8.1 Introduction

Agroforestry is an age-old practice that contains a strong element of management. It is a collective name for land-use systems and technologies where woody perennials are deliberately used on the same land-management unit as agricultural crops and/or animals. This can either be in a spatial arrangement or in rotation, with economic and ecological interactions between the trees and crops. In a review by Franzel (2002), agroforestry is defined by Leaky (1996) as a dynamic, ecologically based, natural resource management system that sustains and diversifies production for improved economic, social and environmental benefits for farmers, through the integration of trees in the agricultural landscape. Trees in this system provide fuel wood, fodder, fruit (productive functions) as well as fencing and shade (service functions). A strict scientific definition of agroforestry should stress two characteristics common to all forms of agroforestry and separate it from other forms of land use, i.e.,

- Deliberate growing of woody perennials in the same unit of land as agricultural crops and/or animals
- There must be significant interaction (+ve or -ve) between the woody and the non-woody component (either ecological or economical)

There are three attributes of agroforestry system, thus:

- Productivity - Agroforestry aims at maintaining or increasing overall productivity, e.g., increased output of tree products, improved yields of associated crops, reduction of inputs, increased labour efficiency
- Sustainability - by conserving the production potential of the resource base mainly through beneficial effects of trees on soils
- Adoptability - improved or new agro-forestry technologies introduced into new areas should conform to local farming practices and therefore “accepted” by farmers
8.2 Historical perspective of Agroforestry

Cultivation of trees with crops in intimate combination with one another is an ancient practice. In Europe, until Middle Ages, a general custom was to clear-fell degraded forest, burn the slash, cultivate food crops for a period before planting trees. These farming systems are no longer popular in Europe. In tropical America, many societies simulated forest conditions to obtain beneficial effects of forest ecosystems, farmers planted more than 20 different species in approximately 0.1 hectares, which included coconut, papaya, bananas, citrus, coffee/cacao, maize, squash. In Asia, the Hanunoo of Philippines practiced complex shifting cultivation where they spared some trees to provide canopy, food, medicines, construction wood and cosmetics. In Africa, most crops (yams, maize, pumpkins, beans, etc) were grown under cover of scattered trees. Trees were therefore an integral part of many traditional land-use practices and these are some examples of what is now known as agroforestry (Nair, 1993).

The origin of agroforestry as a modern scientific study dates back to 70s following a review of research needs, “Trees, Food and People” (Bene et al., 1977) that recognised the key concept that trees and shrubs grown on farmland had distinctive and valuable roles to play. This is where the term ‘agroforestry’ was coined. This led to the establishment of the International Centre for Research in Agroforestry (ICRAF) now World Agroforestry Centre (WAC). Agroforestry was promoted extensively in the 1980s, as a practice that enhanced sustainability showing great potential to increase crop yields, control soil erosion, and enhance nutrient recycling with the added benefit of fuel wood, fodder, fruit and timber production. During this period, the focus of research was on conceptual issues, such as the definition and classification of different types of agroforestry, and on an inventory of existing systems (Nair, 1990). However, in the 1990s and onwards agroforestry studies have been based on research that is process-oriented and more empirical and now agroforestry is recognized as an applied science based on principles of natural resource management.

8.3 Agroforestry Systems and Practices

A typical agroforestry system consists of various components: trees, agricultural crops, pastures, livestock and soils, trees being present at all agroforestry systems and practices (Young, 1997). The living components together with the soil make up the plant-soil system or plant-soil-animal system. An agroforestry system consists of one or more agroforestry practices that are practiced extensively in a given locality or area. The system is usually described according to its biological composition and arrangement, level of technical management, or socio-economic features. An agroforestry practice, on the other hand denotes a specific land-management operation on a farm or other management unit, and consists of arrangements of agroforestry components in space and/or time. These systems are characterised
mainly by distinctive arrangements of components in space and time, together with their objectives or functions. There are thousands of specific agroforestry systems in the world. Examples of these systems include shifting cultivation, managed tree fallows, relay intercropping, taungya (shamba system), trees on crop land, multi-strata systems, home gardens, boundary planting, hedgerow intercropping, biomass transfer, trees on pastures, aquaforestry, and reclamation forestry among others.

