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1. INTRODUCTION

In the recent past, there has been a reawakening among the community of scientists and other experts dealing with land use systems about the value of age-old integrated land use systems. With the scientific attention focussed on multiple cropping and the awareness about the inappropriateness of most of the high-input agricultural technologies for most farmers in the tropics, the search for resource-conserving, socially acceptable farming systems was accelerated. This resulted in a growing appreciation of the relevance of integrated, sustainable, multiple-output land-use systems and the productive and protective value of trees on farmlands.

On the forestry front, the seriousness of forest destruction was realized and its alarming consequences analysed, and it became clear that the major cause of deforestation was the search for more and more areas to produce food and obtain fuelwood. Thus, in the wake of these mounting pressures of food and fuel shortages, and the serious environmental problems associated with deforestation, it was no longer prudent to ignore the conservation benefits and the potential for sustained yields provided by tree-based farming systems.

With this increasing awareness about the role and value of trees and other woody perennials in the everyday life of rural communities, several terms such as village forestry, social forestry, farm forestry, forest village, community forestry, and so on have appeared in common usage among the community of experts. Depending on the priority of objectives and, to some extent, according to the personal opinions and biases, the definitions and interpretations of the terms vary; but in common parlance most of these terms have often been used synonymously, and sometimes even out of context. But strictly speaking, each of the terms has distinct connotations; some are land-use systems (e.g. farm forestry); others are land (forest) management approaches (e.g. community forestry). In a general sense, all these terms denote one or the other form of integration of trees with components of other disciplines relevant to land use and rural development. Although the trees so used are usually neither the conventional forestry species nor are they managed as in a forestry community (natural or planted), all these terms have, unfortunately, a semantic emphasis on

forestry as though they are specific branches of forestry. Agroforestry (AF), which has now got established as an all-embracing generic term for a wide range of integrated land management approaches and systems involving woody perennials to encompass, if not eliminate, most of the earlier-mentioned terms with 'forestry' endings, also caused such a confusion initially about its identity vis-a-vis forestry. However, with a better understanding of the concepts and principles of AF as well as of its role, AF has now earned a distinct identity of its own, as an approach to land use involving deliberate retention or inclusion of trees and other woody perennials in the crop/animal production fields (Lundgren and Raintree, 1983; Nair, 1983a; forthcoming).

2. AGROFORESTRY SYSTEMS

2.1. Systems Overview

Several of the existing land use systems encompass the concept of AF although they have been in existence over a long priod of time without being known by this relatively new name. In order to increase the understanding about AF, an inventory of such systems and practices existing in different parts of the world, with special emphasis on the developing countries, is currently (1982-) being undertaken by the International Council for Research in Agroforestry (ICRAF). The project, with partial financial support of USAID, aims at collecting, collating and synthesizing information on prominent and promising AF and other related land use systems with a view to preparing a state-of-the-art of global AF, identifying the constraints, weaknesses and merits of major AF systems and assessing their research needs. A large number of active AF enthusiasts and other knowledgeable individuals and institutions around the world are collaborating in the task, mainly as resource sources for data gathering. Based on the information gathered thus far in the project, an "Agroforestry Systems Overview" Table has recently been prepared (Nair, forthcoming), which is presented as Table 1.

TABLE 1 HERE

It is an abstract Table, derived from detailed information gathered and stored at ICRAF. As an amplification of the Table, a more detailed

account of some of the prominent examples of such AF system and practices with emphasis on the woody species involved, is given in Table 2.

TABLE 2 HERE

These two Tables give a summary overview of AF systems. They indicate that AF is wide-spread in the developing countries in almost all ecological regions.

2.2. Classification of Agroforestry Systems

One of the major difficulties in improving existing AF systems is that quantitative information does not exist on the structure, function, dynamics and other operational aspects of the systems. Therefore, a concise and critical assessment on the role and contribution of AF to the economy and development of the countries concerned is possible at the moment only in qualitative terms, which is not often very appealing. In order to evaluate the existing systems and develop action plans for their improvement, it is necessary to classify these systems and thus provide a practical and realistic framework. Several criteria can be used to classify and group AF systems. The most commonly used ones are the system's structure (composition and arrangement of components), its functions, its socio-economic scale and level of management, and its ecological spread, as given in Table 3 (Nair, 1985).

TABLE 3 HERE

However, since there are only three basic sets of components that are managed by man in all AF systems, viz, woody perennials, herbaceous plants and animals, a logical first step is to classify AF systems based on their component composition. Thus there are three basic types of AF systems: agrisilvicultural (crops -- including tree/shrub crops -- and trees), silvopastoral (pasture/animals + trees), and agrosilvopastoral (crops + pasture/animals + trees). Other specialised AF systems such as apiculture with trees, aquaculture in mangrove areas, multipurpose tree lots, and so on, can also be specified. Various

subsystems and practices can also be identified under each of these major systems as illustrated in Fig. 1.

FIG. 1 HERE

Arrangement of components in AF systems can be in time (temporal) or space (spatial) and several terms are used to denote the various arrangements. Functional basis refers to the main output and role of components, especially the woody ones. These can be productive functions (production of "basic needs" such as food, fodder, fuelwood, other products, etc.) and protective roles (soil conservation, soil fertility improvement, protection offered by windbreaks and shelter-belts, ans so on). On an ecological basis, sytems can be grouped for any defined agro-ecological zone such as lowland humid tropics, arid and semi-arid tropics, tropical highlands, and so on. The socio-economic scale of production and level of management of the system can be used as the criteria to designate systems as commercial, 'intermediate', or subsistence. Each of these criteria has merits and applicability in specific situations, but they have limitations too so that no single classification scheme can be accepted as universally applicable. Classification will depend upon the purpose for which it is intended. See Nair (1985) for a detailed account on this.

3. USE OF UNDER-EXPLOITED SPECIES IN AGROFORESTRY

3.1. Agroforestry Species

Since agriculture and forestry (in the widest sense of the terms) are the major land use activities, most of the economic plants that are widely cultivated by man are also usually considered to belong to these categories. And, though not based on any precise criteria, there is an apparent distinction between these two groups of crop plants. Thus, species regarded as belonging to agriculture have included mostly (but not exclusively) herbaceous ones that were cultivated with much managerial attention and harvested at frequent intervals for their most important economic produce, either through repeated generations of the same short-duration species, or by repeated

harvesting from the same plant. Foresters, on the other hand, concentrated on woody perennial species that could be cultivated on a large scale, the main objectives being the maximum return of the final product at the end of the fairly long production cycle.

There are also specific groups of species like the so-called "horticultural" crops that transcend the limits of these criteria. But there are no "conventional" agroforestry species because the name agroforestry is new (although the practice is old). Therefore most plant species that are used/found in the various AF systems described above fall under one or the other of the conventional disciplinary groups. Besides, there are also other plants, especially woody ones, which have hitherto been little-studied, but which form important components of existing AF systems, or may prove valuable for potential AF systems.

Based on the experience gained from intercropping and other forms of crop combinations with tree crops, Nair (1980) evaluated the "AF suitability" of a number of conventional agricultural species. He observed that with the knowledge of the ecophysiological requirements of different groups of plants in general, and of the individual species or cultivars in particular, some predictions could be made with a reasonable degree of accuracy about the conditions that are optimum for their best growth. Table 4 gives a summary account of the suitability of these different agricultural species to various ecological regions.

