AGROFORESTRY AND THE UTILISATION OF FRAGILE ECOSYSTEMS

K.F.S. KING

International Council for Research in Agroforestry (ICRAF), P.O. Box 30677, Nairobi (Kenya)

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ABSTRACT


Sixty-five percent of the land in the tropical world occupies fragile ecosystems. The number of people who depend upon these areas for their food and livelihood is 630 million or 35% of the total population of the developing countries. Not only is the physical environment in which they live extremely harsh and unproductive, they are also generally so poor that they cannot afford to purchase food from other less brittle ecological zones. Accordingly, they are forced to utilise these inherently marginally productive areas for food production.

The consequences are that soils are becoming even more degraded, forests are being razed to the ground at an alarming rate, there is desertification and there are periodic floods and droughts. The necessity for food has forced the occupants of these areas to employ land-utilisation practices which have led to the degradation of the ecosystems.

The conventional scientific wisdom prescribes forestry as the best land-use for these areas. Unfortunately the people cannot subsist on the forests alone. They need food. It is therefore necessary to devise a system of land management which combines the practices of agriculture and forestry, which conserves the ecosystem, and which at one and the same time provides food and wood. Such a system is agroforestry.

Although there is considerable evidence which suggests that certain species of agricultural crops can be grown in mixture with forest crops, there is a great need for further research that is designed to evolve suitable management practices and to establish the complementarity of a range of agricultural and forest species in different ecological zones.

PROGRESS IN AGRICULTURE NOT RELEVANT TO FRAGILE ECOSYSTEMS

There have been, during the last two decades or so, remarkable advances in tropical agriculture. Indeed, according to some (see e.g. Borlaug, 1971; Dalrymple, 1972) the progress which has been made in the development, dissemination and adaptation of new agricultural technology has been unprecedented. This "green revolution", as it used to be called, has been based primarily on the development of high-yielding crop varieties (mainly of wheat and rice) and on the intensification of the principles of plantation
agriculture which have served mankind so well in temperate regions and also, for some crops and on some sites, in the tropics.

Unfortunately, the high-yielding crop varieties that are being promoted for use in the tropics seem to require costly inputs of fertilisers, water, pesticides and energy, which few developing countries are able to afford to the extent necessary. Moreover, the areas which are generally and correctly identified by tropical agronomists as being suitable for the growth and production of these high-yielding cereals do not comprise the bulk of tropical land. For these and other reasons, these types of agriculture have not expanded rapidly enough, significantly to reduce the number of people in the developing world who are forced to depend for their very existence on food that is produced:

(i) in the arid and semi-arid zones of this world;
(ii) in the acid savannas of the tropics;
(iii) on the slopes of the mountains of the tropics and sub-tropics; and
(iv) by practising shifting cultivation in the forest areas of the developing world.

I have ascribed the term fragile ecosystems to these areas because their equilibrium appears to be easily upset and because they become ecologically degraded if certain forms of land-use, particularly sedentary agriculture, are practised in them. They have also been described, from another point of view, as wasted lands (King and Chandler, 1978) because they represent areas in which the natural resources are currently being wasted either through overexploitation, underutilisation and mismanagement or through sheer neglect.

THE PLIGHT OF THE POOR

We have estimated that 4,900 million hectares, or 65% of the land in the tropical world may be classified as being "wasted" or as occupying fragile ecosystems. These lands are found in the poorest countries in the developing world. The number of people who depend upon these areas for their food and livelihood is 630 million or 35% of the total population of the developing countries (King, 1978). The people who live in these areas are, on average, poorer than those who live in other parts of their already poor countries. They are thus the poorest of the world's poor.

They cannot afford to purchase food from other less brittle and fragile ecological zones. Accordingly, if they must eat they must either be given "food aid", or be made to settle in areas that are better suited to permanent arable agriculture, or be given alternative occupations so that they might earn money to buy food, or produce food for their sustenance in these fragile ecosystems.

Although food aid is not to be rejected out-of-hand, it must be regarded as essentially an emergency measure. A nation or part of a nation should not be forced to depend upon such assistance for one of the basic necessities of life.
The resettlement of large populations is not only costly, it is bedevilled by a number of social problems which have led to the failure of most of the land settlement schemes that have been attempted in the Third World.

The developing countries find it increasingly difficult to create job opportunities for their citizens. Indeed the average rate of unemployment in the developing world is over 25%. Moreover, the rate of job creation is lowest among those who inhabit the fragile ecosystems of the tropics, partly because of the dearth of industrial skills in these areas, partly because of the paucity and inadequacy of training and educational facilities, and partly because the natural resources that are to be found in these zones do not readily permit the transference of modern techniques. It is therefore not surprising that the third possibility which has been mentioned above, has also not often been tried, and when tried, has not significantly affected the purchasing power of the communities.