The highest level of agroforestry systems classification is based on the components present that are managed by the land user (Huxley, 1986; Young, 1989; Nair, 1990). There are three basic sets of elements or components namely the tree or woody perennial, the agricultural element and the animal. An agroforestry system must always have a woody perennial. Based on this, there are three main systems thus:

- **Agrosilviculture**: In this system selected tree species are integrated in crop production systems. Examples include, among others, taungya or shamba system, trees on cropland and boundary planting.
- **Silvopastoral**: This entails integration of trees in livestock production systems. Examples include most systems of trees in pastures and apiculture involving use of trees to raise bees for honey.
- **Agrosilvipastoral**: entails integration of crops, trees and pasture or annuals in one system. Examples are woody perennials on cropland for fodder, green manure, home gardens including a number of woody plants that are grown with crops and provide fodder for livestock.

Plates 1-2 are examples of typical applications of agro-forestry in land management and household economics in Kenya.

Plate 1: Terrace formation using trees
Plate 2: Feeding calliandra to cows

**Other benefits of agroforestry include:**

- Fruits for nutritional purposes;
- Trees for bee farming;
- Provision of shade;
- Trees as windbreaks;
- Environmental aesthetic;
- Trees for wood fuel;
- Trees as building material;
- Nutrient recycling;
- Dust management
The second level is based on the arrangements of components in space and time. In rotational systems, the association between trees and crops/pastures takes place primarily over time, although there may also be some degree of overlap. A good example of a rotation system is the fallow system or shifting cultivation. In spatial systems, the association is primarily one of trees and crops together on the same land management unit. The third and lowest level of classification is empirical, employing tree density, detailed spatial arrangement, function and management as criteria, for example, open versus dense trees.

The most widely spread form of agroforestry is trees on cropland. In this practice trees are grown on farmers’ fields while crops are grown in the understorey. The trees may be dispersed widely, either spaced systematically or scattered at random. Different tree species are used in different regions for instance, Grevillea robusta (central Kenya), Sesbania sesban (Kakamega District), and Markhamia platycalyx (Siaya District). Trees planted in the cropland provide several products of value to farmers such as food, fuelwood, wood for construction and furniture, fruits, and fodder. They also provide services such as soil conservation and windbreaks.

The fallow system is an old practice where cropped fields are left to lie fallow to allow the soil to rest, auto-regenerate and restore soil fertility. Traditionally, these falls were used for grazing or were left to natural vegetation but when improved fallow agroforestry system is applied the trees replace crops on the fallow fields in sequence over time. In this system the trees are not grown with crops on the same field (area) at the same time but instead they are used in rotation. The fallow period protects the soil from erosion, eliminates weeds, pests and diseases specific to the cropping system and increases the organic matter content of the soil, cycle and trap nutrients from the subsoil and improve soil structure, including aeration, water-holding capacity and tilth (Rocheleau et al., 1988).

However, due to increased population pressure, the fallow periods have reduced and are no longer effective in maintaining soil fertility. This has led to development of improved tree fallows that have shown great potential as an agro-forestry technique in the densely populated areas of western Kenya where there is bimodal rainfall, allowing farmers to fallow for one season per year. Crotalaria grahamiana and Tephrosia vogelii are some of the most popular species with farmers in western Kenya and seeds are broadcast or planted directly. The trees are planted at the time of second weeding of maize field and then left to occupy the field alone in the following rainy season, which is usually the short season (Place et al., 2002). Farmers in western Kenya have also adopted short-duration improved fallows with fast growing leguminous trees and shrubs, several species of which, provide fuel wood and stakes for supporting crops such as tomato and climbing bean in addition to improving soil fertility (Noordin et al., 2002).
Hedgerow intercropping or alley cropping is an agro-forestry practice in which crops are grown between rows of managed nitrogen-fixing trees, such as leucaena and the trees' leafy biomass is also applied to crops. The primary purpose of alley cropping is to maintain or increase crop yields by improvement of fertility and microclimate and weed control (Rocheleau et al., 1988). This was developed at IITA but it has turned out to be a system that has a very niche requirement and has been found to present mixed performances in different regions. A review by Kang (1993), showed that more than 50% of studies con reported reduced crop yields. However, farmers may also get tree products from the hedges like food, fodder, fuelwood and building poles. On sloping lands, hedgerows can reduce soil erosion by reducing the speed of the moving water and trapping the soil. In addition, labour costs are usually high due to planting, planting and incorporation (Swinkels et al., 2002). Calliandra calothyrsus, Gliricidia sepium, Cassia siamea, Sesbania sesban and Leucaena Trichandra are some of the species that have been tried for establishing hedgerow intercropping.