TABLE 4 HERE

It is possible to list a large number of physiological and agronomical characters that decide the compatibility of these species in admixture and the ability of the species to produce a reasonable yield under conditions of reduced supply of growth factors such as light and nutrients where it is grown as an understorey species. Furthermore from the practical viewpoint, the ease of management of the species, its ability to withstand adverse climatic and managerial conditions, its adaptability to low-input systems and marginal areas, marketability, local use of its produce, and so on, are important considerations. All these apply to the woody perennials as well.

3.2. Multipurpose Trees (MPTs)

Since the interactive presence of the woody species is the common denominator in all AF systems, the primary consideration on plant species in AF should involve the woody species. Some common examples of such woody species in existing AF systems have been presented in Table 2. This Table, which by no means is exhaustive, indicates that the woody perennials used in AF systems include a multitude of species in terms of their growth habits, forms, economic products, other biological characteristics, management, etc. Thus firewood crops, fodder trees, timber species, palms, fruit trees, vines, bamboos, shrubs, and so on can be found in different AF systems in various ecological regions.

Trees used outside forestry except a few ornamental and fruit and nut trees had hitherto been relegated to a status of lower economic significance and importance. But, with the recognition of the importance of AF, such trees and other woody perennials used in traditional mixed AF systems and other species of AF potential have earned a higher "ranking" and "status" necessitating a distinct identify and definition for this group of plants. The term multi-purpose tree (MPT) thus emerged and acquired wide acceptance in a rather short time to encompass all such trees and woody perennials of AF significance/potential.

MPT, life AF, also has so universally acceptable definition. Several definitions have been proposed (Burley and von Carlowitz, 1984).

Whatever the definition of MPT, the consensus of opinions is that the catch-word is "multipurpose". It is generally agreed that multiple uses or multiple outputs are considered important attributes of any definition of MPT, and the term should be used to cover species that may be grown for different purposes on different sites. An explanation of this latter point is provided by, say, Grevillea robusta, an accepted timber tree, which if grown in plantations for predominantly timber production, does not form an MPT whereas it becomes an MPT when grown in another situation not only for timber, but also for shade, mulch, honey, etc. Johnson (1984) assersed the multipurpose nature and AF potential of palms and observed that in addition to the four improved, cultivated palms (Areca catechu - areca or betel palm, Cocos nucifera

- coconut palm, Elaeis guineensis - oil palm, and Phoenix dactylifera - date palm) there are 18 unimporved cultivated or managed palms and 29 semi-wild or wild palms of multiple uses and AF potential in different ecoregions. Similarly Nair (1984b) examined the role of several fruit and nut producing trees and shrubs (collectively called "fruit trees") in various AF Systems. He noted that this group of plants ranging from tall, long-duration perennials (e.g. the Brazil nut tree, Beetholletia excelsa) to relatively short, "non-woody" species, such as papaya (Carica papaya) can be found in association with other woody as well as herbaceous components in traditional AF systems in various parts of the world. Some of them are widely distributed in different geographical regions (e.g. mango, papaya) whereas some others are highly localized and found only in certain geographic regions (e.g. rambutan - Nephelium lappaceum - in Southeast Asia; pejibaye palm - Bactris gassipaes - in South America).

An interesting point to note here is that most of such MPTs found in traditional AF systems have little been studied in the past so that they do not fall under the category of conventional forestry/agricultural/ horticultural species. Yet they make significant contribtions in various ways to the livelihood of a large number of people, and more research efforts on these species can lead to the exploitation of their potential to a much larger extent. Efforts are now under way in different parts of the world to study and exploit the potentials of such lesser-known species. Okigbo (1977) has described the significant role played by various plants that have so far been neglected in the traditional farming systems in the humid lowland tropics of West Africa. The US National Academy of Science publications on underexploited tropical plants (1975) and firewood crops (1980; 1984); and some other publications (e.g. Kaul 1970; Ritchie 1979) describe several such species that could be valuable in AF. Some of the 'non-traditional' genera have already received consdierable research attention in the recent years - for example Leucaena (NAS 1977, Leucana Newsletter) and Prosopis (Simpson, 1977; Felker et al., 1981; Mann & Saxena, 1980). Undoubtedly, it is important for AF to tap the hitherto unexploited potential of this large number of multipurpose trees and shrubs.

4. ENVIRONMENTAL PROTECTION THROUGH AGROFORESTRY

The main environmental protection aspects of agroforestry stems from the soil improving and soil conserving functions of the woody perennials involved and the microclimate amelioration and windbreak protection offered by trees. Nair (1984a) examing the soil productivity aspects of AF note that there are various avenues through which the woody perennials, especially legumes, could improve and enrich soil conditions. These include fixation of atmospheric nitrogen, addition of organic matter through litterfall and dead and decaying roots, modification of soil porosity and infiltration rates leading to reduced erodibility of soil and improving the efficiency of nutrient cycling within the soil-plant system. Fig. 2 shows a schematic illustration of some of these soil productivity aspects of AF. However, the main protective function

FIG. 2 HERE

of woody perennials is in physical conservation of the soil, and this is particularly important in the highlands and other sloping areas.

The long tradition of planting *Leucaena leucocephala* in contour hedges for erosion control and soil improvement in Southeast Asia is a typical example. Indirect terraces are also formed when the washed-off soil is collected behind the hedges. Loppings and prunings from such hedgerow species could also produve mulch to aid in preventing sheet erosion between trees (Zeuner, 1981; Neumann, 1983). Wiersum (1984) reviewed the quantitative data on surface erosion in various forest and tree crop systems and evaluated the effect of trees grown in combination with agricultural crops on rainfall erosivity, soil erodibility and soil surface protection. Using data from various places, he concluded that in AF, there exists the possibility that coalesced raindrops falling from high canopy species may cause more damage, than the rain itself. On the other hand, tree canopies may also slightly decrease the amount of water reaching the soil and thus decrease the hazard for runoff and rill erosion. However, as pointed out by Lundgren and Nair (1985), the potential role of agroforestry in soil conservation lies not only in woody perennials acting as a physical barrier against erosive forces, but also in providing mulch and/or fodder and fuelwood at the same time.

Arising from the realization of the protective action of a community of trees in imparting stability to the broad ecosystem or watershed where

they exist, and also alarmed at the ill-effects of forest denudation in the water catchment areas on the reservoirs and farmlands served by such catchment areas, a lot of speculative and often exaggerated thinking has gone into the likely effects of trees on farmlands and other AF systems. However, there is very little direct research information on these aspects. As Hamilton (1983) puts it, it seems to be assumed, often falsely, that when trees are introduced into a cropping or grazing system, nothing but beneficial results will accrue to the watershed parameters.

Two other aspects of ecosystem stability and environmental protection of trees in AF which can be of significance at the micro-site and farm level are the microclimate modification and windbreak/shelterbelt effects; see Nair (1979) and Darnhofer (1984) for discussions on these two aspects respectively.

