



**AGRO-FORESTRY
PROSPECTS AND PROBLEMS'**

K. F. S. KING'

Forest Industry Lecturer

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THE FOREST INDUSTRY LECTURES

Forest industry in northwestern Canada is cooperating with Alberta Energy and Natural Resources to provide funds to enrich the Forestry Program of the Faculty of Agriculture and Forestry at the University of Alberta through sponsorship of noteworthy speakers.

The Forest Industry Lecture Series was started during the 1976-77 term as a seminar course. Desmond I. Crossley and Maxwell T. MacLaggan presented the first series of lectures. The contribution of these two noted Canadian foresters is greatly appreciated.

Subsequent speakers in the series have visited for periods of up to a week, with all visits highlighted by a major public address. It has indeed been a pleasure to host such individuals as C. Ross Silversides, W. Gerald Burch, and Gustaf Siren. The subjects of their talks are listed on the last page.

This booklet contains Dr. K. F. S. King's major public address given on 27 September 1979. Dr. King's talk was recorded, with his permission, at the time of delivery. This paper represents a transcript of the talk edited by staff of the Faculty of Agriculture and Forestry for publication.

We would like to take this opportunity to express our thanks again to the sponsors of this program — we appreciate very much their willing and sustained support:

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Dr. Kenneth King has been Director-General of the International Council for Research in Agroforestry (ICRAF) in Nairobi, since 1977.

Dr. King was raised in Guyana and worked for four years as a forest ranger in the silviculture section of the Guyana Department of Forestry. He then earned degrees of Bachelor of Laws from London University in 1956, B.Sc. from the University of North Wales with first-class honours in 1958, and the Ph.D. from Oxford in 1963. Awards included the Schloch Memorial Prize in 1962, Oppenheimer Foundation Award, and a FAO Fellowship in 1962.

His career experience included Division Forest Officer and Research Officer in charge of research for Guyana. He joined FAO in 1964 in the Forestry and Forest Products Division, becoming advisor on forest policy and management in Nigeria. With FAO he became successively Chief, Department Planning Section, and Forestry and Land Use Officer in Rome. He returned to Guyana in 1972 as Minister of Economic Development and Vice-President of the Guyana State Corporation with responsibility for 17 corporations and companies. In 1974 he rejoined FAO as Assistant Director-General of FAO,

and Head of the Department of Forestry. From that position he went to his present ICRAF position in Nairobi.

Dr. King has about 50 publications to his credit dealing with research and policy. **In** 1973 he received two distinctive honours, awarded the Order of the Republic Forest Class of the Arab Republic of Egypt, and Commander of the National Order of the Republic of Guinea.

AGRO-FORESTRY: PROSPECTS AND PROBLEMS

Ecosystem degradation

The economic conditions under which most people in developing countries exist, and the harsh conditions which often make their physical environment one of the most inhospitable in the world, force us to look in a more scientific manner than we have in the past, at forms of land use which would return higher sustained yields than methods conventionally advocated by the experts of the west and north. These must be forms of land use which do not require high capital inputs, land use methods designed for the people.

There have been, during the last 20 years or so, remarkable advances in tropical agriculture. Indeed, according to some, 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 wheat and rice, and on the intensification of the principles of plantation agriculture. This has served mankind well in temperate regions and, for some crops on some sites, in the tropics. Unfortunately the high yielding varieties that are being promoted for use in the tropics require costly inputs of fertilizers, 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 varieties do not comprise the bulk of tropical lands. This type of agriculture has not, therefore, significantly reduced the number of people forced to depend for their very existence on food produced in the arid and semi-arid regions of the developing world, in the acid-savannas of the tropics, on mountain slopes of the tropics and sub-tropics, or by shifting agriculture in the forests of the developing world.

I ascribe 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 practiced on them. They have also been described from another point of view as

wasted lands because they represent areas in which the natural resources are currently being wasted, either through over-exploitation, under-utilization and mismanagement, or from sheer neglect. We have estimated that 4,900,000,000 hectares, or 65% of lands in the tropical world, can be classified as wasted lands or as occupying fragile ecosystems.