Barrier hedges or contour hedgerows are zonal agroforestry practices in which perennial woody species included, are geometrically arranged in plots or strips interspersed with crops or and grasses (Kilewe, 1989). They are multiple or single line of shrubs, that are closely spaced and planted along contour to form a natural barrier and is quite effective in erosion control. Their punnings can also be planted on cropped alleys as soil cover. Some common species planted as barrier hedges include Calliandra calothyrsus, and Leucaena trichandra. There is also the fanya juu terraces technique where fruit trees are planted in the trenches, which are regularly dug out to support the banks. Some of the fruit trees include; Persea Americana (Avocado), orange, grapefruit, Psidium guajava (guava), Mangifera indica (mango), banana and mulberry trees.

Biomass transfer or cut and carry systems involve growing of trees and/or shrubs along contours on farms or on roadsides and then consequently spreading the leaves on crop fields at planting time or later in the season (Place et al., 2002). Tithonia diversifolia (tithonia), Calliandra calothyrsus (calliandra) and Leucaena trichandra (leucaena) are some of the trees used in biomass transfer systems to their high nutrient levels (Table 1). These shrubs also withstand frequent cutting and coppicing producing new re-growth within a short time of 2 weeks especially under warm and wet conditions.

Agro-forestry with a sylvopastoral component can be enhanced with the use of fodder shrubs and tree legumes for livestock production (Chabeda, 1989). They have low palatability hence act as fodder banks during the critical food deficit period where quantity and quality are limiting factors. Small-scale dairy farmers in central Kenya have widely adopted Calliandra calothyrsus, a leguminous fodder shrub as a fodder shrub (Franzel et al., 2002).
Table 1: Nutrient composition of various plant materials

<table>
<thead>
<tr>
<th>Species</th>
<th>Nitrogen (%)</th>
<th>Phosphorus (%)</th>
<th>Potassium (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tithonia diversifolia</em></td>
<td>3.6</td>
<td>0.3</td>
<td>4.3</td>
</tr>
<tr>
<td><em>Calliandra calothyrsus</em></td>
<td>3.5</td>
<td>0.2</td>
<td>1.6</td>
</tr>
<tr>
<td><em>Leucaena trichandra</em></td>
<td>3.7</td>
<td>0.3</td>
<td>3.3</td>
</tr>
<tr>
<td><em>Grevillea robusta</em></td>
<td>1.4</td>
<td>&lt;0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Maize stover</td>
<td>0.9</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Napier grass</td>
<td>1.97</td>
<td>0.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Bean stover</td>
<td>0.7</td>
<td>0.1</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Source: Palm et al. (1997); Gitahi and Mureithi (2002)

Live fence is another agroforestry practice, which is commonly found in the African landscapes. This is where trees and shrubs are used to mark small-cultivated plots and livestock enclosures. Some of the common tree species used include; *Comiphora africana*, *Euphorbia tirucalli*, *Dovyalis caffra* (kei apple), *Moringa oleifera*, *Psidium guajava* and *Erythrina abyssinica*.

Trees and shrubs on boundaries is another agroforestry practice in Kenya. Here the trees are planted along land boundaries to act as a border mark. Tree boundaries are common along the boundaries of farms, home compounds and pastures. The most common form of boundary planting consists of a single line of widely spaced trees and shrubs. The commonly tree species used to mark boundaries include *Grevillea robusta*, *Eucalyptus*, *Casuarina*, *Euphorbia* species, *Mangifera indica*, *Carica papaya* (papaya), *Citrus* species, sisal plants and *Moringa oleifera*. Other agroforestry practices include tree gardens, plantation crop combinations, windbreaks, trees and shrubs on pastures, and use of multipurpose trees.