5. AGROFORESTRY IN THE CONTEXT OF TRADITIONAL KNOWLEDGE AND CONSERVATION

In a recent evaluation of the impact of agroforestry in the international scene, Castillo (1984) observed the following with some amount of sarcasm:

"Unlike the green revolution, which was a product of journalists' enthusiasm, the projection of AF as a panacea seems to come from the professionals. From the bibliographies scanned, there are such phrases as

- Forest farming - towards a solution to problems of world hunger
- Forestry in the service of agriculture
- Bringing the green revoluation to the shifting cultivator
- A plea for meeting human requirements through trees
- Agroforestry and fragile ecosystems
- Agroforestry as an alternative to shifting cultivation
- Agroforestry to combat desertification
- Employment opportunities in the tropical high forest created by the agrosilviculture
- Agroforestry in the tropics - a new emphasis in rural development
- Agroforestry as a socio-economic enterprise in alleviating national problems on forest conservation
- and so on!!"

(G. Castillo, 1984: Putting Agroforestry into Practice: Some Issues and Options for ICRAF. Mimeo, unpublished).

However, a closer look at these bibliographies indicates that these efforts are aimed at highlighting the various underexploited, by-passed, ignored or unrecognized aspects of traditional land use systems involving trees. Indeed, many of the proponants of AF have been trying to counter this panacea concept of AF, and many documents referred to above have cautionary statements to that effect. The credibility and acceptability of the AF concept lie in the fact that it encompasses the principles and elements of countless number of traditional land use systems and integrated production patterns; it upholds the principles of sustained production using environmentally sound and socially acceptable means, that is the principles of production, protection (conservation) and sustainability.

Most of the currently existing AF systems are manifestations of the use of traditional knowledge where AF is more than just a land use approach; it often represents a way of life of the people. Codaman (1983) in her description of "Agroforestry in the Ifugao Way of Life" in the Philippines expresses this phenomenon of science in an age-old practice as follows:

> "Precursors of agroforestry would argue that it is a relatively new approach to forest conservation and while they labour to generate, verify and apply technological information to prove their point, a mountain tribe comfortably nestled upon the lofty heights of the Cordillors in the North unknowingly holds probaly not all but some key information that would unlock new doors from which other tribes, other nations may evolve their own models of agroforestry development. The Ifugao agroforestry model is a unique showcase of how a people barely schooled, had understood the delicate intricacies of their ecosystem with their system of land-use which beautifully blends agriculture and forestry on scientific principles that astound the world. Theirs is agroforestry as a way of life, in principle and in practice for all the world to see .....
>
> What the Ifugaos really practice is 'common-sense agroforestry' dictated by the primitive ruggedness of their physical environment and its relatively pristine socio-cultural milieu

characterized by a very deep sense of respect, loyalty, concern and satisfaction for both private and public property that stems out of a highly reverent fear of a-all-powerful and all-knowing being".

This sort of poetic description of the relevance and soundness of AF can be applied to several of the existing AF systems, where these land use systems have evolved over centuries in complete harmony with the rhythms of nature and have been sustained by the wisdom of traditional knowledge.

6. ICRAF AND AGROFORESTRY RESEARCH IN ASIA

6.1. Research in Agroforestry

Although the art of agroforestry is old, the 'science' part of it is new. There is no substantial body of primary knowledge on any of its operational aspects. Most of the suggested advantages of AF are conceptual and sometimes speculative. In order to cope with the high levels of enthusiasm on the approach, it is essential that systematic research is undertaken on its various aspects. But there are several problems of varying nature and magnitude to be circumvented to get effective and efficient research efforts on the ground. These include:

- there is no institutional 'niche' for agroforestry and therefore the resources for research, if at all available, are scarce;
- the orientation of most researchers is in conventional disciplinary and thematic lines so that interactive and integrated approaches like AF seldom attract researchers' attention;
- AF research and interpretation of research results demand a thorough modification of conventional norms and procedures of disciplinary research.

6.2. ICRAF

The establishment of ICRAF with headquarters in Nairobi, Kenya, in 1978 was the first international initiative to institutionalize agroforestry. The Council's work plan centres around three foci:

- The development within ICRAF of an interdisciplinary capacity and appropriate methodologies to assess constraints in land-use systems and to identify agroforestry solutions to overcome these constraints.
- The systematic collection and evaluation of existing knowledge about agroforestry technologies, and the development of methods for the appropriate study of such information.
- The establishment of an efficient program for disseminating information about agroforestry methods and technologies to scientists, development planners, and institutions in developing countries.

These objectives are to be achieved through a set of supportive programs within which all ICRAF projects and activities are carried out.

It must be stressed that ICRAF is not set up as an institute to generate locally adapted agroforestry technologies or whole systems through field research. This can only be done by local institutions with the facilities required to carry out long-term field research. Nor is ICRAF able to fund the work of other institutions. It is the only institution established expressly to work with agroforestry research issues on a global scale.

6.3. ICRAF's Collaborative Activities in Asia

In addition to ICRAF's general activities having global coverage (such as inventory of existing AF systems, build-up of multi-purpose tree data base, compilation of research methodologies, dissemination of information, and so on), the specific on-site activities of the Council in Asia, like in other continents, include assistance in project development by technically cooperating with national agencies in designing and implementing AF programmes. It is envisaged that as a result of the combined research and training activities, regional/zonal networks will be established within each ecological zone.

On-going activities of this nature include:

- In South Asia, ICRAF is cooperating with the All-India Coordinated Research Project in Agroforestry of the Indian Council of Agricultural Research (ICAR), with experiments in 22 centres all over India,

- An ICRAF/ICAR training course in agroforestry is scheduled to be held in India in early 1986;
- ICRAF cooperated with IUFRO (International Union of Forestry Research Organization) in IUFRO's Planning Workshop for Asia held in Kandy, Sri Lanka, in July 1984.
- In Southeast Asia, collaborative activities are carried out essentially within the framework of the ASEAN (Association of South East Asian Nations) with the regional support of SEARCA (South East Asia Regional Center for Graduate Study and Research in Agriculture). Within this framework, an AF workshop was held at Los Banos in 1982 and a programme was formulated for ICRAF to cooperate with national institutions of the Philippines, Malaysia, Indonesia and Thailand.
- Two research projects were developed jointly, one for the seasonally dry uplands of Tobango, Leyte, Philippines in cooperation with the Visayas State College of Agriculture (VISCA) and the Philippine Council for Agricultural Research and Resources (PCARR). The other project in the slopping humid lowlands of Batu Arang, Peninsular Malaysia was prepared in cooperation with UPM (Universiti Pertanian Malaysia), FRI (Forest Research Institute, Malaysia) and MARDI (Malaysian Agricultural Research Institute). Both projects are now awaiting donor support.
- Discussions are now under way to cooperate with the Indonesian Agency for Agriculture and Forestry Research and Development (AARD and AFRD) in the implementation of their Uplands Project.
- A Regional Course on Agroforestry Research for Development was held at UPM in October, 1984, sponsored by USAID and organized by UPM and ICRAF, with the participation of national multi-disciplinary teams from Indonesia, Malaysia, Philippines and Thailand, which was centred around the Batu Arang Project.

