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QUANTIFICATION AND DISTRIBUTION OF AGROFORESTRY SYSTEMS AND PRACTICES AT GLOBAL LEVEL

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ABSTRACT : Globally studied remote sensing and geographical information systems data indicated that over 1 billion hectares of agricultural land have more than 10% tree cover, and these areas are home to almost a third of the 1.8 billion people who live on agricultural land. Agroforestry systems and practices vary across the globe such as simple subsistence livestock and pastoral systems to shifting cultivation, home gardens, alley cropping etc. It is estimated that the area currently under agroforestry worldwide is 1,023 m ha. Additionally, substantial extent of areas of unproductive crop, grass, and forest lands as well as degraded lands could be brought under agroforestry. This paper is an attempt to quantification of various agroforestry systems and practices at the global level.

Keywords : *Agroforestry, distribution, quantification, shifting.*

Agroforestry is a kind of land use that has been practiced since long in many parts of the world (Regmi and Garforth, 24). However, the type and composition and extent vary from place to place because of varied topography, biophysical attributes and socio-economics (Singh *et al*., 30). It is an ancient agricultural form of forest land management that should be encouraged as it increases productivity in the short, medium and long term (in comparison with forest land), biodiversity (in comparison with agricultural land) and sustainability of land (multi production system). Agroforestry systems and practices have been defined by Nair (19) as practices which involve "the deliberate integration of trees with agricultural crops and/or livestock either simultaneously or sequentially on the same unit of land". Hence it increases productivity of land fulfilling environment and social aspects. The importance of agroforestry systems at a global scale are high lighted in Agenda 21 of the *Rio Convention*, where agroforestry systems, and therefore agroforestry practices (Mosquera Losada *et.al*., 17), are mentioned as sustainable land management option. In the early 1980s, ICRAF completed an inventory of agroforestry systems in the tropics and subtropics (Nair, 19). Sinclair (28) used the same database to update the classification, focusing on agroforestry practices rather than agroforestry systems. Across these classifications, agroforestry practices are categorised according either to (i) components, (ii) predominant land use, (iii) spatial and temporal structure, (iv) agro-ecological zone, (v) socio-economic status, or (vi) function (Mosquera Losada *et al*., 17).

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Dubious nature of agroforestry leads to fundamental misconceptions that what agroforestry is and lack of data made it hard to find data on actual extent of the agroforestry worldwide (Singh *et al*., 29). These facts led to an assumption that it is globally of little importance, even by people who should know better. During preparation of the IAAST report, USA referees said that everyone knew there were only 50,000 ha of agroforestry in the world and that they were a failure. Such misunderstandings lead to sub-optimal policy decisions, and can best be reversed by providing objective, data-based measures of the extent of agroforestry (Zomer *et al*., 35).

The importance and role of agroforestry both to the livelihood of farming communities as well as total global agricultural production can be assessed by understanding the extent and distribution of trees on agricultural land, at the landscape level, including the numbers and characteristics of farmers and farming communities within those landscapes. Moreover, knowledge of the geographic, ecological, and demographic distribution of agroforestry related land uses can also indicate those areas where increased tree densities could make a major role to livelihoods or landscapes.

Current status of agroforestry in the world

Agroforestry is a feature of agriculture landscapes throughout the world, but the extent to which it is practiced varies from region to region. It ranks high among the significant initiatives in improving land management that have occurred the world over during

