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ECONOMIC CONCEPTS OF AGROFORESTRY

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1. Introduction

Agroforestry has become a relatively popular subject amongst agricultural scientists in the past decade or so. This may have been caused partly by the frequent failure of some traditional approaches to stimulate agriculture and forestry, partly by a genuine belief that agroforestry is a superior land-use system, and partly by the tendency for people to jump on the band-wagon.

Whatever the reason, the ultimate test of agroforestry's usefulness will be its acceptance by land users in the widest sense of the term, i.e. individuals as well as society as a whole. Various traditional agroforestry systems are practised throughout the world, and these have obviously passed this test already. Adaptation of these systems to reflect changes in farming systems and/or environments and development of new technologies are expected to take place in the next decade, and it is precisely these systems/ technologies which have to be put to the test for their usefullness to be proved.

In this paper some of the underlying economic concepts of agroforestry will be briefly explained as well as economic methods for analysing agroforestry systems.

2. Why agroforestry?

The "raison d'être" of agroforestry is that the mixing in time or space of perennials with annuals and/or animals is "profitable" compared to growing them seperately. In this context, the term "profitable" should be interpreted in terms of using less resources to produce the existing output, or to produce more output with the existing resources.

From an economist's point of view, producers may include trees in their land for two reasons:

i. the tree component is chosen for purely economic reasons (income maximization).

ii. the tree component is chosen for other than purely economic reasons, e.g. spreading of risk, diversity of income flow, home consumption of tree products like fuelwood, poles, etc.

In both cases, producers have a choice to grow the trees biologically separate from any of the other components (non-agroforestry land-use system), or to grow them in a system in which they biologically interact with the other components (agroforestry land-use system). In both cases, the agroforestry land-use system is adopted only if the cost of production of the product mixture is lower compared to the alternative non-agroforestry land-use system,

While this will be the only pre-condition for the introduction of agroforestry by land users with the second production objective, land users with the first objective still have another pre-condition for the adoption of trees in either an agroforestry or non-agroforestry land-use system, i.e. the tree component should be economically justified (income maximization). To be more cost-effective than non-agroforestry land use systems, there should be biologically and/or economically advantageous interactions between the individual components of agroforestry systems. Such interactions may be felt either immediately or after some time. In fact it is this "delayed" biologically/economically advantageous interaction, normally referred to as "sustainability", which has pushed agroforestry into the limelight.

3. Biological interations between system components

Biological interactions between the components in an agroforestry system can be subdivided into:

i. complementary

ii. supplementary

iii. competitive

The common yardstick for measuring this biological relationship is the "physical land productivity". In principle it is biologically advantageous to mix trees with crops and/or livestock if such mixtures require a smaller land area than the individual components grown as sole crops between which there is no biological interaction.

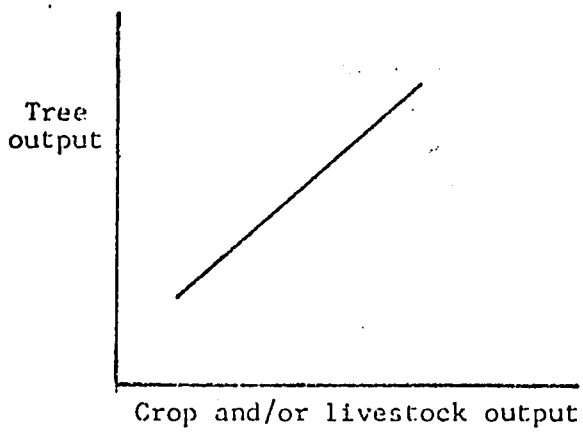
Complementary biological interactions between agroforestry system components are here defined as those in which an increase in the production of the tree component on a given land area automatically leads to an increase in the crop and/or livestock production on the same land area (see Fig. 1).

The most frequently quoted agroforestry example of a complementary biological interaction between system components is bee-keeping, which increases the yield of honey while simultaneously benefiting the fructuation and consequently the yield of seeds and fruits (Filius 1981).

Another example is the inclusion of trees in the upper parts of a watershed, thus gradually reducing the damaging effects of soil and water erosion on the cropland as well as providing

a more continuous flow of ground water. This example also illustrates that such complementarity between components will probably be realistic for part of the curve only i.e. once the trees start occupying too great a portion of the land, the loss in crop area cannot be compensated any more by a yield increase in the remaining area.

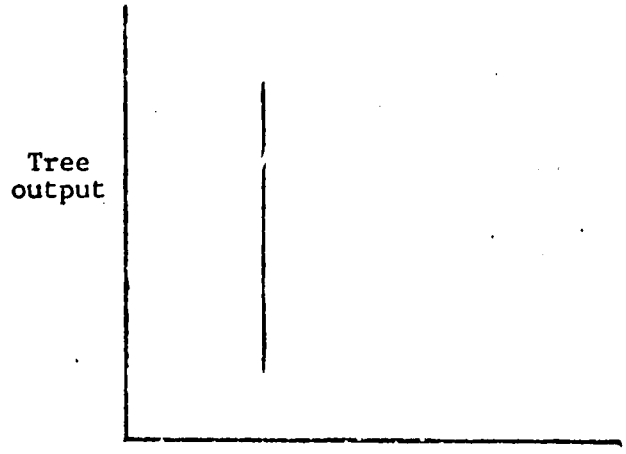
Fig. 1: Complementary biological interaction between trees and crops and/or livestock



Supplementary biological interactions between agroforestry system components are here defined as those in which an increase in the production of the tree component on a given land area does not decrease the crop and/or livestock production on the same land area (see Fig. 2).