Future Collaborative Activities in the Region, that are now in the planning stage include:

- further strengthening of cooperation between ICRAF and ICAR with the support of Ford Foundation;

- ICRAF/IADS (International Agricultural Development Service) cooperation in implementing in Pakistan a large-scale project with a strong agroforestry component;
- establishment of a regional network in SE Asia through the aegis of COFAF (Committee for Food, Agriculture and Forestry) of the ASEAN Group. In a meeting held at Chiang Mai, Thailand on 22-25 January, 1985, the topic of an AF Research Network was already considered.

In summary, ICRAF can assist the national agencies in systematically developing agroforestry research capability. Such efforts are best accomplished through a strong and effective regional network with external (donor) support.

Agroforestry Literature

ICRAF has assembled a large volume of world litarature on various aspects of AF. This includes books, conference proceedings, journal papers, working papers, etc. both by ICRAF staff and others. A large number of other publications that have relevance to one or the other aspects of AF have also been assembled. Subjects covered in this literature collection includes all cognate disciplines and themes such as agronomy, soil science, silviculture, plant sciences, economics, animal sciences, social sciences and so on. This information base is also being constantly up-dated. Further details on this may be obtained from the Information/Documentation Unit of ICRAF (P.O. Box 30677 Nairobi, Kenya).

SELECTED REFERENCES

Codaman, 1983. Agroforestry in the Ifugao Way of Life. Scientia Filipinas Science Magazine of PCARRD-NSTA. 3(1), 10-16.

Darnhofer, T. 1984. Meteorological elements and their observation. ICRAF Working Paper No. 14. Nairobi: ICRAF.

Felker, P., G.H. Cannel, P.R. Clark, J.F. Osborn and P. Nash. 1981. Screening Prosopis (mesquite) species for biofuel production on semi-arid lands. Washington D.C.: US Department of Energy.

Hamilton, L.S. 1983. Consideration of some of the physical soil and water effects resulting from community forestry activity. Honolulu: East-West Environment and Policy Institute.

Kaul, R.N. (ed) 1970. Afforestation in Arid Lands. The Hague: Dr. W. Junk Pub.

Johnson, D.V. 1984. Multipurpose palms in agroforestry: a classification and assessment. International Tree Crops J. 2: 217-244.

Lundgren, B.O. and P.K.R. Nair. 1983. Agroforestry for soil conservation. In: Proc. Sec. Intern. Conf. Soil Erosion and Conservation. Soil Cons. Soc. Amer. (in press).

Lundgren, B.O. and J.B. Raintree. 1983. Sustained agroforestry. In: B. Nestel (ed). Agricultural Research for Development: Potentials and Challenges in Asia. pp. 37-49. The Hague: ISNAR.

Mann, H.S. and S.K. Saxena (ed). 1980. Kherji (Prosopis cineraria) in the Indian Desert. CAZRI Monograph No. 11. Jodhpur, India: Central-Arid Zone Research Institute.

Nair, P.K.R. 1979. Intensive Multiple Cropping with Coconuts in India: Principles, Programmes and Prospects. Berlin (West): Verlag Paul Parey.

Nair, P.K.R. 1980. Agroforestry Species: A crop Sheets Manual. Nairobi: ICRAF.

Nair, P.K.R. 1983a. Multiple land-use and agroforestry. In: Better Crops for Food: CIBA Foundation Symposium 97, pp. 101-115. London: Pitman Books.

Nair, P.K.R. 1983b. Tree integration on farmlands for sustained productivity of smallholdings. In: W. Lockeretz (ed). Environmentally Sound Agriculture, pp. 333-350. New York: Praeger.

Nair, P.K.R. 1984a. Soil Productivity Aspects of Agroforestry. Nairobi: ICRAF.

Nair, P.K.R. 1984b. Fruit Trees in Tropical Agroforestry Systems. Working Paper, Honolulu: East West Center.

Nair, P.K.R. 1985: Classification of agroforestry systems. Working Paper 28. Nairobi: ICRAF.

Nair, P.K.R. (forthcoming). Tropical agroforestry systems and practices. In: J.I. Furtado and K. Ruddle (eds). Tropical Resource Ecology and Development, Chapter 14. Chichester, England: John Wiley (in press).

NAS. 1975. Underexploited Tropical Plants with Promising Economic Values. Washington, D.C.: National Academy of Sciences.

NAS. 1977. Leucaena - Promising Forage and Tree Crop for the Tropics. Washington, D.C.: National Academy of Sciences.

NAS. 1980. Firewood Crops. Washington, D.C.: National Academy of Sciences.

NAS. 1984. Firewood Crops, Vol. 2. Washington, D.C.: National Academy of Sciences.

Neumann, I. 1983. Use of trees in smallholder agriculture in tropical highlands. In: W. Lockeretz (ed). Environmentally Sound Agriculture. pp. 351-374. New York: Praeger.

Okigbo, B.N. 1977. Neglected plants of horticultural importance in traditional farming systems of tropical Africa. Acta Horticultura 53, 131-150.

Ritchie, G.A. (ed) 1979. New Agricultural Crops. Am. Assoc. Adv. Sci. Selected Symp. 38. Boulder, Colorado: Westview Press.

Simpson, B.B. (ed) 1977. Mesquite - Its Biology in two Desert Scrub Ecosystems. Strousberg, Pennsylvania: Dowden, Hutchinson & Ross.

Wiersum, K.F. 1984. Surface erosion under various tropical agroforestry systems. Paper at the symp. Effects of Forest Land Use on Erosion and Slope Stability, May 1984, Honolulu, Hawaii.

Zeuner, T.H. 1981. An ecological approach to farming: some experience of the agro-pastoral project, Nyabisindu, Rwanda. In: L. Buck (ed) Proc. Kenya National Seminar on Agroforestry. pp. 329-353. Nairobi: ICRAF.

TABLE 1. SOME EXAMPLES OF PROMINENT AGROFORESTRY SYSTEMS AND PRACTICES IN THE DEVELOPING COUNTRIES (NAIR, forthcoming)

