Assessment of indigenous tree species conservation in subsistence agricultural production systems: A case study of Lari Sub-county, Kiambu County, Kenya

KAMAU MARYGORETTI WAWIRA, THUITA THENYA*
Department of Geography & Environmental Studies, University of Nairobi, Kenya. Hyslop Building, P.O. Box 72335-00200, Nairobi, Kenya.
Tel: +254-0721-471082,*email: tthenya@yahoo.co.uk

Manuscript received: 19 July 2017. Revision accepted: 8 October 2017.

Abstract. Wawira KM, Thenya T. 2017. Assessment of indigenous tree species conservation in subsistence agricultural production systems: A case study of Lari Sub-county, Kiambu County, Kenya. Asian J For 1: 55-63. Conservation of indigenous trees is important because they regulate nutrients, build organic matter of topsoil, fix nitrogen and create habitat for beneficial soil micro-organisms. Subsistence agriculture is characteristic land use feature in Kenya especially in the humid and sub-humid regions. Often indigenous trees are cleared to pave way for farming and replaced with exotic trees. The results showed that various indigenous tree species were retained on-farm including species like Acacia abyssinica, Olea europaea, Ficus thonningii, Brachylaena hutchinsii, Allophylus abyssinicus, Vitex keniensis and Prunus africana. The remnants of indigenous trees were scattered on farm with 38.9% around the homestead 2.6% inside the farm and on riverine areas 1.1%. Soil conservation, timber, and fuel wood, were given as the main reasons for conserving indigenous tree species on the farm. While the main reason for planting exotic on farm includes economic purposes like income, fuel wood and decreased land sizes, according to 60% of respondents. Overall the findings indicate significant decrease of indigenous trees conservation on farm due to longer maturity span compared to exotic trees. There is need to promote alternative uses of indigenous trees as well as reinforce the 10% tree cover to include that 2% of the latter should be indigenous in nature.

Keywords: Conservation, indigenous tree species, on farm, subsistence agriculture

INTRODUCTION

Trees have been part of local land use systems for millennia in the world. The products derived from them, such as food, medicine, cooking fuel, animal fodder and construction materials, are critical for the subsistence of hundreds of millions of people throughout the world. Trees in rural landscapes also have protective functions at farm, landscape and global levels in terms of soil erosion prevention. They maintain soil fertility, allow more efficient water and nutrient resource use, control water erosion, and contribute to micro-climate moderation. The ecosystem services they provide at a global level in terms of carbon sequestration and biodiversity conservation are also significant.

Globally, between years 2000 (averaged 2000-2002) to 2010 (averaged 2008-2010) a statistical analysis by the World Agroforestry Center showed that the amount of tree cover on agricultural land increased substantially, with the area of >10% tree cover increasing by 3%, or more than 828,000 km². It is essential that this is recognized by all involved in agricultural production, planning and policy development (Zomer et al. 2014). The largest increase was in South America with areas having >10% tree cover being more than 489,000 km²; an increase of 12.6%. South Asia also showed a large increase (6.7%), along with East Asia (5%), Oceania (3.2%) and Southeast Asia (2.7%). In Central America, the area with >10% tree cover increased by 1.6% to reach 96% of all agricultural land. For Sub-Saharan Africa, their increase has been at 2% but with both Northern and Central Asia showing a decrease of-2.9%.

Removal of trees from landscapes has for long been seen as a sign of intensification and progress, especially where mechanization of agriculture was involved (Zomer et al. 2014). Kenya is among developing countries in sub-Saharan Africa that shares problems of deforestation with other eastern Africa nations due to conversion of forests to other land use especially agriculture and settlement to meet the needs of ever-increasing human population. Globally, around 13 million hectares of forest were converted to other uses, largely agriculture, or lost through natural causes each year in the last decade. This compares with a revised figure of 16 million hectares per year in the 1990s (UNEP 2012). Estimates of the change in forest area over time provide an indication of the demand for land for forestry against other uses.

