ECONOMICS OF INTERCROPPING

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INTRODUCTION

Intercropping is: "growing two or more crops simultaneously in the same field". This includes cases of crops arranged in a geometric pattern, in alternate rows and in no noticeable arrangement or "mixed cropping". It is a case of "multiple cropping" or the growing of more than one crop on the same land in one year which also includes "relay cropping" and "crop sequences" (Andrews and Kassam, 1976).

To discuss the economics of intercropping requires the study of its evolution and dispersion in order to interpret its benefits and importance for society. It also implies interpreting its advantages and limitations as an enterprise and a production systems which permits a rational use of resources and other benefits for society in the present and future. This is partly attempted in this document. Particular attention will be given to soybeans in intercropping.

HISTORY AND WORLD PERSPECTIVE

General background: Intercropping as a form of multiple cropping is of widespread use in the world (Beets, 1982). However, specific documentation of its early history is not readily available.

Some authors relate its appearance as one of the primitive cropping systems used by man to the dawn of agriculture when people began

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selecting fron nature some useful crops and followed the patterns in which they grew (Mandel, 1968).

Before urbanization became widespread, agriculture and economics were inseparable. Because of the limited development of markets for produce, agricultural enterprises were mostly for subsistence and a family affair. Production systems were not as varied as at present, and farmers were slow to respond to technical economic and environmental changes. The only sources of energy were human and animal power. Soil fertility could be maintained and pest problems reduced, although not always successfully, by the use of crops rotation, animal manures, composts and ash resulting from burning existing vegetation. Mixed cropping, including intercropping, were suitable and rational production systems under those conditions. They were common in most farms (Beets, 1972).

The first Europeans to arrive in the Americas found the indians growing mixtures of maize (Zea mays L.), beans (Phaseolus vulgaris L.) and squash (Cucurbita sp.) from Argentina to the Great Lakes, a systems that had undoubtedly evolved one or two thousand years earlier (Grigg, 1974).

Recent history of multiple cropping and intercropping is better documented for Asia than for Africa and America. In Asia, the development of Taiwan and India features the importance of multiple cropping systems (Wang and Yu, 1975; Beets, 1982).

Soybean: Even though the history of soybean as a crop is related back to ancient times in China when it was mostly used for human consumption,

no clear reference is found to its intercropping with other crops previous to its introduction in the West. However, the tradition of intercropping in this region makes it likely that soybean has long been intercropped there. Futthermore, Bernard (1975) states that in the Central Chinese province of Kirim, virtually all soybeans are intercropped with maize. Following their introduction to the United States in the late nineteenth century (Probst and Judd, 1973), soybeans were principally grown as a forage crop and often interplanted with maize to improve silage quality (Wiggans, 1937). Thatcher (1925) reported that 56 percent of the soybean acreage in Ohio was grown in mixtures with maize in 1923, but only 40 percent in 1924. According to Hackleman et al (1928) nearly 60 percent of the 650,000 acres of soybean crop in Illinois during the 1923 - 1926 period was mixed with maize. It would seem that as soybean changed from forage to a grain and oil crop in the period 1920-1940, intercropping was gradually replaced by monoculture (Probst and Judd, 1973; Crookston and Hill, 1979).

General Dispersion: The present dispersion and importance of intercropping in the world are mostly associated with the agriculture of less developed countries, particularly in tropical areas (Finlay, 1974; Beets, 1982; Gomez and Gomez, 1983). There, in turn, intercropping is associated with the diversified farming systems found in the numerous small farms and also with the production of food and feed crops. An important proportion of these crops is used for consumption at farm level

The agricultural technology found on these farms is considered traditional and sometimes archaic in relation to what is known as "modern" in agriculture. This consideration is usually extended to the different forms of intercropping and contributes to their dismissal as a form of production with economic potential for contemporary and future agriculture.

In many aspects, the production and economic conditions under which intercropping is widely used are similar to those of agriculture in the past. Under those restricted conditions, intercropping becomes a rational form of using agriculture resources to benefit society.

In macro terms, the most important determinants of the comparative importance and benefits of intercropping and monocropping for a given society are the relative availability of labor, land and capital inputs for agriculture and the relative importance of the last for the economy at large. Intercropping, in most of its modern forms, can provide more production, employment and even income per unit of land in relation to most cases of monocropping, when a given amount of capital is used in the same environment (Finlay, 1974), Thus, traditional intercropping tends to be associated with situations of relative abundance of labor in respect to land and capital. However, different forms of intercropping are found under other conditions, including relative abundance and development of capital in respect to land and labor.