8.4 Role of Agro-forestry in land and water management

Soil degradation has received a global concern as the major cause of declining per capita food production in many African countries usually referred to as sub-Saharan Africa. Soil degradation is a reduction of soil quality or the inherent ability of the soil to perform a range of productive, environmental and habitat functions. A degraded land/soil can be interpreted as having low soil organic matter, inadequate plant nutrients, low water holding capacity, low soil depth and poor soil physical characteristics. On many farms, this has resulted from a combination of high rates of soil erosion, leaching, removal of crop residues and continuous cultivation without adequate addition of plant nutrients and inadequate fallowing.
In addition, increasing population pressure has resulted in introduction of short-duration agricultural species that are continuously cultivated in pure stands in combination with perennials without adequate soil replenishment. This consequently led to much higher nutrient outflows than inflows and the subsequent breakdown of many traditional soil fertility maintaining strategies such as fallow land, intercropping with legume crops, and mixed crop-livestock farming. In turn, farmers are unable to sufficiently compensate these losses via addition of crop residues, manures or mineral fertilizers. It is in this context that it becomes important to exploit the desirable soil enhancing and/or restoring characteristics of woody perennials or agroforestry to its full extent. According to several authors (Roucheleau et al., 1988; Young, 1989; Nair, 1990; 1993; Sanchez et al., 1991), agroforestry has frequently been invoked as a solution to the problems of land and water degradation and shortage of food, fuelwood, cash income, animal fodder and building material. However, agroforestry is only one of several approaches for improving land use in any given situation. Agroforestry has both productive and service functions (Young, 1997). The distinctive contribution to production is to obtain tree products from the farm; these include the fuel wood, fodder and fruit together with construction wood and a host of other items such as gums, thatching materials and medicinal products. The relative importance of these products varies between systems, according to environment and socio-economic circumstances.

The service functions are also varied, including shade, reduction in wind speed, control of weeds, and fencing. The major service function of agroforestry is its role in soil management, including control of erosion and maintenance and improvement of soil fertility. The tree in the agroforestry system increases soil fertility whereas the crop component reduces it. Highly fertile soils in turn, result in high crop yields and sufficiently good plant cover minimizing detrimental erosive effects of rainfall, wind and run-off. Hence, there is a need to design agroforestry systems in such a manner that tree and crop components will augment each other for increased soil fertility. Alley cropping, tree gardens, plantation crop combinations, biomass transfer, trees on cropland, controlled or planted fallow, trees and shrubs on pastures and windbreaks are some of the practices that can be used to achieve this aim (Kile 1989). The tree component in agroforestry maintains and improves soil through:

- Processes that facilitate additions to the soil such as nitrogen fixation; carbon fixation by photosynthesis and its transfer to soil humus through litter and root decay; retrieval of soils from deeper soil horizons; furnishing of favourable conditions for nutrient input by dust and rainfall.
- Processes that reduce soil losses such as erosion control; prevention of leaching by trapping of nutrients and retrieval of lost nutrients through uptake of nutrients by roots.
Processes that determine the quality of plant residue through provision of varied choice of plant litter and timing of the transfer of nutrients to the soil by management of pruning and effects of shading on microclimate, so as to synchronise release of nutrients with uptake requirements by crops.

Soil physical properties enhancement, as soil beneath trees are structurally stable and have good water-holding capacity due to maintenance of organic matter and growth and decay of roots.

Agroforestry can assist in ameliorating soil toxicities by checking acidification through the buffering effect exerted by organic matter obtained from tree litter and also incorporating trees in the reclamation of saline and alkaline soils with the help of drainage and gypsum, as has been done in India.

