a 1983 photograph of the farm. Only cacao plants are fertilized in this combination. In 1982, the 9 year-old clove plants yielded an average of 3 kg dry cloves per plant. By 1984, the average yield went up to 5 kg/plant, and cacao, which was then 7 years old, produced 600 kg (dry beans) per hectare. The market price (1984) was the equivalent of USS 4/kg of cloves and USS 1.6/kg of cacao beans (these being the prices paid to the farmer).

Figure 3. Crop combintion involving mainly clove (10 years old) and cacao (6 years old) in a private farm near Ubaitaba, Southeast Bahia. Other crops such as black pepper, coffee and papaya as well as the leaves of a coconut palm on the border can also be seen in the picture. (Photo: P.K.R. Nair)

In some other farms in the region, 9 year-old cloves are interplanted with coffee and chillies (*Capsicum* spp). There are also mixed plantings of clove and coconut. Since coconuts cast little shade when they are over 30 years old [5] this kind of permanent mixed cropping will possibly result in realising the full yield potential of both the species. 'Fazenda Boa Esperanca' in Valenca and 'Fazenda Auxiliadora' near Taperoa present two examples of the most organized and, apparently remunerative, examples of multiple systems with clove. In the former cloves planted at 7.5 x 7.5 m spacing are inter-planted with passion fruit, papaya and coffee. Data on the yield and other growth parameters are, however, not available as the owner is too reserved

to divulge such information to outsiders. 'Fazenda Auxiliodora' consists of a 4-ha plot of clove in multistoreyed combination with Pejibaye or peach palm (*Bacteris gasipaes),* papaya, coffee, patchouli, cardamom and vanilla. Figure 4 is the schematic arrangement of different crops and Figure 5 shows a photograph of a section of the farm showing patchouli, vanilla, pejibaye, cardamom and coffee with clove trees.

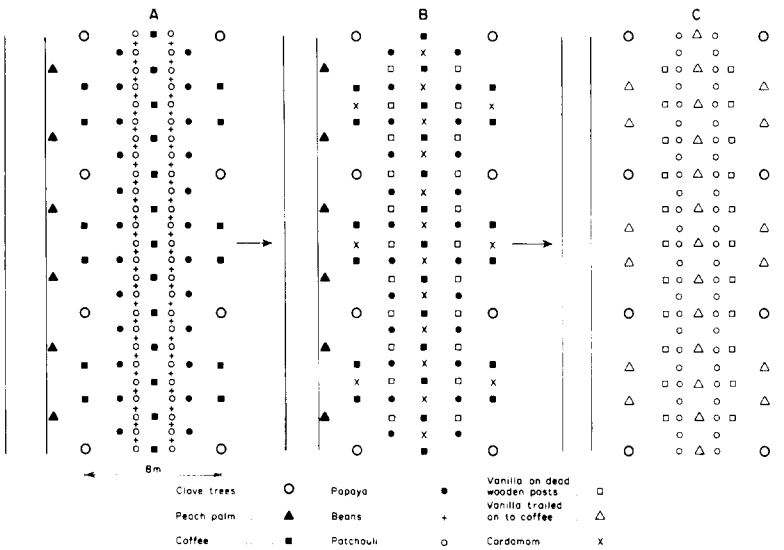


Figure 4. Schematic arrangements of the various components of crop combinations with clove at the 'Fazenda Auxiliadora' in Taperoa, Southeast Bahia. (A) with peach palm, coffee, papaya, beans and patchouli. (B) with peach palm, coffee, papaya, cardomom and vanilla on wooden posts. (C) with patchouli and vanilla on wooden posts and on coffee.

The cloves were planted 8 m apart in 1974. Vanilla cuttings are trailed on to dead wooden posts as well as pruned coffee plants. Shade tolerant species like patchouli and cardamom form the lower storey of this crop mix. As a consequence of this intimate plant association, weed growth could almost totally be suppressed. Vegetables and other food crops are grown in an adjacent area along with coffee, cardamom, patchouli and vanilla. Pigs reared in a separate site and fed with crop wastes provide organic manure that is added to the soil. Chemical fertilizers are given only to coffee, patchouli and papaya, but the quantities given were not disclosed by the farmer. Patchouli, harvested once every 3 months yielded about 3 kg of commercial product (fresh leaves and stem) per metre row length; yield of clove was 937 kg/ha of the mixed garden. Yield data of cardamom and vanilla were not available (disclosed by the farmer). Patchouli was sold at the equivalent of US$ 0.5 per kg of fresh produce, vanilla $ 80/kg and cardamom $ 20/kg.