SYSTEMS		EXAMPLES FROM DIFFERENT GEOGRAPHIC REGIONS*						
Major Systems	Sub-Systems/Practices	Pacific	Southeast Asia	South Asia	Middle East and Mediterranean	East and Central Africa	West Africa	American Tropics
AGROSILVICULTURAL SYSTEMS	Improved "Fallow" (in shifting cultivation areas)		Forest villages of Thailand Various fruit trees & plantation crops used as "fallow" species in Indonesia	Improvements to Shifting Cultivation; several approaches e.g. in the north eastern parts of India		Improvements to Shifting Cultivation e.g. gum gardens of the Sudan	*Acacia barteri*, *Anthonotha macrophylla*, *Gliricidia sepium*, etc. tried as "fallow" species	Several forms
	The Taungya System	(e.g. Taro with *Cedrella* and *Anthocephalus* trees)	Widely practised; forest villages of Thailand is an improved form	Several forms, several names		The 'Shamba' System	Several forms	Several forms
	Tree Gardens	Involving fruit trees	Dominated by fruit trees	In all ecological regions	The Dehesa system; "Parc arboré"			e.g. 'Paraiso Vendiot' of Paraguay
	Hedgerow Intercropping (Alley Cropping)		Extensive use of *Sesbania grandiflora*, *Leucaena leucocephala* and *Calliandra calothyrsus*	Several experimental approaches e.g. Conservation farming in Sri Lanka		The Corridor System of Zaire	Experimental systems on alley cropping with *leucaena* and others	
	Multipurpose Trees and Shrubs on Farmlands	Mainly fruit or nut trees (e.g. *Canarium*, *Pometia*, *Barringtonia*, *Pandanus*, *Artocarpus altilis*)	Dominated by fruit trees; also *Acacia mearnsii* - cropping system, Indonesia	Several forms both in lowlands and highlands e.g. Hill Farming in Nepal; 'Khejri' - based system in the dry parts of India	The Oasis system; Crop combinations with the Carob tree; The Dehesa system; Irrigated systems; Olive trees + cereals	Various forms; The Chagga system of Tanzanian highlands; The Nyabisindu system of Rwanda	*Acacia albida*-based food production systems in dry areas; *Butyrospermum* + *Parkia* systems; "Parc arboré"	Various forms in all ecological regions
	Crop Combination with Plantation Crops	Plant. crops and other multipurpose trees: e.g. *Casuarina* and coffee in the highlands of PNG; also *Gliricidia* and *Leucaena* with cacao	Plant. crops + fruit trees; smallholder systems of crop combinations with plantation crops; plantation crops with spice trees	Integrated production systems in smallholdings; shade trees in plantations; other crop mixtures including various spices	Irrigated systems; Olive trees + cereals	Integrated production; shade trees in commercial plantations; mixed systems in the highlands	Plantation crop mixtures; smallholder production systems	Plantation crop mixtures; shade trees in commercial plantations; mixed systems in smallholdings; spice trees
	AF Fuelwood Production	Multipurpose fuelwood trees around settlements	Several examples in different ecological regions	Various forms		Various forms	Common in the dry regions	Several forms in the dry regions
	Shelterbelts, Windbreaks, Soil Conservation Hedges	*Casuarina oligodon* in the highlands as shelterbelts and soil improver	Terrace stabilization in steep slopes	Use of *Casuarina* spp. as shelterbelts; several windbreaks	Tree spices for erosion control	The Nyabisindu system of Rwanda	Various forms	Live fences, windbreaks especially in highlands
SILVOPASTORAL SYSTEMS	Protein Bank (Cut-and-carry Fodder Production)		Very common, especially in highlands	Multipurpose fodder trees on or around farmlands especially in highlands		Very common	Very common	Very common
	Living Fence of Fodder Trees and Hedges		*Leucaena*, *Calliandra*, etc. used extensively	*Sesbania*, *Euphorbia*, *Syzigium* etc. common		Very common in all ecological regions		Very common in the highlands
	Trees and Shrubs on Pastures	Cattle under coconuts, pines and *Eucalyptus deglupta*	Grazing under coconuts and other plantations	Several tree species being used very widely	Very common in the dry regions; the Dehesa system	The *Acacia* dominated system in the arid parts of Kenya, Somalia and Ethiopia	Cattle under oil palm; Cattle and sheep under coconut	Common in humid as well as dry regions e.g. Grazing under plantion crops in Brazil
AGROSILVOPASTORAL SYSTEMS	Woody Hedges for Browse, Mulch, Green Manure, Soil Conservation, etc.	Various forms: *Casuarina oligodon* widely used to provide mulch and compost	Various forms	Various forms especially in lowlands			Very common	
	Home Gardens (involving a large number of herbaceous and woody plants with or without animals)		Very common; Java Home Gardens often quoted as good examples	Common in all ecological regions	The Oasis system	Various forms (The Chagga homegardens; the Nyabisindu system)	Compound farms of humid lowlands	Very common in the thickly populated areas
OTHER SYSTEMS	Agro-Silvo-Fishery ('Aquaforestry')		Silviculture in mangrove areas; trees on the bunds of fish-breeding ponds					
	Various forms of Shifting Cultivation	Common	e.g. Swidden farming	Very common; various names		Very common	Very common in the lowlands	Very common in all ecological regions
	Apiculture with trees	Common	Common		Common	Common	Common	

* See table 2 for a list of the common trees involved and literature references on each of the sub-system/practice

TABLE 2. FIELD EXAMPLES OF SOME COMMON AGROFORESTRY SYSTEMS AND PRACTICES IN THE TROPICS (NAIR, forthcoming)

Sub-system/ Practice	Country/ Region	Some examples of the woody species involved	Remarks/ Major references
I.A. AGROSILVICULTURAL SYSTEMS - Humid/Sub-humid Lowlands			
Improved "Fallow" (in shifting cultivation areas)	Indonesia	*Aleurites moluccana* *Erythrina* spp. *Styrax* spp.	Kunstadter et al. (1978)
Woody species planted and left to grow during the "Fallow phase"	Nigeria	*Acioa barteri* *Anthonotha macrophylla*	Getahun et al. (1982)
Tree Gardens Multilayer, multi-species plant associations with no organized planting arrangement	Nigeria	*Daniellia oliveri* *Gliricidia sepium* *Parkia clappertoniana* *Pterocarpus africana*	Getahun et al. (1982)
	Pacific Islands	*Inocarpus edulis* *Morus nigra* *Spondias dulce*	Richardson (1982)
	India, Sri Lanka	*Areca catechu* *Artocarpus* spp. *Cocos nucifera* *Mangifera indica*	Coconut intercropping: Nair (1979; 1983); Liyanage et al. (1984)
	Paraguay	*Melia azedarach*	The Paraiso woodlot (Evans and Rombold, 1984)
	SE Asia	*Albizia falcataria* *Artocarpus* spp. *Bambusa* spp. *Durio zebethinus* *Nephelium lapaceum*	Ambar (1982) Forest Villages of Thailand (Boonkird et al., 1984)
Hedgerow intercropping (Alley cropping)	SE Asia	*Calliandra callothyrsus*	
Woody species in hedges; agri. species in between hedges (alleys)	Nigeria	*Leucaena leucocephala*	Wilson and Kang (1981)
Multipurpose trees and shrubs on farmlands Trees scattered haphazardly or according to some systematic patterns	Brazil	*Cassia excelsa* *L. leucocephala* *Mimosa scabrella*	
	India	*Derris indica* *Emblica officinalis* *Moringa oleifera* *Tamarindus indica*	NAS (1980)
	Kenya	*Anacardium occidentale* *Ceiba petandra* *Mangifera indica* *Manilkara achras*	

TABLE 2 (CONT'D)

	SE Asia	*Acacia mangium* *Artocarpus* spp. *Durio zibethinus* *Gliricidia sepium* *Sesbania grandiflora*	
Crop combinations with plantation crops 1) Integrated production of plantation crops and other crops in intimate plant associations 2) Mixtures of plantation crops e.g. coconut and cacao 3) Shade trees for commercial plantation crops		<u>Plantation crops</u> *Anacardium occidentale* *Camellia sinensis* *Cocos nucifera* *Coffea arabica* *Elaeis guineensis* *Hevea brasiliensis* *Piper nigrum* *Theobroma cacao*	
	Brazil	*Bertholletia excelsa* *Copernicia prunifera* *Cordia alliodora* *Inga* spp. *Orbignya* spp. *Samanea saman*	Hecht (1982) Alvim and Nair (1984)
	Costa Rica	*Cordia alliodora* *Erythrina poeppigiana* *Gliricidia sepium* *Inga* spp.	Budowski (1983) Heuveldop and Lagemann (1981)
	India	*Albizia* spp. *Cassia* spp. *Erythrina* spp. *Grevillea robusta*	Coconut intercropping (Nair, 1979; 1983; Liyanage et al., 1984)
	SE Asia	Various fruit trees	
	West Indies	*Inga vera*	
	Western Samoa	*Erythrina variegata* *Gliricidia sepium* *Leucaena leucocephala*	Richardson (1982)
AF for fuelwood Production Interplanting fire-wood species on or around agricultural lands	India	*Albizia* spp. *Cassia siamea* *Derris indica* *Emblica officinalis*	ICAR (1979) NAS (1980)
	Indonesia	*Albizia falcataria* *Calliandra callothyrsus* *Sesbania grandiflora* *Trema orientalis*	NAS (1980)