The role of trees in soil conservation and erosion control is one of the most acclaimed and compelling reasons for including trees in farmlands that are prone to erosion hazards. The beneficial effects of trees in this regard extend beyond protecting the immediate farmland to imparting stability to the ecosystem and reducing the rate of siliation of downstream aquatic ecosystems, dams and reservoirs. Barrier ridges are very effective in controlling soil erosion by run-off, especially after prunings are placed on the cropped areas (Box 1). This is because a) dense-growing barrier and the accumulated litter slow down run-off, b) prunings provide soil cover and increase surface roughness, c) barrier and litter increase infiltration hence reducing total run-off, d) they enhance natural development of the barrier into terraces through accumulation of soil on the upper sides of the hedges, e) decomposition of shrub prunings lead to improved soil fertility and soil structure. Similarly, alley cropping exhibits high potential for erosion control (Kilewe, 1989).

According to Sanchez (1995), sequential improved tree fallow systems are more robust than simultaneous agroforestry systems. This is because competition for light, water, and nutrients between the improved fallow and the crop is minimized by the relay intercropping or sequential agroforestry systems. Also, the deep-rooted fallow species are able to utilize subsoil water and nutrients inaccessible to annual crops during the dry seasons and droughts. Consequently, much of the biomass accumulation of improved fallows can occur during the dry seasons and during unreliable short rainy seasons. Litter fall from fallows also provide carbon as an energy source for soil microbes to enhance nutrient cycling and soil carbon sequestration. Farmers interviewed in a formal survey also mentioned soil erosion control as another ecological benefit of improved fallows (De Wolf and Rommelse, 2000).
Box 1: Kanga Muga

Kanga Muga, 71 years is a farmer from Meru South who has experienced the benefits of using agroforestry structures to control soil erosion. A large part of his farm is sloppy and Kanga indicates that there is a time when there was high soil erosion before he implemented soil conservation structures. In 2001 he planted his first calliandra and leucaena trees along contours mainly for soil conservation. Kanga says, “I have seen a lot of benefits from these calliandra and leucaena trees. When I first planted them, the soil used to move to the next bench but now I do not see any soil moving. They seem to prevent the soil from moving downslope. The soil fertility has also improved on this piece of land and benches have also formed”.

In Kenya, tree fallow species such as Crotalaria grahamiana and Tephrosia vogel have been found to contribute high nutrient levels from both leafy and root biomass in addition to the leguminous trees fixing atmospheric nitrogen. An improved tree fallow produces up to 150 kg ha-1 of N and recycles 50-60 kg ha-1 of K and 5-10 kg ha-1 of P during the fallow phase. They also enhance soil structure, infiltration, organic matter and soil carbon and also reduce weed prevalence (Place et al., 2002).

The biomass transfer system may be practiced by transferring of tree biomass produced from one field to another farm or by transferring biomass produced outside the farms as in the case of tithonia. Mugendi et al. (1999) reported that calliandra green biomass (with or without fertilizer) had significant increase in maize grain yields as compared to the inorganic fertilizer. With biomass incorporation 4.1 Mg ha-1 of maize grain per season was obtained, compared to 3.3 Mg ha-1 obtained from the application of the recommended level of mineral fertilizer and 3.1 Mg ha-1 per season for the absolute control. The rate of soil fertility decline was also reduced, with total soil nitrogen increasing by 1-8%, however, without the application of biomass total soil nitrogen declined by 2-4%. According to Mucheru-Muna et al. (2006), maize yields especially in Meru South District (Chuka) have increased almost five-fold following use of tithonia, calliandra and leucaena (Figure 1).

For farmers with livestock, it is possible to feed the prunings of some agroforestry trees/shrubs like calliandra and leucaena to the animals. Calliandra and leucaena biomass is highly palatable fodder, rich in crude protein, which is desirable for high milk production. Research has shown that 3 kg of fresh prunings of calliandra or leucaena give the same milk response as 1 kg of dairy meal. Because on average farmers feed 2 kg of dairy meal per day, it has been recommended that 6 kg of
fresh biomass of calliandra or leucaena can be used to substitute for the 2 kg of dairy meal. While feeding this amount a farmer would need about 500 trees to feed one cow for one year. To improve soil fertility, manure from the animals should be recycled to the farms. This is advantageous because the farmer will benefit from increased milk yields and from improved manure quality.