The two most common situations in which intercropping occurs are: 1) where there is abundant labor and both land and capital are limiting, as in southeast Asia and parts of Africa and Latin America; and 2) where

there is abundant land and both capital and labor are limiting as in the slash-and-burn agriculture of Africa and Latin America. The latter situation also occurs in certain tree-pasture associations and where three crops are grown within natural forest (Von Platen et al, 1982; Van Tienhoven et al, 1982). Some forms of intercropping associated with the production of vegetables, fruits and flowers are also appearing in the situation where capital is more abundant than both land and labor, as in western Europe, Japan and parts of the U.S. Examples include the case of olives (Olea europea) and grapes (Vitis sp.) associated with other crops practiced in Mediterranean countries (Grigg, 1974). This situation has led to considerable innovativeness in the development of practices that are most efficient in the use of land since a high degree of technological infrastructure is already available. Finally, there is the situation where only capital is limiting; thus intercropping may be the cheapest way of providing shade needed by certain plantation crops as in the cases of cocoa (Theobroma cacao L.) and coffee (Coffea sp.) (Pinchinat et al, 1976). There are other situations where land is abundant but limited for agricultre due to water restrictions as in the case of semi-arid tropical areas with very short rainy seasons. Intercropping of maize and sorghum (Sorghum sp.) or of sorghum and millet (Pennisteum sp.) are ways of better exploiting soil water under those conditions. The interplanting of vegetable or field crops in the establishment stage of perennials is another way of improving resource use efficiency (Pinchinat et al, 1976) Intercropping is seldom found

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in situations where labor is the only limiting resource as in most of the U.S. agriculture.

Soybean: This crop is commonly intercropped with maize and sorghum in Southeast Asia (Shanmugasundaran, Kuo and Nalampang, 1980). In this region soybean is principally cropped for human consumption. This is not the situation in other regions of the world where soybean is not regularly grown by small holders who practice intercropping. However, other legumes are frequently intercropped with cereals. Arnon (1972) estimated that 98 percent of the cowpea (Vigna unguiculata (L.) Walp.) grown in Africa, where it is the most important food legume, is associated with other crops. Francis, Flor and Temple (1976) inform that the production of beans in Colombia, Brazil and Guatemala comes from associated plantings in 90, 80 and 73 percent, respectively. Other food legumes frequently intercropped are pigeon pea (Cajanus cajan (L.) Millsp.) (Dalal, 1974) and peanuts (Arachis hypogaca L.) (Evans, 1960). Soybean has been intercropped in the U.S., usually for the production of forage and not uncommonly as green manure. Other forms of relay cropping with cereals have also been attempted in the U.S. and in Brazil (Beets, 1982).

ADVANTAGES OF INTERCROPPING

The economic rationale of intercropping stems from the possibility of growing two or more crops together, diminishing their competition and

increasing their supplementarity and complementarity in the use of available resources and of their production profiles in a given area and time. Most of the caracteristics of intercropping have short-run as well as long-run economic implications. They include:

a) Better utilization of environmental resources: Plants of different growth habits and cycles often differ in their environmental requirements or in their use of resources; therefore many intercrops exhibit complementarity in the structure of their canopies and rooting systems. Thus, they are able to exploit light, nutrients and water more fully than monoculture. The more complete ground cover by the intercrops can reduce erosion, weed competition and moisture loss through evaporation. One of the species in the mixture may benefit nitrogen or possessing mycorrhiza which brings more phosphorus into the system. In the case of failure of one of the crops because of environmental accidents, the other can exploit the resources unused by the crop that failed. This would not be possible if the crops were planted in different fields. Spread of insects and diseases in one species may be slowed down by the presence of non-susceptible species within the planting.

b) Input and output management flexibility. Particularly when land is limited, crops could be selected and their relative sowing and planting dates arranged so as to fit the profiles and optimize the use of available labor, inputs, implements and money per hectare

during cultivation and harvesting. Similarly, the crops and planting dates could be selected to obtain a production profile and composition which would fit farm consumption requirements or market availability for the different products. This would also contribute to the improvement of nutrition and cash flow and to diminish storage losses.

c) Risk minimization and profit maximization. Better utilization of resources and stabilization of production to counteract environmental variations or the attack of insects and diseases tend to reduce the risks of production. Flexibility in the use of labor and other farm resources plus an extended and varied supply of produce tend to minimize marketing risks in the face of price fluctuations, as well as the risk of storage losses. Generally a higher yield and greater gross return per hectare can be obtained by intercropping two or more crops. Sometimes this higher output can be obtained from a less than proportional addition of inputs; usually labor or specialized labor-substituting-capital. When the opportunity cost for this extra input is sufficiently small the intercropping results in an increase of net income per hectare in relation to the monocrop.

Observations which reflect these advantages of intercropping are reported by many authors (Darlrymple, 1971; Willey, 1975; Kass, 1978; Beets, 1982).

ECONOMIC MEASUREMENT AND INTERCROPPING

Economic measurements are seldom reported in the literature on intercropping of soybean. This reflects the inherent complexities of intercropping but also the general bias towards agronomic evaluations and the lack of familiarity with appropriate tools in research.