TABLE 2 (CONT'D)

Shelterbelts, windbreaks, soil conservation hedges	India	*Casuarina equisetifolia* *Syzygium cuminii*	NAS (1980)
Planting around agricultural lands as windbreaks and shelterbelts; planting along contours for terrace stabilization and soil conservation	Indonesia (and other parts of SE Asia)	*Gliricidia sepium* *Leucaena leucocephala* *Sesbania grandiflora*	NAS (1980)
I. B. AGROSILVICULTURAL SYSTEMS - Tropical Highlands			
Multipurpose trees and shrubs on farm-lands	India	*Albizia* spp. *Bauhinia variegata* *Dalbergia sissoo*	NAS (1980)
	Kenya	*Ceiba petandra* *Eriobotrya japonica* *Grevillea robusta*	
	Nepal	*Bauhinia* spp. *Erythrina* spp. *Ficus* spp. *Litsea polyntha*	Hill farming in Nepal (Fonzen and Oberholzer, 1984)
	Paraguay	*Melia azedarach*	The Paraiso woodlot (Evans and Rombold, 1984)
	Tanzania	*Albizia* spp. *Cordia africana* *Croton macrostachys* *Trema guineensis*	The Chagga system (Fernandes et al., 1984)
Crop combinations with plantation crops	Brazil	*Alnus acuminata* *Enterolobium contorsiliquum* *Erythrina velutina*	
	Costa Rica	*Alnus acuminata* *Erythrina poeppigiana* *Inga* spp.	Budowski (1983)
	India, Sri Lanka	*Albizia* spp. *Grevillea robusta*	
	Kenya Papua New Guinea Philippines	*Grevillea robusta* *Casuarina olygodon* *Trema orientalis*	Bourke (1984)
	Rwanda Tanzania	*Albizia* spp. *Cordia africana* *Grevillea robusta* *Trema guineensis*	Fernandes et al. (1984) Neumann (1983)

TABLE 2 (CONT'D)

AF Fuelwood Production	India, Nepal	*Albizia stipulata* *Bauhinia* spp. *Grewia* spp.	ICAR (1979) NAS (1980)
Shelterbelts, Windbreaks, Soil Conservation Hedges	(same as in lowlands)		
I.C. AGROSILVICULTURAL SYSTEMS - Arid and Semi Arid Regions			
Multipurpose Trees and Shrubs on Farmlands	Brazil	*Caesalpinia ferrea* *Prosopis juliflora* *Zizyphus joazeiro*	Johnson (1983)
	Central African Republic	*Adansonia digitata* *Balanites aegyptiaca* *Borassus aethiopium*	Yandji (1982)
	India	*Cajanus cajan* *Derris indica* *Prosopis cineraria* *Tamarindus indica*	NAS (1980)
	Kenya	*Acacia* spp. *Balanites aegyptiaca* *Cajanus cajan*	
	Tanzania	*Acacia* sp. *Combretum* spp.	
AF Fuelwood Production	Chile India	*Prosopis tamarugo* *Albizia lebbek* *Cassia siamea* *Prosopis* spp.	NAS (1980) Little (1983) ICAR (1979)
	Sahel	*Acacia albida* *A. senegal* *A. tortilis*	von Maydell (1984)
Shelterbelts and Windbreaks	India, Pakistan	*Azadirachta indica* *Cajanus cajan* *Cassia siamea* *Eucalyptus* spp. *Pithecellobium dulce* *Populus* spp.	Sheikh and Chima (1976), Sheikh and Khalique (1982)

TABLE 2 (CONT'D)

II. SILVOPASTORAL SYSTEMS - Humid/Sub-humid Lowlands			
Protein Bank (Multi-purpose Fodder Trees on or around Farmlands)	India, Nepal, Sri Lanka	*Artocarpus* spp. *Anogeissus latifolia* *Bombax malabaricum* *Cordia dichotoma* *Dalbergia sissoo* *Eugenia jambolana* *Samanea saman* *Zizyphus jujuba*	ICAR (1979) Pandey (1982) Singh (1982)
Living Fences of Fodder Trees and Hedges	Costa Rica	*Diphysa robinoides* *Gliricida sepium*	
	Ethiopia	*Erythrina abyssinica*	
	SE Asia	*Sesbania grandiflora*	
Trees and Shrubs on Pastures (similar to multipurpose trees on farmlands)	Brazil	*Acacia* spp. *Anacardium occidentale* *Cedrela odorata* *Cordia alliodora*	Hecht (1982) Johnson and Nair (1984)
	Costa Rica	*Enterolobium cyclocarpum* *Erythrina poeppigiana* *Samanea saman*	De las Salas (1979)
	India	*Derris indica* *Emblica officinalis* *Psidium guajava* *Tamarindus indica*	Singh (1982)

II. SILVOPASTORAL SYSTEMS - Tropical Highlands		
Protein Bank	Indian subcontinent	*Albizia stipulata* *Bauhinia* spp. *Ficus* spp. *Grewia oppositifolia* *Morus alba*
Living Fences	Costa Rica Ethiopia East Africa	*Gliricidia sepium* *Erythrina abyssinica* *Dovyalis caffra* *Euphorbia tirucalli* *Ibosa multiflora*
Trees and Shrubs on Pastures	Brazil	*Desmanthus varigatus* *Desmodium discolor*
	Costa Rica	*Alnus acuminata*
	Indian subcontinent	*Albizia stipulata* *Alnus napalensis* *Grewia* spp. *Robinia pseudoacacia*

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TABLE 2 (CONT'D)