The consequence of this failure to offer alternative sources of income or food is that most of the inhabitants of fragile ecosystems must perforce, now and in the foreseeable future, themselves provide their own food.

THE DEGRADATION OF TROPICAL LAND

However, studies of the arid and semi-arid zones reveal a history of degradation of vegetation and soils, and a reduced productivity of both natural and "managed" ecosystems. Traditionally, the populations of these areas have coped with the extreme environment by practising forms of land-use that were extensive, by being mobile, and by being a part of a social system that was based on economic inter-dependence. Today, the rapid increase of populations and the introduction of inappropriate technologies have resulted in the removal of protective trees and shrubs for fuel and shelter, and the cultivation of soils that are ill-suited to arable agriculture. Moreover, many of the intensive farming practices that have been attempted, although increasing yields in the short-run, have made the soils more vulnerable to erosion and have indeed led to desertification. In addition, in areas where there is a close connection between dryland cultivation and grazing, the collapse of the crop-based system tends to lead to the failure of the pastoral (King and Chandler, 1978).

The situation in the acid savannas, which are to be found mainly in South America, is no less reprehensible. Here again, an extensive resource is not only being underutilised, it is also being degraded. The savannas in this fragile ecosystem have soils that are acid and toxic. Even though the land is generally level, extremely poor soil strength in terms of cohesion and friction makes the soils susceptible to erosion if the plant cover is disturbed. And yet, crop farmers in these areas customarily practise rotational burning of the mature forage during the dry season to obtain tender forage for cattle feeding. Despite the practice, however, the savannas have a low grazing capacity, much of the area being capable of supporting only one head for
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every 8—16 ha. The returns to the society for the ecological degradation that is caused on these sites are therefore low.

Forests, in tropical and sub-tropical mountain ecosystems, are being razed to the ground at alarming rates to provide wood for fuel and shelter to rapidly growing populations, and to yield land for farming for food for the inhabitants of these areas. The improper land-use of upland areas obviously affects the development of those who live there. What is perhaps more important, is that malpractices in the utilisation of the slopes of these hills and mountains often lead to erosion, increased run-off, siltation of the rivers, flooding and droughts. Agricultural productivity in the often more fertile and higher-yielding valleys is therefore adversely affected; irrigation works are rendered ineffective, and the rate of both agricultural and industrial development is reduced. The ravages of the forests in mountain ecosystems are to be observed mainly on the foothills of the Himalayas, and it is perhaps no coincidence that the highest incidence of recurring floods and droughts is to be found in the Indian sub-continent.

Shifting cultivation is practised on every continent that is occupied by developing countries. In general, the systems described by the term "shifting cultivation" are characterised by the felling and burning of woody vegetation, followed by one to several years of cultivation, and then by a period of forest or brush fallow. After fallow, the cycle is repeated. Shifting cultivators produce food for more than 250 million people, but in doing so, because in recent times they have had to reduce the fallow periods to accommodate increasing populations, soils have become degraded, indeed often to the point of making the land incapable of supporting further crops. In addition, only about 15% of the timber cut is utilised, the wastage being estimated at $50 per hectare per annum. The practice of shifting cultivation has destroyed thousands of hectares of forests, valuable timber resources have been depleted and the protective cover removed from vast watershed areas.

It is evident that in all the areas which I have described as being "fragile ecosystems", the necessity for food has forced the occupants to employ land-utilisation practices which have led to the degradation of the ecosystems.

Now, the conventional scientific wisdom would prescribe forestry as the "best" type of land-use for these areas. The foresters and the conservationists would point out with truth that there are many species of tree which can be grown on poor soils; that trees exist in a closed self-sustaining nutrient cycle; that forests maintain and improve the fertility of the soils beneath them; that natural and well-managed tropical forests tend to have a multi-storeyed structure which, together with the litter and humic layers, provides several lines of defence against rain, reduces soil compaction and increases infiltration, and thus minimises the incidence of floods and droughts.

"Unfortunately, the people who live in those areas for which the conventional land-utilisation wisdom prescribes that only protection forests be established, find
it difficult to subsist on the forests alone. In addition to their need for wood for cooking and heating they require food. Indeed, the demand for food is often the dominant imperative in these societies .... "It therefore seems necessary to attempt to devise and perfect a system of land management, which eschews the false dichotomy of agriculture and forestry, which conserves the ecosystem, and which at one and the same time provides food and wood. Such a system is agroforestry" (King, 1978).

AGROFORESTRY

Agroforestry has been defined as a "sustainable land management system which increases the yield of the land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentially on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population (see Bene et al., 1977; King and Chandler, 1978).