These lands are found in the poorest countries of the developing world. The number of people who depend on these areas for their food and livelihood is 630,000,000 or 35% of the total population of the developing world. 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, therefore, the poorest of the 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, be made to settle in areas that are better suited for permanent arable agriculture, be given alternative occupations so that they might earn the money to buy the food they need, or produce food for their very sustenance in these fragile ecosystems.

Although food aid is not to be rejected out of hand, to my mind it must be regarded as essentially an emergency measure. A nation, or part of a nation, should not be forced to depend on such assistance for one of the basic necessities of life.

The resettlement of large populations is not only costly, it is bedeviled by a number of social problems which have led to the failure of most of the land settlement schemes attempted in the third world.

The average rate of unemployment in the developing world is over 25%, and developing countries find it increasingly difficult to create job opportunities for their citizens. Moreover, the rate of job creation is lowest among those who inhabit the fragile ecosystems of the tropics. This is partly due to a 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, particularly modern techniques of agriculture. It is, therefore, not surprising that the third possibility, that of providing alternative occupations, has not often been tried in these areas, and

when it has been tried it has not significantly affected the purchasing power of 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, provide their own food from their own resources.

Studies of the arid and semi-arid zones reveal a history of degradation of vegetation and soils and reduced productivity of both natural and managed ecosystems. Traditionally the populations of these areas have coped with their extreme environment by practicing forms of land use that were extensive, by being mobile, and by being a part of a social system based on economic interdependence.

The rapid increase of populations in these fragile ecosystems, and the introduction of inappropriate technologies, have resulted in the removal of protective trees and shrubs, for fuel and for 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 led to desertification. In addition, in areas where there is a close connection between dry land cultivation and grazing, the collapse of the crop-based system tends to lead to failure of the pasturage system.

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 under utilized, it is also being degraded.

The savannas in this fragile ecosystem have soils which are acid and toxic. Even though the land is generally level, extremely poor soil strength, in terms of cohesion and friction, make the soils susceptible to erosion if the plant cover is removed. And yet, crop farmers in these areas customarily practice rotational burning of mature forage during the dry season to obtain tender forage for their cattle. Despite this practice the savannas have a low grazing capacity, much of the area being capable of supporting only one head for every eight to sixteen hectares. The returns to society for the ecological degradation caused on these sites are low.

Forests in tropical and sub-tropical mountain ecosystems are being razed to the ground at alarming rates to provide fuel and shelter and cleared land for farming, to feed and house the rapidly growing populations of these regions.

This improper land use obviously affects the development of those who live there. What is perhaps more important though, is that malpractices in the utilization of the slopes of these hills often lead to erosion, increased runoff, siltation of the rivers, flooding and droughts which adversely affect agricultural productivity in the fertile neighbouring valleys. Irrigation works are rendered ineffective and the rate of both agricultural and industrial development is reduced.

The ravages to 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 are to be found on the Indian sub-continent.

Shifting cultivation is practiced on every continent that is occupied by developing countries. In general, systems described by the term shifting cultivation are characterized by a repeated cycle of felling and burning of woody vegetation followed by one to several years of cultivation and then by a fallow period of forest or brush cover.

Shifting cultivators produce food for more than 250,000,000 people but in doing so, because fallow periods have been reduced to accommodate increasing populations, soils have become degraded, often to the point of making the land incapable of supporting further crops. In addition, only about 15% of the timber cut by shifting cultivators is utilized, the wastage being estimated at \$50/hectare/annum.

The practice of shifting cultivation has destroyed thousands of hectares of forests. Valuable timber resources have been depleted and, perhaps more important, the protective forest cover has been removed from vast watershed areas.

Search for an alternative

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

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

Unfortunately, the people who live in these areas, for which the conventional land utilization prescription is that of protection forest establishment, find it difficult to subsist on the forest alone. In addition to their need for wood for cooking and for heating they require food. Indeed, the demand for food is often the dominant imperative in these societies.

It therefore seems necessary to devise and perfect a system of land management which refuses to recognize the traditional distinction between agriculture and forestry, which conserves the ecosystem, and which at one and the same time provides food and wood. Such a system is agro-forestry.

Agro-forestry has been defined as a sustainable land management system which increases the yield of the land, combines production of tree crops and agricultural 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.