An example of a supplementary biological interaction between trees and crops is coconuts and animals. Providing that light is not normally the limiting factor for the understorey crops when grown as sole crops on a farmer's field, the presence of tall, well-spaced, mature coconuts will have little effect on crop yield (Raintree, 1983).

Fig. 2: Supplementary biological interaction between tree and crop and/or livestock

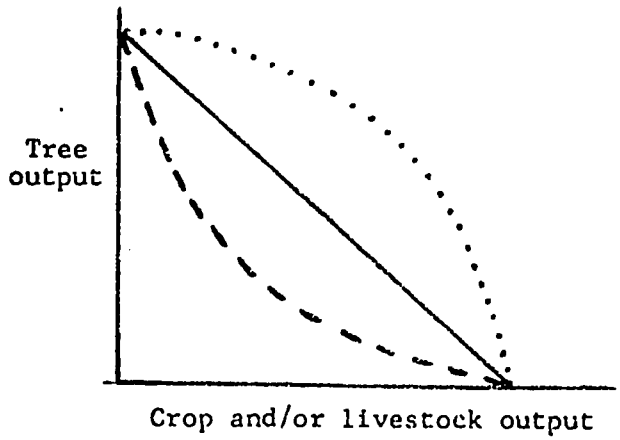


Competitive biological interactions between agroforestry system components are here defined as those in which an increase in the production of the tree component in a given land area leads to a decrease in the crop and/or livestock production on the same land area.

The most frequently encountered biological relationship between agroforestry system components can take various forms. The solid line (———) in figure 3 shows a fixed decrease in the production of the crop and/or livestock component with an increase in the production of the trees. from a biological point of view, mixing crops does not have any merit under such a competitive relationship. The dotted curve (.....) in figure 3 also displays a competitive relationship between the system components. However, the lower part of the curve shows that an increase in the tree production causes a less than proportional decrease in the crop and/or livestock production, while on the upper part of the curve the reverse is true. Therefore if such an inter-

action between components exists, mixing components is advantageous from a biological viewpoint. The broken line (------) in figure 3 shows a competitive relationship between the system components which is "poisonous" to both, and therefore not advisable from a biological viewpoint.

Fig. 3: Competitive biological interaction between trees and crops and/or livestock



4. Economic interactions between system components

The concept of biological interaction can be easily extended to economic interaction when the physical output per land unit is replaced by physical output per unit of total resource cost, i.e. land, labour and capital input multiplied by their unit prices. Just as in the case of biological interactionsbetween components, there are also complementary, supplementary and competitive economic interactions between components.

Before scrutinising the nature of economic interactions between the components in an agroforestry system,it should be remembered that an economic interaction between components

alone will not make the system an agroforesty one. The basis for an agroforestry system is a positive biological interaction resulting in positive economic interaction. (ICRAF, 1983a.)

Generally speaking most biologically advantageous interactions between system components will also be advantageous from the point of view of labour and capital use, i.e. less labour and capital will be used to produce the same amount of tree crop and/or livestock products compared to mono-production systems. This can be easily understood because most labour and capital inputs are directly related to the land area used. There are, of course, exceptions which may cause capital and/or labour cost to increase under an agroforestry system. A good example of such an increase in resource use is the protection of individual trees in silvi-pastoral systems, especially during the early stages of tree growth. Another one could be the increased use of bird-scaring measures because of the introduction of trees into cropland. Especially in mechanized production, the presence of scattered trees in the field may be a nuisance, leading to increased use of labour and machine inputs. If such additional resource use exceeds the reduced resource use derived from a favourable biological interaction, the agroforestry system stands only a poor chance of adoption. On the other hand, there may also be additional savings in the use of labour and capital resources over and above the ones resulting from the reduced land requirement. Such savings may be obtained by combining certain activities, which are difficult or impossible to combine under mono-production systems. An example of such a saving in resource use is the collection of fuelwood from scattered trees while simultaneously herding animals.

The valuation of the resources used to plant trees may easily lead to the identification of complementary and supplementary economic relations within agroforestry as well as non-agroforestry land-use systems.

Especially on farms operated by families in developing countries, it may easily happen that some idle land and idle labour are used to plant a few trees for poles, timber, fuelwood or fruit production. Although more resources are used, the cost of such resources would be zero, and therefore there is a supplementary economic interaction between the trees and the crop and/or livestock components. However, if such trees do not provide a biological service to neighbouring crops or livestock, such "mixture" should, in fact, not be mistaken for an agroforestry system. Needless to say, it would be profitable for a farmer to put it into practice.