the past few decades. Today, nearly a billion hectares of agricultural landscapes already have more than 10% tree cover and an estimated total of 1.6 billion hectares of land worldwide has the potential to be under agroforestry management in the foreseeable future (Nair and Garrity, 21). Worldwide, approximately 560 million people live in agricultural ecosystems with more than 10% tree cover, which equates to 31% of all humans inhabiting farm landscapes. An estimated 1.2 billion rural people currently practice agroforestry on their farms and in their communities, and depend upon its products (World Bank, 2004). Total agricultural area at world level is 22,183,204 km^2. Amongst this 10,120,000 km^2 (46% of agriculture land) have more than 10% tree cover, 5,960,000 km^2 (27% of agricultural land) have more than 20% tree cover and only 1,670,000 km^2 (7.5%) have more than 50% tree cover. Because of the fact that tree cover ranges from zero to high, it is not helpful to decide some minimum tree cover percentage as representing 'agroforestry'. At the global level trees are integrated with crops into different manners in farming areas are economically important agroforestry systems which have low tree canopy cover. Examples are the parkland systems in the Sahel and the poplar-wheat/barley agroforestry systems of Northern India. Worldwide estimate show that agricultural land that involves agroforestry is 17% (>30% tree cover), and at a wider plane 46% (>10% tree cover). According to the definition of ICRAF, agricultural land (22.2 million square kilometers) and a minimum 10% tree cover agroforestry, there are more than 10 million square kilometers of agricultural land considered also under agroforestry. There is now general agreement about the magnitude and scale of the integration of trees into agricultural lands and their active management by farmers and pastoralists. Zomer *et al.* (35) conducted a global assessment of tree cover on agricultural land and found that 48% of all agricultural land had at least 10% tree cover. A high percentage of tree cover is found in nearly all continents of the world, highest being in Central America and southeast Asia. Although Africa shows a smaller percentage of tree cover at continental level, the most widespread farming system in Africa is the so-called agroforestry parkland (scattered trees in crop land), making Africa a typically "treed continent" in agricultural areas (Boffa, 5). The FAO Forest Resources Assessment Report has integrated since 2000 the assessment of trees outside forests, which consist mainly in agroforestry systems as well as tree systems in urban areas.In terms of potential, currently area under agroforestry worldwide is 1,023 m ha. It is estimated that 823 m ha area globally is under agroforestry and silvopastoral systems. Of these, 307 m ha are agroforestry (Nair *et al*., 22). Dixon (8) estimated a total of 585–1215 m ha of land in Africa, Asia and the Americas under agroforestry. However, this is an estimate of the area they judge technically suitable for these systems, not occupied by them. According to an estimate by IPCC (13), additionally, 630 m ha of unproductive crop lands and grasslands could be converted to agroforestry. Maximum areas of agroforestry are found in South America (3.2 million square kilometer), followed by Sub-Saharan Africa (1.9 million square kilometer) and South East Asia (1.3 million square kilometer). In Europe and North America large scale commercial agricultural sectors are found even though they have significant proportion of agroforestry. Trees are an integral part of the agricultural landscape in all regions except North Africa/West Asia. Almost all Central America agriculture has >10% tree cover, as 82% of South East Asian agriculture and 81% of South American agriculture. Sub-Saharan Africa, Europe and North America, each have more than 39% of area under agroforestry. Significant proportion of land also found under agroforestry in all the remaining regions excluding from North and West Africa registering proportions of between 0.21 and 0.27 of agroforestry. Central America and South East Asia have more than 50% of agricultural land under more than 30% tree cover. In these areas, which have substantial cover of tree crops and 'agroforests' the wider agricultural landscapes are also well stocked with trees. In all regions, however, the contribution of high tree cover agroforestry (>30%) to total agroforestry (>10%) is significant, the lowest being in south Asia where the proportion is 0.25. The abundance of sparser tree cover (between 10-20% tree cover) in relation to tree cover greater than 20 per cent is high in some regions such as South America, Sub-Saharan Africa, Northern and Central Asia, South Asia, and Europe (Zomer *et al*., 35). Intercropping of trees and crops is practiced on 3 m ha in China (Sen, 27) and in the United Kingdom; a range of timber/ cereal and timber/pasture systems has been profitable to farmers (McAdam, *et al.,* 16). Trees produced *on-farm* are major sources of timber in Asia (e.g. China, India, and Pakistan), East Africa (e.g. Tanzania) and Southern Africa (e.g Zambia).

More recent estimates suggest that 2.82% of the geographical area is under tree cover in India and the tree cover has been defined as tree patches less than 1 ha with the canopy density >10%. In fact, agroforestry has proven as an important tool for crop diversification. National Agriculture Policy, 2000 recommends