Agro-forestry is a generic term which embraces the following components: agri-silviculture which is the conscious and deliberate use of land for the concurrent production of agricultural crops and forest crops; silvo-pastoral systems in which forests are managed for the production of wood as well as for the rearing of domesticated animals; agri-silvo-pasturage systems in which land is managed for the concurrent production of agricultural and forest crops and for the rearing of domestic animals; and multi-purpose forestry production systems in which forest tree species are regenerated and managed

for their ability to produce not only wood, as is the conventional objective in forestry, but also leaves and/or fruit that are suitable for food and/or fodder.

The forest: an essential component

Now, what are the premises on which agro-forestry is based? The first premise rests on the ameliorating effects of trees.

The most important properties of the earth's surface which affect climate and which human activity can influence, are reflectivity, heat capacity, conductivity, availability of water, atmospheric dust, aerodynamic roughness, emissivity in the infra-red band, and heat release to the ground. In all these aspects the forests are important.

The reflectivity of the forest is low because of the high light-absorptive capacity of green leaves. Indeed, it is well established that densely built-up areas and deserts, as well as grasslands, have a higher albedo than forests, and that a unit increase in the earth's albedo will cause a decrease in average surface temperature of about 1.1°C.

Recently, in an interesting experiment, two integrations of a global general circulation model, differing only in the prescribed surface albedo of the Sahara, showed that increased albedo resulting from a decrease in plant cover caused a decrease in rainfall. Thus it appears that any tendency for plant cover to decrease would be reinforced by a decrease in rainfall which could initiate or perpetuate a drought.

Because large amounts of latent heat are fixed during the evapotranspiration process the capacity of forests to absorb heat is very high. In contrast, forests have a low heat conductivity because their thick and complex structure prevents rapid cooling or heating, thereby regulating heat release to the ground.

Forests also regulate water supplies by restricting runoff during peak rainy periods and releasing water through springs and rivers during the dry season. Thus, the total amount of water available for use may be significantly increased through its release from the forests in those seasons when it is needed most. In addition, forests act as windbreaks, create aerodynamic roughness and assist in arresting dust particles, and their emissivity of the infra-red band is

very high. It is evident, therefore, that forests affect many important climatic factors.

Forests also affect the composition of the atmosphere. Green plants convert radiant energy from the sun into chemical energy. During this process of photosynthesis, carbon dioxide is assimilated and oxygen is released. Total natural photosynthesis is estimated to fix nearly 80,000,000,000 tons of carbon a year. When it is realized that nearly half of this process occurs in forests, their significance as atmospheric purifying agents should be clearly appreciated.

The point I'm trying to make is that forests are one of the climatic buffers on which mankind depends. A buffer which, because of its complex organic structure, is able to withstand somewhat severe perturbations of its physical environment provided the changes and stresses to which it is subjected are not pushed beyond a certain threshold.

In addition, the unique physiognomy of forests, together with their litter and humic layers, minimizes compaction of the forest soil by rainfall and protects the earth against erosion. Thus, the presence of forests in critical areas reduces the possibility of siltation of rivers and reservoirs, effectively prevents the denudation of the countryside, and contributes significantly to economic activity in neighbouring valleys.

I think that forests are of special significance to the survival of mankind in tropical rural areas. In many areas of the tropics there can be no agriculture as we understand it, and as we know how to practice it, without forests. In other words, the presence of forests in critical areas, in certain types of watersheds, is an absolute necessity if tropical agriculture is to flourish.

I am not saying that everywhere in the tropics forests must protect agricultural lands, or must be planted with agricultural crops. I am saying that in some places, where the slopes are steep, the rainfall intense, and the soil erodible, or where the ecosystems are otherwise fragile, forests must be retained.

I am not saying that in each tropical country 20 or 25%, or some such magical proportion, of the total land area should be under forests. What I am asserting is that in some regions, in some areas, it may be necessary to retain all the forests. It is not a question of a statistical balance between forests and

other forms of land use. Whether forests are retained or not retained will depend upon a careful analysis of the ecological factors of each area. It is my contention that such analyses would reveal that a high proportion of the watersheds in most tropical countries should remain in forest, or become clothed with forest, if tropical agriculture is to begin to meet the demand for food.