II. C. SILVOPASTORAL SYSTEMS - Arid and Semi-arid Regions			
Protein Bank	India	*Acacia nilotica* *Ailanthus excelsa* *Opuntia ficus indica* *Prosopis* spp. *Rhus sinuata*	Singh (1982)
Living Fences	East Africa	*Acacia* spp. *Commiphora africana* *Euphorbia tirucalli* *Ziziphus mucronata*	
Trees and Shrubs on Pastures	India	*Acacia* spp. *Prosopis* spp. *Tamarindus indica*	
	Middle East and Mediterranean	*Acacia* spp. *Ceratonia siliqua* *Haloxylon* spp. *Prosopis cineraria* *Tamarix aphylla*	
III. AGROSILVOPASTORAL SYSTEMS			
Woody Hedgerows for Browse, Mulch, Green Manure and Soil Conservation	Indian subcontinent (Humid lowlands), SE Asia	*Erythrina* spp. *Leucaena leucocephala* *Sesbania* spp.	
Tree-Crop-Livestock Mix around Homestead (known as Home Gardens, these associations are found in almost all ecological regions and several countries; only some examples are given)	South and SE Asia (Humid lowlands)	Fruit trees and some plantation crops mentioned under Agro-silvicultural systems	e.g. Home Gardens of Java (Wiersum, 1982)
	Nigeria (Humid lowlands)	*Cola acuminata* *Garcinia kola* *Irvingia gabonensis* *Pterocarpus soyauxii* *Treculia africana*	
	Latin American countries	Several species mentioned under Agrosilvicultural systems	Wilken (1978)
	Tanzania (Highlands)	*Albizia* spp. *Cordia africana* *Morus alba* *Trema guineensis*	Chagga Home-gardens (Fernandes et al. 1984)

Table 3

MAJOR APPROACHES IN CLASSIFICATION OF AGROFORESTRY SYSTEMS (AND PRACTICES)

CATEGORIZATION OF SYSTEMS (BASED ON THEIR STRUCTURE AND FUNCTION)			GROUPING OF SYSTEMS (ACCORDING TO THEIR SPREAD AND MANAGEMENT)	
STRUCTURE (Nature and arrangement of components, especially woody ones)		FUNCTION (Role and/or output of components, especially woody ones)	AGRO-ECOLOGICAL/ ENVIRONMENTAL ADAPTABILITY	SOCIO-ECONOMIC AND MANAGEMENT LEVEL
Nature of components	Arrangement of components			
Agrisilviculture (crops and trees incl. shrubs/trees and trees) Silvopastoral (pasture/animals and trees) Agrosilvopastoral (crops, pasture/animals, and trees) Others (multipurpose tree lots, apiculture with trees, aquaculture with trees, etc.)	<u>In space</u> (Spatial) Mixed dense (e.g.: Home garden) Mixed sparce (e.g.: Most systems of trees in pastures) Strip (width of strip to be more than one tree) Boundary (trees on edges of plots/fields) <u>In time</u> (Temporal) Coincident Concomitant Overlapping Sequential (separate) Interpolated	<u>Productive Function</u> Food Fodder Fuelwood Other woods Other products <u>Protective Function</u> Windbreak Sheiterbelt Soil conservation Moisture conservation Soil improvement Shade (for crop, animal, and man)	<u>Systems in/for</u> Lowland humid tropics Highland humid tropics (above 1,200 m a.s.l; e.g.: Andes, India, Malaysia) Lowland subhumid tropics (e.g.: savanna zone of Africa, Cerrado of South America) Highland subhumid tropics (Tropical highlands) (e.g.: in Kenya, Ethiopia)	<u>Based on level of technology input</u> Low input (Marginal) Medium input High input <u>Based on cost/benefit relations</u> Commercial Intermediate Subsistence

TABLE 4. CROPS FOR AGROFORESTRY

POTENTIAL AGRICULTURAL AND HORTICULTURAL CROPS*

To round out the lists of potential components in agroforestry systems, this appendix presents a list of well-known agricultural and horticultural crops along with a chart showing their range of ecological adaptability. The list is by no means exhaustive, but it may serve to stimulate thinking about possible components for inclusion in agroforestry systems. This appendix supplements the lists of woody perennials given in Appendices C-8 and C-9.

General grouping of the selected crops according to their adaptability to different ecological regions in the tropics

LOWLANDS (UP TO 500 m)			MEDIUM ELEVATION (500-1200 m)			HIGHLANDS (ABOVE 1200 m)		
[1]PERHUMID - SUBHUMID	[2]SEMIHUMID - SEMIARID	[3]SUBARID - PERARID	[1]PERHUMID - SUBHUMID	[2]SEMIHUMID - SEMIARID	[3]SUBARID - PERARID	[1]PERHUMID - SUBHUMID	[2]SEMIHUMID - SEMIARID	[3]SUBARID - PERARID
Arecanut	Arecanut	Cowpea	Arecanut	Arecanut	Cowpea	Banana	Banana	Cowpea
Arrowroot	Banana	Finger millet	Arrowroot	Banana	Finger millet	Cardamom	Cassava	Finger millet
Banana	Cassava	Groundnut	Banana	Cashew	Groundnut	Cinchona	Castor	Groundnut
Breadfruit	Castor	Mung bean	Breadfruit	Cassava	Mung bean	Coffee	Cinchona	Mung bean
Cacao	Cinnamon	Pearl millet	Clove	Castor	Pearl millet	Pyrethrum	Coffee	Pearl millet
Clove	Clove	Pigeon pea	Coffee-Robusta	Cinnamon	Pigeon pea	Yam	Cowpea	Pigeon pea
Coconut	Coconut	Sesame	Ginger	Cowpea	Sesame		Finger millet	Sorghum
Ginger	Cowpea	Sorghum	Papaya	Finger millet	Sorghum		Maize	Sweet potato
Oil palm	Finger millet	Sweet potato	Passion fruit	Ginger	Sweet potato		Mung bean	
Papaya	Ginger		Pepper	Groundnut			Passion fruit	
Pepper	Groundnut		Pineapple	Kapok			Pearl millet	
Pineapple	Kapok		Rubber	Maize			Pigeon pea	
Rubber	Maize		Taro	Mung bean			Pineapple	
Taro	Mung bean		Turmeric	Papaya			Potato	
Turmeric	Papaya		Yam	Passion fruit			Pyrethrum	
Yam	Pearl millet			Pearl millet			Soya bean	
	Pigeon pea			Pigeon pea			Sweet potato	
	Pineapple			Pineapple			Yam	
	Sesame			Sesame				
	Sisal			Sisal				
	Sorghum			Sorghum				
	Soya bean			Soya bean				
	Sweet potato			Sweet potato				
	Taro			Taro				
	Turmeric			Turmeric				
	Yam			Yam				

[1]PERHUMID - SUBHUMID: areas with 0-4 dry months and more than 1200 mm rain per year

[2]SEMIHUMID - SEMIARID: areas with 5-8 dry months and 500-1200 mm rain per year

[3]SUBARID - PERARID: areas with more than 9 dry months and less than 500 mm rain per year

A month is considered 'dry' when the potential evapotranspiration is more than the precipitation received during the month.

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*Excerpted from P.K.R. Nair. 1980. Agroforestry Species: A Crop Sheets Manual. ICRAF. Nairobi.