agroforestry for sustainable agriculture and advocates bringing up agroforestry in areas currently under shifting cultivation. National Forest Policy, 1988 sets a goal of increasing forest cover on one-third geographical area of the country. Major Policy initiatives including National Forest Policy 1952, 1988 and the National Agriculture Policy 2000, Task Force on Greening India 2001 and National Bamboo Mission 2002 emphasized the role of agroforestry for efficient nutrient cycling, organic matter addition for sustainable agriculture and for improving forest cover. Dhyani *et al*. (7) has reported that about 7.45 m ha area has been planted with different types of agroforestry plantations. Besides about 25.72 m ha area is under various types of tree plantations which include agroforestry, social forestry and farm forestry. Future prospects for expansion of area under agroforests in different agro ecological regions of India exists. The task force on Greening India has identified a potential of 10 m ha irrigated and 18 m ha rainfed areas that could be developed through agroforestry on a watershed basis, and another 15 m ha degraded forest through joint forest management (JFM). The area under plantation including agroforestry is expected to be 94.7 m ha. Out of that the area under the forest is 69.70 m ha and in agroforestry 25 m ha. The current area under agroforestry in India is estimated as 25.32 m ha (Dhyani *et al*., 7) or 8.2 per cent of the total geographical area of the country. There is further scope of increasing the area under agroforestry in future by another 28.0 m ha. The major share of the land to be brought under agroforestry will come from fallows, cultivable fallows, pastures, groves and rehabilitation of problem soils. Thus, a total of 53.32 m ha, representing about 17.5 per cent of the total reported geographical area of the country, could potentially be brought under agroforestry in the near future, which will make agroforestry a major land-use activity, after agriculture (140.86 m ha, 46.08 % of the total reported geographical area) and forestry (69.63 m ha, 22.78% of the total reported geographical area) in India (Dhyani *et al*., 7). As reported by Sathaye and Ravindranath (26) agroforestry land in India is 96 m ha while in China is 75.9 m ha. Agroforestry systems in India include trees in farms and a variety of local forest management and ethnoforestry practices. India is estimated to have between 14,224 million and 24,602 million trees outside forests, spread over an equivalent area of 17 m ha. Forest Survey of India earlier has estimated that 2.68 billion trees outside forests exist over an equivalent area of 9.99 m ha. More recent estimates suggest that an equivalent area of 92,769 km^2 (i.e., 2.82% of the geographical area) is under tree cover in India. The current growing stock has been estimated to be about 1.616 billion cubic meters. For these calculations the tree cover has been defined as tree patches less than 1 ha with the canopy density >10%.

In some states where good analyses are now available, the Haryana and Kerala are a case in point. With merely 3.5 per cent of Haryana's area under forests, the state has become self-sufficient in small wood, fuelwood and industrial timber by establishing large-scale plantations on farmlands. Trees in agroecosystems have increased the extent of area under forest and tree cover to 6.63 per cent. Similarly, the case of Kerala suggests that the state has a surplus of wood in terms of consumption. In the total wood production of the state, the forests provide only about 10 per cent and trees in home gardens and mixed cropping multi-tier agroforestry system contribute to the remaining 90 per cent. After creation of Uttaranchal state in the year 2000, the tree cover in Uttar Pradesh has reduced to only 4.46% whereas, the State Forest Policy 1998 envisaged that one third of the total geographical area should come under forest/tree cover. Hence, agro forestry is now the only option to increase the desired tree cover of 33%. In Uttar Pradesh, practices of agro forestry vary considerably according to the agro climatic zones, socio-economic conditions and site-specific tree species.

Quantification of agroforestry systems and practices

Agroforestry is the use of trees and shrubs in agricultural crop and/or animal production and land management systems. Trees are used in many traditional and modern farming and rangeland systems. Trees on farms are particularly prevalent in Southeast Asia and Central and South America. Farmers have always grown trees on their land, often noting that this has beneficial effects for the soil and crop yields. This capacity of trees and other plants to restore soil fertility was utilized in African traditional agricultural systems based on shifting cultivation.

Agroforestry systems and practices come in many forms, including improved fallows, *taungya* (growing annual agricultural crops during the establishment of a forest plantation), home gardens, growing multipurpose trees and shrubs, boundary planting, farm woodlots, orchards, plantation/crop combinations, shelterbelts, windbreaks, conservation hedges, fodder banks, live fences, trees on pasture and tree apiculture (Sinclair, 28). Agroforestry provides cost-effective alternatives that can increase profits and meet

environmental goals (Kurtz, 15). Most of the agroforestry systems practiced globally are silvoarable forest farming, riparian buffer strips, improved fallow, shifting cultivation, multipurpose trees and silvopasture etc. (Alavalapati and Nair, 2; Alavalapati *et al*., 3). According to the definition given by ICRAF (12) several authors have produced estimates of the extent of particular systems (Table 1).

Table 1 : Examples of land areas under agroforestry.

Country	Area (m ha)	Specific information	Reference
Indonesia	2.8	Jungle rubber agroforests	Wibava *et al*. (32)
Indonesia	3.5	All multistrata agro forests	Van Noordwijk and Ong (31)
India	7.4	National estimates	Zomer *et al*. (34)
Nigeria	5.0-6.0	Recently planted	Gray Tappan (Pers. Com.)
Mali	5.1	90% of agricultural land	Cisse, M.I. (6); Boffa, (5)
C. America	9.2	Silvopastoral systems	Beer *et al*. (4)
C. America	0.77	Coffee agroforests	Beer *et al*. (4)
Spain/ Portugal	6.0	Dehasa agroforestry	Gaspar *et al*., (10)
Worldwide	7.8	Cocoa agroforests	Van Grinsven (Pers. Com.)