In their literature reviews, Kass (1978) and Crookston and Hill (1979) found that in the 1920-1940 period, most of the U.S. experimental stations in states where soybeans were grown carried on research on crop mixtures. Although the main interest of these studies was forage or silage production, grain yields were sometimes reported but not related economic analysis were given. In most cases of research the objective was a greater production of protein, or sometimes, total digestible nutrients per hectare by intercropping soybeans in different arrangements with maize or other crops. Brown (1935) found increased soil organic matter, N and P in plots following five years of maize-soybean mixture in comparison with maize planted alone. Wiggans (1937) stated that maize-soybean mixtures produce considerable benefits for a slight increase in costs but his economic analysis went no further.

The most common indicator used to evaluate the advantages of intercropping is the Land Equivalent Ratio (LER). This index relates the land area needed by the monocrop of all component crops to the land area needed to obtain the same production under intercrop. It has been modified to take into consideration the time period during which the ground would be used in each case (Hiebsch, 1980). Usually the LER ob-

tained from intercropping is greater than one. However, Crookston and Hill (1979) report data from different sites in Minnesota over a three-year period where the LER for a maize-soybean intercrop was seldom superior to one under different plant populations. This was explained by the short growing season which prevented a better temporal arrangements of the component crops. This is not the case found in most tropical areas, even though short rainy seasons in semi-arid areas may impose similar problems (Makena and Doto, 1980). Some reported values for the LER in maize-soybean intercrops are: 1.43 in Kentucky (Kinney and Roberts, 1921); 1,32 in Tennessee (Mooers, 1927); 1.48 in the Philippines (Sastrawinata, 1976) and 1.22 in Alabama (Allen and Obura, 1983).

Other evaluations consider the trade-off between the decrease in yields of the preferred crop in intercropping and the yields of the companion crop. On some occasions, the associated monetary value is also considered, but on fewer occasions the cost side is explicity accounted.

One of the main research lines associated with intercropping of soybean is related to the development and evaluation of mechanical harvestings. Beste (1976) recommended planting maize and soybeans in the same rows as damage by topping (Weber, 1955) would be less than the problem of running machinery over the soybean rows. Strip intercropping can provide some of the benefits of intercropping while allowing mechanization (Dolezal, 1983).

Just recently, economic analysis is being incorporated as a normal component of agricultural research. The basic tools include different forms of budget analysis, selected by the possibility of obtaining the

data needed to reflect as closely as possible normal production conditions. Some problems are related to price projection and labor measurement under research conditions. Possibly, the most beneficial in this trend is the motivation for researchers to observe and evaluate the use of inputs and resources which is necessary to properly identify and weigh the economic benefits and outputs of intercropping (Johda, 1979).

In an economic evaluation of 20 trials to compare the association of maize and beans with the respective monocrops in Colombia, Francis and Sanders (1978) found that monocropping was more profitable over a wide range of relative prices but the risk was also higher. However, the probability of obtaining a consistent income with relatively lower investment was higher for the association. Profit increase projections up to 40 percent were obtained from trials of cassava intercropped with maize or beans in relation to the monocrop in Costa Rica (Navarro, 1978; Meneses et al, 1983). Nevertheless, these results are highly dependent on price relations. The intercropping of soybean with castorbean (Ricinus sp.) was the only cropping pattern which failed to produce a profit in four years of experiments in India (Reddy, Rao and Reddy, 1965). On the other hand, in the Philippines, the intercropping of ginger (Zingiber officinalis L.) with soybean and ginger with soybean and vegetables showed to be more profitable than ginger planted alone (Paner, 1975).

Intercropping has also proved to be promissing in relation to monocropping when the energy intake and production is budgeted (Kass, 1976).

Clearly, further work is needed to develop appropriate tools and procedures to fully determine and evaluate short-run as well as long-run economic costs and benefits of intercroppings. This is one possible line of research. Others include the development of appropriate machinery that will determine the future use of intercropping under a capital intensive agriculture.

PERSPECTIVES FOR RESEARCH ON INTERCROPPING

Since intercropping has been considered a traditional practice, not suited to mechanization and other means of increasing efficiency, it did not receive much attention from investigators in the 1940-1970 period, when rapid increases of productivity were the main research goals. However, with the realization of the limitation of this approach and the introduction of the "farming systems" approach to research, it became clear that present knowledge and research technology were often inadequate for dealing with problems of fertilization, weed control and varietal betterment, and for improving efficiency in traditional systems. A new interest for understainding traditional farming practices and investigation efforts for upgrading them by utilizing their basic advantages are part of the agendas in International Research Centers including IRRI, IITA, CIAT, ICRISAT, CIMMYT, AVRDC, and ICARDA, and also in some Regional Research Centers, including CATIE in Latin America and different National Research and Extension Institutions in Asia, Africa and Latin America (Consultative Group, 1978).

Many U.S. Universities are also making efforts of this kind as part of their own International Programs and also as part of different joint efforts developed under the Title XII programs. Furthermore, several international institutions of support for agricultural development are encouraging these efforts.

NOTES

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