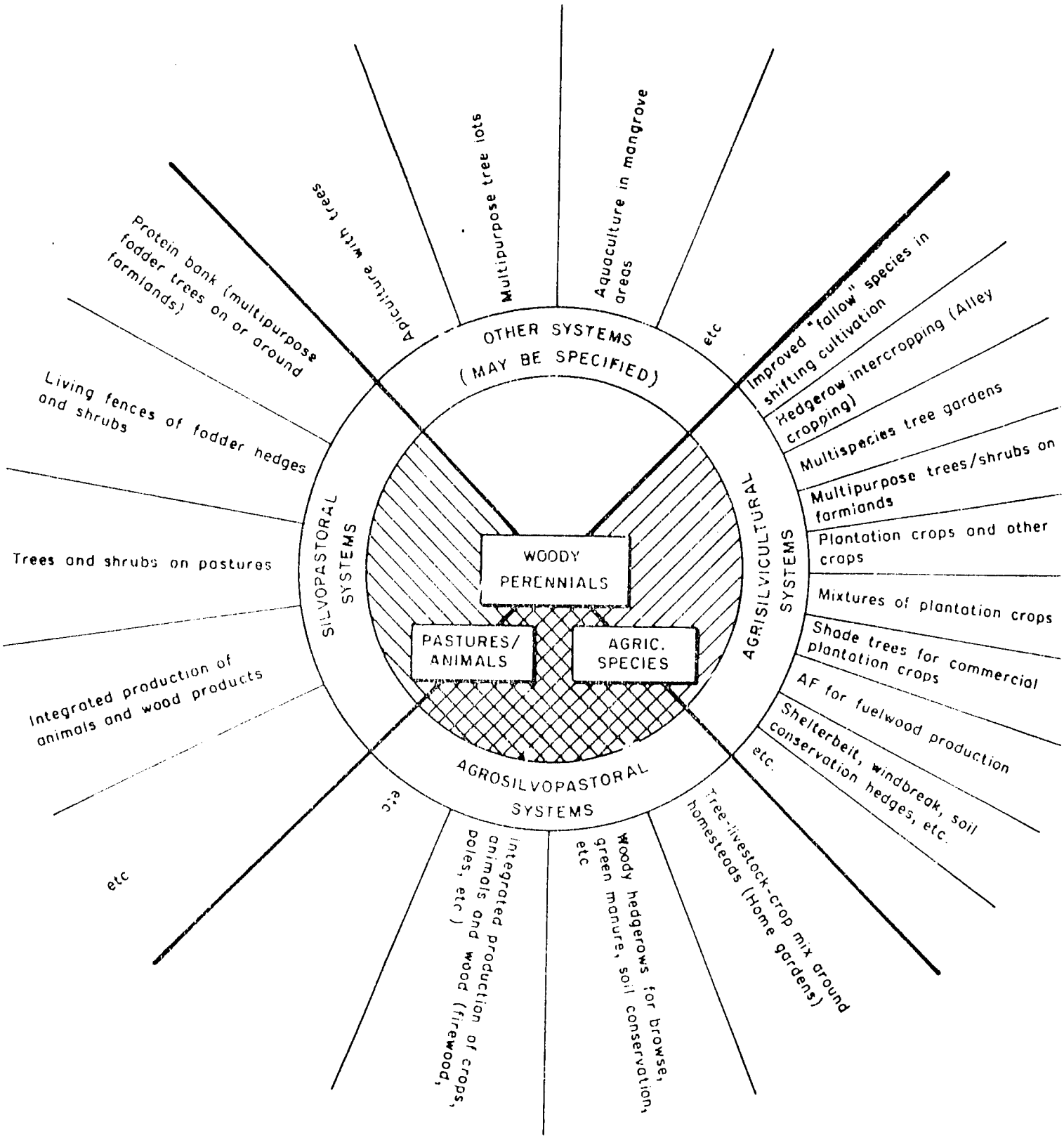

Fig. 1. Categorization of Agroforestry Systems based on the Nature of Components (with examples of common sub-systems/practices under each system).

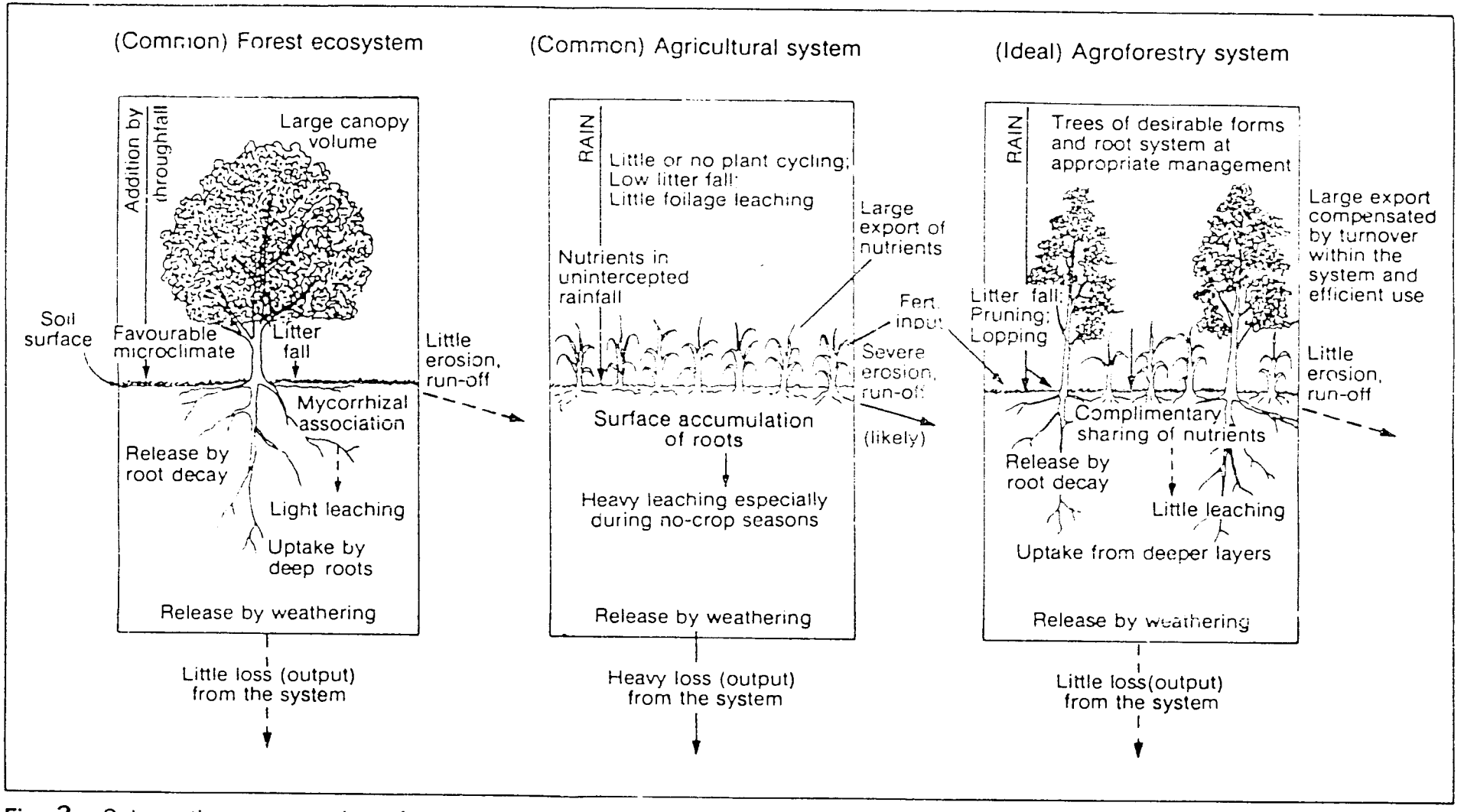

Fig. 2. Schematic representation of nutrient relations and advantages of ideal agroforestry systems in comparison with common agricultural and forestry systems.