![Maize yield responses following application of different inputs in Meru South District](image)

Figure 1: Maize yield responses following application of different inputs in Meru South District

Lilian Kagendo (51 years) a farmer from Meru South planted her first trees of calliandra and leucaena in 2001. She has a total of about 1500 trees. Kagendo says, “I have seen a lot of benefits from these trees. I use my calliandra and leucaena to feed my dairy animals and also for applying into the soil to improve soil fertility. When I started feeding calliandra to my cows, I realized a difference in milk production especially in the morning. The milk increased from 5 to 6 litres in the morning while it increased from 4 to 4.5 litres in the evening. The health of my dairy cow has improved and it looks fatter and smoother than before and the milk has also improved in cream content. However, the basal diet still remains Napier grass, stovers (maize and bean) and banana stems and leaves”. Mbae M’rachi (37 years) a farmer from Meru South also planted his first calliandra and leucaena trees in 2001 and currently has about 2000 trees. Initially he used to use prunings from these trees for soil fertility improvement and for feeding animals but now only uses them for feeding his animals (cows, goats, rabbits). Mbae uses the fodder trees to substitute dairy meal and feeds his two dairy cows at 6 kg of fresh prunings daily per cow (Plate 4 above). Mbae says, “Substituting dairy meal with fodder prunings
did not affect milk production from my cows but reduced costs because I no longer have to buy daily meal”.

Reduction of pests especially where tithonia is used has been reported. In Western Kenya, there has been reported reduced bean rot (a fungal disease found in beans) and less incidences of termite damage to crops growing in plots where tithonia was applied. In Central Kenya, farmers have reported fewer incidences of Chilo grubs in plots where tithonia is being used.

8.5 Adoption challenges of agro-forestry in Kenya

Case studies conducted in Vihiga District, Kenya inferred that labour for collecting and incorporating biomass was the biggest problem faced by farmers, especially in biomass transfer technologies (Place et al., 2002). In the case of improved fallows, a number of factors still hinder large scale adoption (Sahyoun et al., 1999). These include (a) households that are landless or near land-less but, they are unlikely to leave even modest areas uncultivated, (b) situation where intensive livestock production system where non-cropped land may be put to fodder production, (c) in perennial cropping systems, e.g., coffee growing, (d) where farmers do not recognize soil fertility as an important problem to give it the priority it deserves, and (e) supply of germplasm of improved fallow species and accessions. One-third of farmers interviewed claimed that land preparation for an improved fallow was more difficult than after a natural fallow and one-third discontinued the technology, although more felt otherwise. Other issues that affect adoption included caterpillar attack on crotalaria, especially during the El-nino period, and the negative influence on maize crop (Place et al., 2002). Otherwise, most farmers generally accepted improved fallows technology.

Village committees/groups are one of the tools used for dissemination of agro-forestry technologies in some parts of Kenya such as Vihiga and Meru South District. However, most of these village committees/groups remain inactive mainly due to lack of funds to carry out activities hence village action plans are not carried out. Co-ordination of soil conservation activities, supplying inputs and organising tours are also part of the core activities of these committees and these do not have frequent follow-up by project field officers. If the follow-up is weak, as has happened in some cases, so will be the uptake of agroforestry technologies. Study tours and field exchange visits provide a forum for farmer networking, and acquiring information and seeds. Unfortunately, such visits can be costly depending on the number of farmers participating and the distance travelled (Noordin et al., 2006).

Technology development of agroforestry in Kenya has also been impeded by weak linkages between research and extension, scanty information and lack of availability of germplasm to farmers. Agroforestry extension has also been weak resulting in slow diffusion of technologies.
adoption rate of agro-forestry practices. Extension is problematic because extension agents lack agroforestry training, have limited resources of public extension systems, and lack properly validated and locally adapted extension messages. In addition, duplication of roles and assignments among agricultural and extension institutions undermines overall output. Ultimately some farmers remain ignorant of the value of tree prunings in soil fertility management, and have been observed to wasting nutrient rich tithonia by cutting it and either throwing it away or leaving it where it was cut. Various factors have impeded scaling up of agro-forestry in Kenya. These include transaction costs such as operational and staff time funds, lack of commitment, obstacles in pooling resources leading to duplication in effort and weak documentation of the research activities carried out in the region resulting in minimal exchange of information among various stakeholders.