The agriculture and environment interface, according to Altieri and Nicholls (2005), is a growing source of concern, due to not only the frequently denounced negative effects of agriculture on the environment, but also to the increasingly strong constraints that environmental conservation places on small-scale farmers and collective rangeland management. It is widely recognized that change in agricultural land use is an important driver of biodiversity loss in developing countries (Wretenberg and Berg 2010). In Kenya, limited studies have been carried out
to assess factors associated with indigenous tree planting and retention by farmers in order to realize the expected output of improving tree cover (Oeba et al. 2012). The decision by farmers to plant trees may be difficult due to many land use needs especially agriculture in enhancing food security of about 40 million Kenyans.

A study Zomer et al. (2014) has shown the importance of trees outside forests at a global scale: almost half of the agricultural land in the world (more than 1 billion hectares) has tree cover of more than 10%. However, in most countries, trees outside forests are still poorly reported in the official statistics used to support national decision-making and policy. Trees outside forests are thus most often ignored in land-use planning and development policies. One major reason for this lack of information is the difficulty and cost of assessing trees outside forests at the national scale. In Lari farms are dotted with remnants of indigenous trees and it is for this reason that this research was undertaken to find out the types of indigenous trees, where they are grown and why they are retained in agricultural production systems in Lari Sub-county.

**MATERIALS AND METHODS**

**Study area**

**Geographical location**

Lari Sub-county covers an area of 439.20 km² (169.58 sq mi) with elevation ranging between 2415 to 2591m above sea level (a.s.l) and receives precipitation between 1,150 to 1,276mm. The study area covers two wards that are Kinale Ward, which has an area of 112.3 km² with a population density of 130 person per km² (Figure 1). The agroecological zone supports sheep and dairy farming, tea farming and forestry. While Kijabe Ward has an area of 29.8 km² with a population density of 711 person per km² while the associated agro-ecological zone supports wheat-maize-barley-pyrethrum farming and dairy zone.

Majority of the people in the study area depends on agriculture for their livelihood, with 304,449 directly or indirectly employed in the sector. Coffee and tea are the main cash crops while maize, beans, and Irish potatoes are the main food crops commonly grown on small scale. The majority of the people depend on small-scale farming with the average size of the land being 0.8 ha. The land is purely an agriculture zone and agricultural practices are rain dependent. In relation to the land use patterns, Lari lies in the high to moderate fertility where livestock, tea, coffee, and horticulture agro-enterprises are practiced. The soils are well drained, extremely deep, grey or red or dark brown friable clays.

![Figure 1. Locator map of Lari Sub-county, Kenya](image-url)
Study design
The study design adopted for this research was both descriptive as well as cross-sectional research designs. The study was designed to capture two agro-ecological zones; these were selected through purposive sampling based on the agro-ecological characteristics and population size. The sample selected through multi-stage sampling was subjected to both observation and interrogative data collection. However, only a cross-section of farmers was selected to participate in the study since data collection was only done for farms along major roads. The purpose of selecting these farms was based on the assumption that farms nearer to the major road networks hardly had any indigenous trees because of the already high demand for timber.

The first sampling point was at the Sub-county administrator office of each sub location and then 5th farm to the right side of the road after the Sub-county administrator office and thereafter every 5th household alternating among the road. A total of 96 farms were sampled with Kinale having 60% of the sample population (57 households) and Kijabe 40% of the population (39 households), based on population. Agricultural field officers were engaged during data collection to assist in identification of the various indigenous trees on farm while structured questionnaires were used to collect views from the 96 farmers. A walk in the farm under study after getting permission from the owner was necessary for effective data collection. The position of the trees on farm was marked by Global Positioning Systems was used to collect spatial data of trees on farm combined with tree inventory observation schedule. Data collected included relative position, height, breadth and reasons for maintaining of the trees on the farm. Photographic evidence of the trees on the farm was also taken. The research encouraged the farm owner to take the walk together on farm to help identify the name of tree in local language.

Data analysis
Data from the questionnaire were entered into SPSS analyzed through descriptive statistics while correlational analysis was to show how variables were related. Indices for various measures were also computed. The Likert scale (0-5) was also used to show degree of influence. On spatial analysis, the GPS points that were recorded in degrees and minutes were first converted to decimal degrees for compatibility with the GIS software (ArcGIS). The converted data layers (for Kijabe and Kinale) were displayed in the GIS software (ArcGIS) and converted to GIS layers. The layers were then overlaid on Kijabe and Kinale Wards layers for map preparation.