Agro-forestry: a developing science

I hope that I have now made the point that forests have an extremely important part to play in land use. I turn now to a consideration of the incorporation of forestry into agricultural systems, and/or the incorporation of agriculture into forestry systems. Although other forms of agro-forestry have an important role, indeed a germane role, to play in the management of fragile ecosystems, I shall confine my remarks to agri-silvicultural systems. This restriction in treatment is in part for convenience and partly because I believe that discussion of the problems of agri-silviculture will also serve to illustrate the problems of the other agro-forestry systems.

What is the evidence to suggest that forestry and agricultural crops can be grown together without deterioration of the sites?

First there is the evidence which is gained from the practice of the so called 'taungya' system. An Englishman called Benford has described how the 'taungya' system was begun in Burma in 1854. Since then this system, called by various names, has spread throughout Asia, to Latin America, and to Africa. Indeed, many of the plantations which have been established in the tropical world, particularly in Asia and Africa, owe their origin to this system of agri-silviculture. There is, therefore, little doubt that in the initial stages of a forest plantation, trees can be grown together with annual agricultural crops. There is also evidence that, generally, most agricultural crops have no adverse effects on tree crops, and *vice versa*. Indeed, some workers have reported higher yields for both types of crops in some circumstances and under certain conditions.

Secondly, there is evidence from traditional farming practices of the tropics. An American, who has been working in Latin America, 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 1/10 hectare may contain two dozen different species of plants, each of a different form which together correspond to the layered configuration of a mixed tropical forest. A typical farm plot might have an upper story of coconut or papaya, a lower layer of bananas or citrus, a shrub layer of coffee or cocoa, tall and low annuals such as maize and beans, and finally, spreading ground cover plants such as squash.

There is also evidence emerging from the mixed cropping of annual crops. Most authorities now appear to agree that mixed cropping of annual crops is a more efficient means of utilizing land area in the tropics than cropping pure stands.

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

There is, however, a great need for 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 spacings for both types of crop must be ascertained. Felling regimes designed to optimize the yields of both the tree and agricultural crop must be established. Optimum species combinations must be investigated.

In addition, fundamental studies must be undertaken to support this applied research, and to provide, eventually, a body of basic principles. There should be studies of the dynamics of the various nutrient cycles which occur when forests are cleared, during the cropping period, and during fallow; studies of the allelopathy and complementarity of various species; studies of the competition for solar energy among trees, and between trees and agricultural crops; studies of the morphology and physiology of various tree species; of leaf production and leaf fall of particular species and their influence on competition for solar energy and on the nutrient cycle.

It seems to me, from a search of the literature, that the ideal agro-forestry tree can at least be described. It should be tolerant of early wide spacing, and it should be self-pruning or be amendable to early and intensive pruning. By this I mean that, if heavily pruned, its photosynthetic

efficiency should not be unduly impaired. The architecture of the tree should be such that it permits intercropping with agricultural species, it should be light branching, and its phylotaxy should be such that it permits maximum penetration of solar energy to the soil beneath.

In addition, its roots should tap areas of soil not normally tapped by the agricultural intercrop species, thereby serving as an efficient nutrient pump to bring nutrients up from the lower layers of the soil. In this way it would eventually, through the deposition of litter, the conversion of the litter to humus, and the subsequent incorporation of the humus into the soil itself, add nutrients to the rhizosphere of the intercrop plants. The point that I am making here is that, in agro-forestry systems, choosing tree species which root deeply into areas that are not normally exploited will, in effect, add fertilizer to the normal rhizosphere of the soil.

The phenology of the tree, particularly in leaf flush and leaf form, should assist the growth of the agricultural species. In this respect a species found in Africa, *Acacia albida*, is interesting. This species loses its leaves at the onset of the rains, thus providing the intercrop plant with valuable nutrients. At the same time, by losing its leaves at the beginning of the growing season, it permits the maximum amount of sunlight or solar energy to penetrate to the ground when the agricultural species need it most. In addition, it keeps its leaves in the dry season, thus protecting the agricultural plants from the adverse effects of sun, heat, and wind, when such protection is needed most.