Policy constraints in some parts of Kenya occasioned by ordinances that require farmers to obtain permits before cutting trees have acted as disincentives for promotion of agro-forestry. This is because farmers will be less inclined to plant trees if they feel they will not benefit from them. Other challenges include land tenure problems, intra-household disputes, poor tree establishment and even lack of interest.

8.6 Emerging Research Needs in Agroforestry

More research needs to be done on the adoption potential of agroforestry practices. This is important, as the feedback obtained has been used to guide research programmes in developing improved tree fallows for many farmers. These assessments would also demonstrate the impact of investing in agroforestry technology development and dissemination e.g. adoption of calliandra as a fodder tree among the small-scale dairy farmer’s of Kenya has potential benefits accruing to US$139 million year-1 (Franzel et al., 2002a). Adoption studies would also enhance inter-disciplinary and inter-institutional cooperation and assist to identify factors that promote or hinder successful technology development programmes.

Research also needs to focus on the main biophysical and socio-economic conditions that influence adoption of new technologies. Geographical information systems should be incorporated to assess boundary conditions of new technologies. Guidelines and recommendations based on such systems can be useful in assessing the advantages and disadvantages of different options in differing biophysical and socio-economic conditions (Franzel and Scherr, 2002).

More research has to be done in spreading the benefits of agroforestry practices or scaling up across large areas (Franzel and Scherr, 2002). For instance, more focus has to be placed on means of developing decentralized, financially sustainable, village-level germplasm/seed production and distribution systems. Research on increasing biodiversity at gene, species and ecosystem levels of tree species used is also essential as it will assist in reducing risks. More research needs to be conducted
on effective ways of disseminating information to as many farmers as possible, ways of putting in place functional farmer information networks and community group learning. More studies need to be conducted on scaling up so as to generate a continuous stream of technology options based on integration of science and farmer innovation. Studies should also be conducted on how farmers can market their agro-forestry products to local, regional and international markets (Franzel et al., 2002b). In addition, ways in which monitoring and evaluation systems can be designed to capture knowledge created by farmers as they adapt and implement innovations to suit their conditions should be put in place.

Focus on the watershed/landscape scale should be increased as scaling up from plot and farm scales to the watershed pose methodological challenges such as the quantification of patch dynamics and biodiversity and the design of thorough participatory community level methods. In addition, methods for valuing ecosystem services such as the value of biodiversity have to be developed in the context of tropical countries (ICRAF, 1999).

Research should be done to device ways of making policy makers effective and promoting local farmer organisations and agro-forestry development. Studies should also be conducted on how to devise more strategic partnerships and reduce their costs. There is need to seek ways in which research institutions can act more structurally and functionally for the purpose of being more affective partners in scaling up and rural development (Franzel et al., 2002b). More research also needs to be conducted on the impact of agro-forestry practices on the living standards of poor farmers, more so women, and the environment. Scientists/Researchers should seek better ways of facilitating farmer and community-based monitoring and evaluation.

8.7 Policy Issues Related to Agro-forestry in Kenya

A policy environment that is conducive is critical for the adoption and scaling up of agro-forestry practices. This fact is underlined by the complexity involving plant and distribution of planting material for trees as they require nurseries. Agro-forestry practices also involve mixing trees with crops and returns are usually generated after several years. Therefore, agro-forestry practices do require rigorous and supportive policies for their development and widespread adoption.

In Kenya, the Tree Seed Regulation derives its authority from the Seeds and Plant Varieties Act that was passed in 1972 with the aim of regulating production and use of seeds and introduction of new plant varieties. This act stipulates that processes of seed production, collection, distribution and marketing be inspected against set standards and conditions. In this way, high productive forestry and agro-forestry systems are guaranteed and sustained through involvement of the public, local organizations and the Government. This regulation also promotes the adoption of research recommendations from various research programmes carried out. The overall purpose of this regulation is to promote stability, sustainability...
productivity and genetic diversity in agro-forestry through provision and utilisation of high quality seeds whose sources are protected and soundly managed (Omondi and Were, 1997).