**Source : IAASTD (11)*

An estimated 1.2 billion rural people in the developing world currently practice and benefit from agroforestry (Garrity, 9). For example 75- 85% of the fuel wood used in Indonesia, Java, Pakistan, the Philippines, Sri lanka and Vietnam is harvested from farmland. In the arid parts of sub-Sahara Africa, over 7,500 species that grow in Silvopasture system are used as fodder and supply up to 50% of livestock feed. The use of nitrogen- fixing species including *Acacia albida, Vita kariaparadoxa and Acacia senegal* in parklands in West Africa is an example of traditional tree – based farming systems (Sadio, 25). Agenda 21, the blueprint for action into the 21st century adopted by world leaders meeting at the 1992 Rio Earth Summit, identifies agroforestry as one way of rehabilitating the degraded dry lands of the world. Agroforestry, one of several approaches for improving land use, is also frequently invoked as an answer to shortages of fuel wood, cash income, animal fodder and building materials in sub-Saharan Africa (Rocheleau, 24).

Agroforestry practices are major features of the land-use systems in the dry lands of Eastern and Central Africa. Trees are used for a variety of purposes in both cropped lands and in livestock grazing systems. Trees in the land and homestead find various domestic and commercial applications for both wood and non-wood products (Jama and Zeila, 14; Regmi and Garforth, 23). Agroforestry systems are important sources of timber and fuel wood throughout the world in both developing and developed countries. For example, intercropping of trees and crops is practiced on three million hectares in China (Sen, 27) and in the United Kingdom; a range of timber/ cereal and timber/pasture systems has been profitable to farmers (McAdam *et al.*, 16). Trees produced on farm are major sources of timber in Asia (e.g. China, India, and Pakistan), East Africa (e.g. Tanzania) and Southern Africa (e.g Zambia), Increasing wood production on farms can take pressure off forests, which would otherwise result in their degradation. The extent of alley cropping, silvopasture, windbreaks and riparian buffers in the USA is 235.2 m ha (Nair and Nair, 20). Silvopasture is becoming an increasingly popular agroforestry practice in southern United States, (Workman *et al.,* 33). Agroforestry systems for fodder are also profitable in developed countries. For example, in the northern agricultural region of Western Australia, using tagasaste (*Chamaecytisus proliferus*) has increased returns to farmers whose cattle formerly grazed on annual grasses and legumes (Abadi *et al*. 1). Currently, the silvopasture and silvoarable are the major agroforestry practices followed in Europe. Swidden cultivation is the mainstay of subsistence livelihood in the developing countries of Pacific Region consisting 27 countries and territories with a total land area of 542000 km^2 and over five million inhabitants.

Problems in estimation of agro- forestry systems and practices

Major problems in estimation of the area under agroforestry is lack of proper procedures for delineating the area influenced by trees in a mixed stand of trees and crops. In simultaneous systems, the entire area occupied by multistrata systems such as homegardens and shaded perennial systems and intensive tree-intercropping situations can be listed as agroforestry. However, most of the agroforestry systems are rather extensive, where the components, especially trees, are not planted at regular spacing or density; for example, the parkland system and extensive silvopastures. The problem is more difficult in the case of practices such as windbreaks and boundary planting where although

the trees are planted at wide distances between rows (windbreaks) or around agricultural or pastoral parcels (boundary planting), because the influence of trees extends over a larger than easily perceivable extent of areas. The problem has a different dimension of difficulty when it comes to sequential tropical systems such as improved fallows and shifting cultivation. In such situations, the beneficial effect of trees and other woody vegetation (in the fallow phase) on the crops that follow them (in the cropping phase) is believed to last for a variable length of time (years) (Nair *et al.,* 22).

Limitations

The study has several limitations. *e.g.,* tree cover estimates are based on computer analysis of remote sensing of one kilometre square pixels. Fifty per cent tree cover in a square kilometer could mean one large block of trees in other words, a small forest or an even scattering across farmland. And the analysis provides no information about the nature and use of trees on farmland. The global figures for tree cover are almost certainly conservative. There are large areas of agroforestry that are excluded from agricultural land, such as the jungle rubber systems in Indonesia and cocoa agroforestry in West Africa. In global land cover databases these areas are usually classified as forest, not as agricultural land.

Conclusion

Agroforestry is a complex subject in nature and the quantification of agroforestry at global level is not an easy task. The data available previously was a hypothetical estimation which ranged wildly. Agroforestry is still a growing child and the quantification of agroforestry systems and practices is in the stage of infancy which will take the time to come in a stage of maturity but on the basis of this study it can be said that although this is the beginning but significant step towards destiny.

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