RESULTS AND DISCUSSIONS

Tree species
Several species of indigenous tree species were found on farm in both Kinale and Kijabe Wards, Kenya (Table 1). These include trees such as Muiku-Kikuyu or dombeya (Dombeya torrida), croton tree (Croton megalocarpus), Melia (Melia volkensii), etc.

Table 1. Indigenous trees on farm in Lari Sub-county, Kenya

| Name of tree (kik) as referred to by farmers | Common name | Scientific name |
|---------------------------------------------|-------------|-----------------|
| Murera                                      | Thorn tree  | Acacia abyssinica |
| Mukumo/mugumo                               | Strangler fig | Ficus thonningii |
| Mubuu                                       | Silk oak    | Brachylaena hutchinssii |
| Muchami                                     | Allophylus  | Allophylus abyssinicus |
| Muhorou/muhoru                              | Meru oak    | Vitex keniensis |
| Muiri                                       | Red sink wood | Prunus africana |
| Mukau                                       | Melia       | Melia volkensii |
| Mukue                                       | Dombeya     | Dombeya torrida |
| Mukindori                                   | Croton      | Croton megalocarpus |
| Mutamaiyu                                   | African olive | Olea europaena |
| Mutarakwa                                   | African juniper | Juniperus procer |
| Mutati                                      | Parasol tree | Polyscias kikuyen |
| Muthai                                      | Schefflera  | Schefflera volkensii |
| Muthegera                                   | Podo        | Podocarpus milanjianus |
| Mugaita                                     | Rapanea     | Rapanea ralanphloes / Myrsna melanphloes |

Indigenous tree species occurrence in Lari Sub-county
Table 2 and 3 shows a diversity index of the indigenous tree species still found on farm in Lari Sub-county per ward. A diversity index is a quantitative measure that reflects how many different types (such as species) there are in a dataset, and simultaneously takes into account how evenly the basic entities (such as individuals) are distributed among those types. The value of a diversity index increases both when the number of types increases and when evenness increases. From Table 2 and 3, it is clear there is a high highest diversity of indigenous tree species in Kijabe than Kinale Ward. Meru Oak (Vitex keniensis) dominate in Kijabe while the African juniper (Juniperus procura ) tree dominates the Kinale Wards farms.

The lowest diversity is among the silk oak (Brachylaena hutchinssii) and rapanea (Rapanea ralanphloes) species in both Kinale and Kijabe Wards. There is no strangler fig, silk oak and rapanea tree species in Kijabe and in Kinale there is no alloxylus (Allophylus abyssinicus), croton (Croton megalocarpus), schefflera (Schefflera volkensii) and thorn trees (Acacia abyssinica) recorded on farm. While the parasol tree and podo trees occurrence is both Kijabe and Kinale Ward.

Relative location of indigenous trees species on farm in Lari Sub-county
The study analyzed where these indigenous trees grow most within Lari Sub-county. This was categorized into 4 regions. Scattered on farm (SF) these are trees that grew almost anywhere inside the farm but not near the homestead area. The second category was boundary trees (B) these trees are those that were grown purposely as fences to mark the boundary between one farm and the other. The third category Homestead (H) this showed the trees that grew near the homestead area but not where the farmer is practicing agriculture. The last category was on Riverine (R) these are the trees that grew along streams/streams that were passing via the farms.
Relative position of indigenous trees on farms in Lari Sub-county

Overall most of the trees were scattered on farm (57.4%) in Lari Sub-county (Table 4). This could be because trees create a conducive ecosystem that encourages agricultural undergrowth thus the rationale to leave them there or plant. Only 1.1% of the trees were found on riverine areas.

In terms of species count in Kinale the highest number of species were boundary planting with the African juniper (*Juniperus procera*) having the highest number followed by *Podo* (*Podocarpus milanjianus*) (Table 5). Within the homestead, we see that all indigenous trees found in Kinale are found also at the homestead. Dombeya (*Dombeya torrida*) has the highest number of trees scattered on various farms in Kinale Ward. The Red stink wood (*Prunus africana*) tree is found majorly on riverine areas while the podo (*P. milanjianus*) tree has the highest diversity within the homestead.