Finally, the ideal agro-forestry tree should be capable of fixing nitrogen. Although this list of desirable characteristics is by no means exhaustive, I submit that it is sufficient to indicate the type of forest species for which we are looking.

Here I emphasize the necessity for breeding programs which bear these characteristics in mind. Genetic selection in forestry to date has been confined almost exclusively to the pursuit of fast-growing, high-yielding, varieties for timber production. What we need to look for in agro-forestry are characteristics which complement the growth habits of the agricultural crops, particularly the rooting capacity and above ground architecture of the tree.

I think that it should be evident by now that what I am advocating is, in many respects, a radical departure from agriculture and forestry as they are

currently practiced in the north, and as they are transferred from the north to the south by those that are euphemistically called experts, under schemes that are, even more euphemistically, called aid.

If successful agro-forestry schemes are to be implemented there is a great need for institutional change. I have enumerated the gaps in our knowledge and the need for more research. However, it is my considered opinion that the fundamental prerequisite is for change in our educational systems. Foresters and agriculturalists must be trained to be land managers: They must be taught to view the problems of land use, not in a myopic manner, but as a system. They must be made to realize that both great professions, agriculture and forestry, each possess a considerable amount of knowledge that can complement the other. It is to the universities, which have contributed much to the perpetuation of this false dichotomy between agriculture and forestry, that we must look for this needed change.

In addition, there must be changes in the forest laws which now exist in the developing countries. These pieces of legislation are perhaps the most primitive in the world, and were, in fact, designed for the forests and for foresters, not for the people.

If we are to encourage integrated land use, if we are to support the practice of agro-forestry, then our laws should be more progressive and more developmental. The farmer should be permitted to come into the forest. They should not be excluded from forest reserves that have been established without benefit of land capability classification or land use planning.

Agro-forestry: a workable solution

I have been asked, in advocating the practice of agro-forestry in developing countries, whether we are not recommending a regression to the primitive? I have been asked if such a system does not condemn the African, the Asian, and the Latin American peasant, to a life of poverty?

It has been suggested that advocates of agro-forestry, by implicitly denying these people the sophisticated implements of modern agricultural technology, are sentencing them to be forever hewers of wood and drawers of water. I submit that this is indeed their present life, and this will be their lot in the foreseeable future if present practices continue to be followed.

Indeed, the World Bank, in its most recent annual report, underlined the stark reality of the contemporary world. The report says that whatever action is taken, whatever remotely credible economic growth rate is possible, there is absolutely no possibility that the poor countries of the world will ever achieve what passes at present for an adequate standard of living among the rich. The figures for the past 10 years provide no hope that the so called gap between the developing and industrialized world may be narrowed. The report states that, "Even if the developing countries were to manage to double their per capita growth rate, while the industrialized countries maintain their own, it would take almost a century to close the absolute gap between the rich countries and the poor countries".

The point I am delivering to you is that, in pursuing our present disastrous course, we have no hope of substantially raising the standard of living of the people who inhabit the third world in general, and certainly much less hope of raising the level of income and the standard of living of the people who inhabit the areas which I have described as fragile ecosystems, and in which I think agro-forestry should be practiced.

All this is based on the assumption that we do not evolve different means of development, and that we do not seek different definitions, parameters, and objectives for development in these areas.

It is my belief that agro-forestry is one small, insignificant, system which may help us to get our priorities right and to chart new courses of tropical land use. The issue in tropical land use is to devise means of utilizing the land resource, improving productivity, and at the same time conserving the ecosystem. The issue is to devise means which are capable of adaptation in the social, economic and physical environment.

These objectives may appear to be conflicting. In some cases they may be, but in the majority of cases it seems to me that systems can be devised which will protect the environment as they produce, systems for conserving the ecosystems, and raising and sustaining productivity.

Agro-forestry is one such system.

FOREST INDUSTRY LECTURE SERIES

1. Industrial Forestry in a Changing Canada, by C. Ross Silversides. 17 November, 1977.
2. The Role of Integrated Forest Companies in Western Canada, by W. Gerald Burch. 15 March, 1978.
3. Premises of Energy Forestry in Sweden, by Gustaf Siren. 7 March, 1979.
4. Agro-forestry - Prospects and Problems, by K.F.S. King. 27 September, 1979.

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