Figure 5. Photograph of one of the crop combinations mentioned in Figure 4 showing patchouli, vanilla, pejibaye, and coffee with clove trees. (Photo: P.K.R. Nair)

4. Multiple cropping with rubber

Southeast Bahia has about 30 000 ha under rubber, most of which are in pure (sole crop) stands. But in about 2 000 ha, cacao is interplanted at the rate of 1–2 rows between every two rows of rubber (Figure 6). Both rubber and cacao are spaced 3 m along the rows, and rows of rubber are 7 m apart. Thus, there will be 476 rubber trees per ha and 476 or 952 cacao plants – depending on whether one or two rows of cacao appear between two rows of rubber. The most successful arrangement so far seems to be two rows of cacao in every inter-row space of rubber trees.

Research data and other systematically collected information are not available on the yield figures of the two components of this combination because research station trials are in their early stages on the one hand, and farmers who adopt the practice are not very cooperative to give the actual yield figures, on the other. Some field observations were made from a number of farms of Southeast Bahia with representative areas of cacao of different age groups (4–10 years); in all cases cacao seedlings had been introduced after the rubber trees had attained maturity). The findings of the survey are summarized in Table 1. These figures indicate that the performance of cacao grown in combination with rubber is comparable to that of the average crop

Figure 6. Interplanting of cacao in mature (20 years old) stands of rubber trees. (Photo: R. Alvim)

Table 1. Average yields of cacao and rubber in Southeast Bahia

	Cacao kg dry beans/ha	Rubber kg dry rubber/ha
1. *Pure stands*		
a) general level (conventional farming practices; unregulated shade for cacao)	650	600
b) improved management (cacao under moderate shade, usually of Erythrina trees 18 m apart)	1000	1200
c) experiment station yields	2500	2000
2. Mixed stand of rubber and cacao; cacao 4- 10 years old (average of data from several farms)	645 (range 195–1155)	588 (range 488–671)

in the locality, but lower than that of cacao in sole stands and improved management. The yield of rubber trees in the mixture is also comparable to, if not better than, that of trees in pure stands. The rubber trees in the mixture are benefitted from reduced weed competition as well as from the fertilizer application and other aspects of cacao management.

Because of the dense canopy of rubber trees and the convenience of management, commercial rubber plantations always consist of sole crop stands (except for the legume cover crops). Until recently, crop combinations with rubber were even considered not feasible [2]. However, intercropping with rubber is a usual practice in smallholdings, and research efforts are now under way in Malaysia and other rubber-growing countries to improve this practice [9], [10]. Crop combinations with rubber seem particularly suitable in Bahia conditions where rubber trees are usually defoliated severely (in addition to their natural leaf shedding) by fungal diseases and insect damages. Improved clones of rubber having a synchronous leaf fall pattern will be more suitable for this crop combination.

New rubber plantations are now being established in the flat lands (Tabuleiros') of Southeast Bahia as a consequence of the subsidy and credit schemes implemented by the Brazilian Government. In these areas, especially near market outlets, the farmers interplant a variety of food crops and vegetables with young rubber trees, and most of the field operations are mechanized. However, the choice of intercrops with rubber is rather limited in the hilly areas nearer the traditional cacao producing areas which have little possibilities for mechanization. Local practices by some farmers indicate the suitability of some intercrops for these areas. For example, on relatively poor soils in Una, acai palms, (*Euterpe oleracea*), planted at 3.5 m x 1 m spacing under old rubber trees, yielded commercially valuable hearts of palms (2.5 cm in diameter and weighing 400 g per plant) in four years after planting, even without addition of any fertilizers. Moreover, the palm suppressed weed growth after they were about 30 months old. Another potentially promising crop mixture in the region is a combination of black pepper and patchouli between the rows of young rubber trees. However, this combination needs considerably higher levels of inputs and management attention than in the case of acai palms. Old rubber stands are also being interplanted with guarana (*Paullinia cupana*), but its yields are considerably lower than in its pure (unshaded) stands. Passion fruit (*Passiflora* spp.) is another cash crop that is being popularised, thanks to the establishment of passion-fruit juice industries. Sometimes rubber and mangosteen (*Garcinia mangostana*) are planted between rows of passion fruit vines.

5. Multiple cropping with coconuts

There is very little to report on mixed or multiple cropping with coconuts in Bahia, mainly because productive coconut areas in the region are found

almost entirely in marginal, sandy soils along the coast. Recent plantings in better soils are still too young to introduce shade tolerant species like cacao under the palms. Scattered farms, however, are found where coconuts have been underplanted with guarana, black-pepper and, in a small case on the coast, with cashew, similar to the practices in areas further north in the Northeast Region [3].