As King (1978) has pointed out, *agroforestry* is a generic term which embraces the following components:

*agri-silviculture* — the conscious and deliberate use of land for the concurrent production of agricultural crops (including tree crops) and forest crops;

*sylvo-pastoral systems* — land management systems in which forests are managed for the production of wood as well as for the rearing of domesticated animals;

*agro-sylvo-pastoral systems* — systems in which land is managed for the concurrent production of agricultural and forest crops and for the rearing of domesticated animals;

*multipurpose forest tree production systems* — in which forest tree species are regenerated and managed for their ability to produce not only wood, but leaves and/or fruit that are suitable for food and/or fodder.

I shall now confine my remarks to agri-silvicultural systems. This is not to deny that the other systems have an important role, indeed a germane role, to play in the management of fragile ecosystems. The restriction in treatment is partly because of convenience, and partly because a discussion of the problems of agri-silviculture would also serve to illustrate the problems of the other systems.

THE EVIDENCE OF THE POSSIBILITIES OF AGROFORESTRY

What is the evidence which suggests that forest trees and agricultural crops can be grown together without deterioration of the site? The evidence may be gleaned from several sources.

First, there is the evidence which is gained from the practice of the *taungya* system. Blanford (1958) has described how the taungya system was begun in Burma in 1856. Since then the system, though called by various names (see King, 1968), has spread throughout Asia, and to Africa
and Latin America. Many of the forest plantations which have been established in the tropical world, particularly in Asia and Africa, owe their origin to the system. There is little doubt, therefore, that in the initial stages of a forest plantation's existence trees can be grown together with annual agricultural crops (see King, 1968 and Von Hesmer, 1966, 1970, for lists of the tree and agricultural crops that are generally grown together). There is also evidence that generally most agricultural crops have no adverse effects on forest crops and vice versa. Indeed, some workers have reported higher yields from both types of crops in certain circumstances and under certain conditions (see e.g. Shebbeare, 1932; Mackay, 1952; Griffith and Howland, 1958; Fishwick, 1961; Ogbe, 1967).

Secondly, there is the evidence from the traditional farming practices of the tropics. One example will suffice. Wilken (1977) has pointed out that some societies simulate forest conditions in their farms in order to obtain the beneficial effects of forest structures. For instance, farmers in Central America imitate the structure and species diversity of tropical forests by planting a variety of crops with different growth habits. Plots of no more than 0.1 ha contain two dozen different species of plant each with a different form, and together corresponding to the layered configuration of mixed forests: coconut or papaya with a lower layer of bananas or citrus, a shrub layer of coffee or cacao, tall and low annuals such as maize and beans, and finally a spreading ground cover of plants such as squash.

And third, there is the evidence which is emerging from the mixed cropping of annual crops. Most authorities now appear to agree that the mixed cropping of annual crops is a more efficient means of utilising land area than are pure stands (Fisher, 1976).

It would appear, therefore, that there are sufficient grounds for assuming that agri-silvicultural systems might provide one of the answers to the utilisation of fragile ecosystems.

RESEARCH NEEDS

There is, however, a great need for further research. The shade tolerance of various agricultural species must be tested. Forest species which protect the soil but do not reduce energy levels on the forest floor must be identified. Optimum espacements for both types of crop must be ascertained. Thinning regimes designed to optimise the yields of both the tree and agricultural crop must be established. Optimum species combinations must be investigated.

In addition, the following fundamental studies must be undertaken to underpin the field work described in the previous paragraph and to provide eventually, a body of basic principles. Studies of:

(i) the dynamics of the various nutrient cycles which occur when the forest is cleared, during the cropping period, and during fallow;
(ii) the alleopathy and complementarity of various species;
(iii) the competition for solar energy among trees and between trees and agricultural crops;
(iv) the morphology and physiology of various tree species;
(v) leaf production and leaf fall of particular species and the influence of their occurrence on competition for solar energy and the nutrient cycle, respectively.

Moreover, new breeding schemes should be designed to obtain in both forest and tree species those characteristics that are considered necessary for successful and efficient intercropping.

It was because of the potential importance of agroforestry, the need for research, and the difficulty of conducting such research that the International Council for Research in Apofotestry (ICRAF) was established.

ICRAF is an autonomous non-profit, international institute, the objective of which is to improve the social, economic and nutritional well-being of the peoples of the developing countries by promoting agroforestry systems to achieve better land use in developing countries without detriment to their environment; encouraging and supporting research and training in agroforestry systems; facilitating the collection and dissemination of information relevant to such systems; and assisting in the international co-ordination of agroforestry development.

The issue in tropical land-use is to devise means of utilising the resource, improving productivity, and at the same time conserving the ecosystem. These objectives may appear to be conflicting. In some cases they may be, but in the majority of cases systems can be devised which will protect the environment as they produce. Agroforestry is one such system.

REFERENCES