A low per unit cost price of capital, land and labour does not, as such, favour an agroforestry land-use system over a non-agroforestry land-use system. Only if such lower per unit costs are linked to lower input requirements under an agroforestry system will they result in farmers' preference for agroforestry over non-agroforestry systems.

The following conclusions may be drawn from the economic interactions between the tree and crop and/or livestock components in an agroforestry system.

i. Land requirements/cost per unit of production under a viable agroforestry system will be lower than for the same product mix produced under a non-agroforestry land-use system.

ii. The combined labour and capital cost per unit of production under an agroforestry system will often be lower than for the same product mix in a non-agroforestry system; where it is higher, the additional cost cannot exceed the savings in the cost of land.

5. Design implications of component interactions

The challenge in the design of agroforestry systems lies in massaging interactions between components into the most advantageous forms, i.e. maximize positive interactions and minimize negative ones. For scientists to accomplish this, first of all existing land management systems should be diagnosed to determine their problems, potentials and constraints. Secondly, information is required on tree/crop interactions in a biological as well as an economic sense (see ICRAF, 1983 b).

Manipulation of biological and economic interactions between components can be achieved through the proper choice of components and management practices.

The choice of management practices can take various forms, including spatial arrangement, plant densities, cultivation practices, timing of activities, etc, (Cannell, 1983). Especially when availability of labour and capital resources fluctuates significantly between time periods and hence these resources command a different price in an economic sense, it is worthwhile to examine the biological consequences of scheduling operations of the time of highest availability so as to reduce overall resource cost.

6. The impact of time.

For the sake of simplicity, the time horizon in an agroforestry production system has been ignored so far, i.e. tree products to be reaped at some future time are assumed to have a similar value as if harvested now. However, for a variety of reasons, future net benefits are usually valued lower than present-day net benefits.

Some of these reasons are:

- present-day net benefits may be re-invested or put on a savings account, thereby increasing in value over time;

- risk increases over time, not only because of uncertainty about yields but also because of prices;

- the expected level of consumption in the future is usually higher than the present level of consumption. Assuming that the marginal value of consumption decreases with an increase in the level of consumption is valued higher than future consumption.

It is therefore common to compute the present-day value of future net benefits by multiplying the latter values with a discount factor*. The formula used for this discounting procedure is:

$$V_o = V_v (1 + r)^{-n}$$

where

V_o = present value

V_v = future value in year n

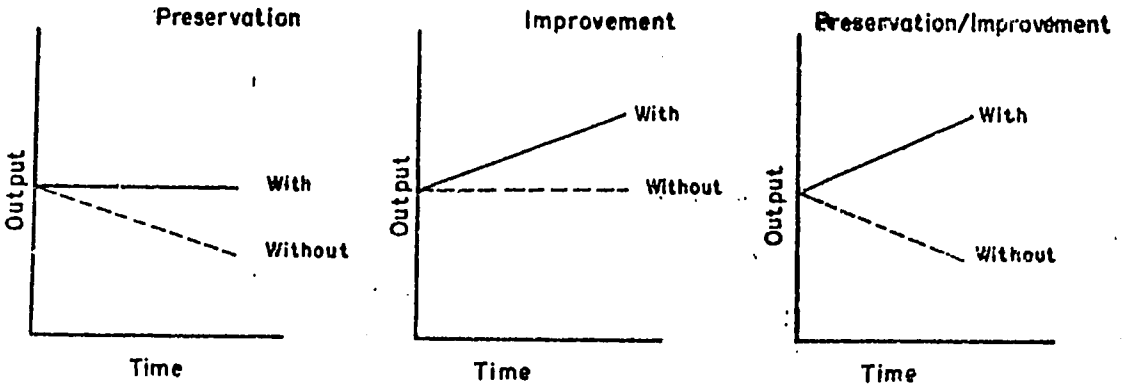
r = discount rate

n = number of years until future value occurs.

Another important aspect of time in agroforestry land-use systems is the sustainability of the system. Like the production role this service role of agroforestry systems will often only be felt after some time partly because trees take quite some time to grow, and also because the possible deterioration of the existing production system will take time. The different types of service, or environmental, benefits derived from agroforesry are shown in figure 4.

* Several authors have argued against incorporating risk into the discount factor, prefering to lower the estimated output value.

Fig. 4: Environmental output



7. Tools/methods for analysis

To compare the different combinations of tree and crop and/or livestock components with each other in order to find the optimum combination of components may be attempted with multi-period linear programming and dynamic programming. However, a survey of the literature on the economic analysis of agroforestry systems shows the extensive use of partial budgeting (Etherington & Matthews, 1983). Such an analysis will not lead to the optimum solution, but it will offer scientists an opportunity to determine which one of a few proposed system combinations is the best. The major advantage of this technique is that it requires much less data than the linear programming methods, while at the same time it is easier to understand and to compute.

Recently, ICRAF and the Australian National University collaborated in a project in which a micro computer program for multi-component, multi-period budgeting (MULBUD) was developed for the analysis of agroforestry systems. (Etherington & Matthews, 1984)

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