Mixed coconut and guarana seems to be an interesting combination in view of the yields obtained from both crops and the reduced costs of weeding. Some small farmers are underplanting single or double rows of guarana spaced 4 or 5 m in the row, when the coconuts are 3 to 5 years old.

6. Evaluation and research needs

The crop combination systems described here have several advantages in the agricultural and socio-economic context of Southeast Bahia. As discussed by Nair [5], [8], crop diversification systems can make more efficient use of labour and equipment over a calendar year or other relevant time span, reduce the cost of weeding that would be required in sole crop stands, make complementary (and thus more efficient) use of soil fertility resources, reduce erosion hazards and increase the land's total productivity on a sustained basis. Socio-economic advantages lie not only in increasing the overall productivity but also avoiding the over-reliance on a single commodity and other risks of monocultural cropping. Some of the additional crops that are being tried or are potentially feasiable (e.g. various spices and medicinal plants) have a strong international market whereas the various fruits and vegetables enjoy a high demand within the country. Environmentally also, crop mixtures are preferred systems than monocultures [6].

The feasibility of expanding crop combinations with various tree crops is evident from the success attained by the few farmers who adopt these practices, as already cited. Among the three tree crops examined here, crop combinations are most popular with clove and least with coconuts. However, this is possibly a reflection of the soil conditions under which these crops grow and the managerial skill of the farmers involved rather than the suitability or amenability of the particular tree crops for intercropping. Morphologically, among these three crops, rubber which has a dense canopy that easily closes, is the least suitable for intercropping, and coconut the most. Because of the high proportion of light reaching the plantation floor during the early and late stages of coconut's growth, intercropping with coconuts is particularly feasible during these periods [5]. Weed competition in monoculture stands for coconuts is a serious problem, but it can be overcome, to some extent, through intercropping. Livestock, like sheep, feeding on food-crop wastes or grazing on interplanted cover crops could also keep the growth of weeds under check. Such practices of crop diversification and animal intergration with coconut palms are popular in several other countries

[7], [4], and even in the northern parts of Northeast of Brazil [3]. Failure in expanding these promising practices to the desirable extent in Southeast Bahia can be ascribed to the lack of sufficient technical and scientific know-how on the subject.

Obviously a great deal of research and development efforts need to be put in the realize the full potential of these systems. As already mentioned, there are quite a few examples of very promising crop mixtures with cloves. But the practitioners of these systems would not easily divulge the information on the agronomic management and production particulars of their farms. With some amount of tactful persuation these details can be gathered which could form the basis for further studies on improvement of the already existing systems on the one hand, and for extension of the method to other potentially feasible farms, on the other. In the case of intercropping with coconuts, a great deal of research information is already available from elsewhere [5], [7], [8], which could be tried extensively in the region. The main tasks in popularizing these practices would be the choice of appropriate intercrops, deciding their agronomic requirements, training the traditional monoculturist farmers in the management and processing of several crops, and ensuring the marketability of the various products.

In addition to the three main crops listed here, a large number of other crops can also be combined with cacao. An excellent illustration of this possibility is the complex system of agroforestry combination being practised very successfully by farmers of Japanese origin in Tome Acu near Belem in Para State of Brazil. An inventory of the commonly cultivated plants in these mixed systems lists 32 species ranging from the tall Brazil nut tree (*Bertholletia excelsa*) to herbaceous crops like rice and soyabean in various types of intimate plant association [1]. Several Brazilian agencies such as EMBRAPA (The Brazilian National Council for Agricultural Research), CEPLAC (Executive Commission for the Development of Cacao) and others are now undertaking such perennial crop combination experiments in various parts of the country.

These crop combinations systems are, understandably, more demanding than the monoculture in terms of not only labour and capital but also technical and managerial skills. Care and management of a large number of crops where one or two grew before involve considerable amounts of technical knowledge and competence. Processing the various products and their marketing can also pose problems of serious proportions. Lack of possibilities for mechanization of various farm operations is another issue that is often cited as a disincentive to crop combination schemes, so that the feasibility of such practices are seen as confined to small-scale farmers who usually undertake most of their farm operations manually. Nevertheless, the agronomic, soci-economic and environmental advantages of the systems are so vivid and appealing that they are potentially very suitable for the traditional small-holder cacao production areas of southeast Bahia (and

possibly such other areas). Researchers and development experts need to be encouraged to bestow more attention to surmounting the technical and operational constraints in popularizing these systems.

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