In some parts of Kenya, ordinances require farmers to obtain a permit before cutting down a tree. Although the policy may harbour good intentions, it impedes implementation of agro-forestry as it discourages farmers from planting trees that they believe will never benefit them. Furthermore, the ordinances are sometimes abused as farmers are forced to pay bribes or go through stifling bureaucracies. However, this issue has been addressed by agro-forestry researchers and development staff through informing policy makers (such as the provincial administration) on the strains such policies place on development efforts of agro-forestry and persuading them to obliterate issuance of permits for cutting trees. From case studies conducted, it is imperative to equate the importance of local policy makers to that of national policy makers based in the city, as great potential exists to mobilise local authorities to promote agro-forestry development. In Kenya, successful local pilot projects have been scaled up to national level through policy contacts.

The Agriculture act, which is part of Kenya's current land use legislation, holds the greatest promise as an agroforestry legal framework. The act provides a comprehensive range of enabling powers for land use supervision with the purpose of agricultural production (sections 64-74) and coincidentally providing a framework for the development of forests in agricultural land (sections 48-62). Thus the act is essential in easing the integration of trees into farming systems in Kenya. On the other hand, the Forest Act proffers exclusivity of forests in such a manner no other forms of land use can be practiced in forests. It is advisable to look for an alternative legal framework to tackle this problem (Okoth-Owiro, 1988).

8.8 Conclusion and Recommendations

Studies conducted in Africa have shown that agro-forestry can solve land use and management problems posed by expansion and intensification of farming. Farmers in Kenya have adopted a wide array of agro-forestry practises such as improved tree fallows, barrier hedges, biomass transfer, boundary planting and others. These agroforestry systems perform both productive and service roles and the most important service role is that of land and water management. Depletion of soil through erosion, nutrient loses and other processes remain serious problems in Africa. Replenishment through organic inputs such as crop residues and animal manures is limited by their availability and the use of inorganic fertilizers is constrained by high costs. Technologies are required to recover depleted soils and the incorporation of soil improving and compatible woody species on farmlands can considerably retard the rates of undesirable processes of soil degradation and productivity decline that are experienced in many farmlands of Africa.
It has been noted that agroforestry is central to soil conservation through additions to the soil via nitrogen and carbon fixation and also through processes that reduce soil erosion and leaching. Nitrogen fixation, in turn, alleviates the need to use chemical fertilizers saving farmers much needed income. In addition, national or regional food security is enhanced. Where agroforestry practices are entrenched, fuel wood is obtained on-farm easing pressure on forests. A wide range of products and services are to be obtained from agroforestry including timber for domestic use and sale, food, medicine, livestock feed, shade, boundary marking, windbreak and beauty.

Agroforestry has the potential to be a big industry player, pending putting in place proper marketing, research and extension strategies, as shown by the success of the adoption of calliandra fodder shrub by small scale dairy farmers in central Kenya. Agroforestry technologies such as improved fallows and biomass transfer have generally been well accepted by farmers in western Kenya and have proved to be reasonably feasible. Farmers in central Kenya, known for their dynamism have readily adopted fodder shrubs due to high demand and easy access to markets for milk.

Vigorous marketing, at both the local and international level, of agroforestry products will greatly increase awareness leading to higher sales and income for the farmer. It is imperative to strengthen the link between research and extension for the agroforestry technologies to reach as many farmers as possible. At the same time, farmers should have continuous access to tree seeds, as this will promote adoption and scaling up of agro-forestry practices. These and other research needs need to be addressed immediately and effectively for quick adoption of agroforestry technologies. Finally, it is important to support policies that promote agroforestry and expunge or modify those that hinder implementation, adoption and scaling up of agroforestry.

8.9 Review Questions

i. Using practical examples explain the differences and relationships between an agroforestry system and agroforestry practice

ii. Agroforestry is one of the sciences of sustainable land management. Discuss using relevant examples

iii. Which challenges and opportunities exist at your home when it comes to tapping into agroforestry and maximising on its benefits?
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