### Table 2. Indigenous tree occurrence in Lari Sub-county, Kinale Ward, Kenya

| Name of tree         | African juniper | African olive | Dombeya | Meru oak | Parasol tree | Podo | Rapanea | Red stink wood | Silk oak | Strangler fig | Total |
|----------------------|-----------------|---------------|---------|----------|--------------|------|---------|----------------|----------|---------------|-------|
| Frequency            | 6612            | 89            | 70      | 32       | 9            | 94   | 1       | 89             | 15       | 2             | 7013  |
| percentage           | 94.28           | 1.3           | 1:00    | 0.46     | 0.13         | 1.54 | 0.01    | 1.3             | 0.01     | 0.03          | 100   |

### Table 3. Indigenous tree occurrence in Lari Sub-county, Kijabe Ward, Kenya

| Name of tree         | African juniper | African olive | Dombeya | Meru Oak | Parasol tree | Podo | Red stink wood | Allophylus | Silk Oak | Schefflera | Thorn tree | Total |
|----------------------|-----------------|---------------|---------|----------|--------------|------|----------------|------------|----------|------------|------------|-------|
| Frequency            | 94              | 23            | 297     | 10003    | 14           | 14   | 126            | 2          | 5        | 3          | 10         | 10641 |
| percentage           | 0.91            | 0.29          | 2.84    | 94.22    | 0.14         | 0.14 | 1.22           | 0.03       | 0.06     | 0.05       | 0.10       | 100   |

### Table 4. Relative position of indigenous trees on farm

| Relative position of tree on farm | Scattered on farm | Boundary | Homestead | Riverine | Total |
|-----------------------------------|-------------------|----------|-----------|----------|-------|
| Frequency                         | 10134             | 6876     | 456       | 188      | 17654 |
| Percentage                        | 57.4              | 38.9     | 2.6       | 1.1      | 100   |

### Table 5. Relative position of indigenous trees in Kinale Ward, Kenya

| Relative location of tree         | African juniper | African olive | Dombeya | Meru Oak | Parasol tree | Podo | Rapanea | Red stink wood | Silk oak | Strangler fig | Total |
|-----------------------------------|-----------------|---------------|---------|----------|--------------|------|---------|----------------|----------|---------------|-------|
| Boundary                          | 6608            | 2             | 22      | 6        | 3            |      |         |                |          |               | 6641  |
| Scattered on farm                 | 5               | 36            | 5       | 6        | 5            | 1    | 1       | 15             |          |               | 73    |
| Riverine                          | 60              | 50            | 5       | 3        | 1            | 70   | 15      | 2              |          |               | 143   |
| Homestead                         | 4               | 22            | 7       | 16       | 89           | 15   | 2       | 15             |          |               | 156   |
| Total                             | 6612            | 89            | 70      | 32       | 94           | 89   | 15      | 15             |          |               | 7013  |

### Table 6. Relative position of indigenous trees in Kijabe Ward, Kenya

| Relative location of tree         | African juniper | African olive | Dombeya | Meru Oak | Parasol tree | Podo | Red stink wood | Allophylus | Croton | Schefflera | Thorn tree | Total |
|-----------------------------------|-----------------|---------------|---------|----------|--------------|------|----------------|------------|--------|------------|------------|-------|
| Boundary                          | 26              | 16            | 143     | 5        | 12           | 23   | 1              |            |        |            |            | 10    |
| Scattered on farm                 | 60              | 10000         | 1       |          |              |      |                |            |        |            |            | 10061 |
| Riverine                          | 3               | 40            | 1       | 1        |              |      |                |            |        |            |            | 45    |
| Homestead                         | 68              | 4             | 54      | 2        | 8            | 2    | 102            | 2          | 55     | 3          |            | 300   |
| Total                             | 94              | 23            | 297     | 10003    | 14           | 14   | 126            | 2          | 55     | 3          | 10        | 10641 |
Figure 2 shows the relative position of indigenous trees in Kijabe Ward and it shows that Meru oak (*V. keniensis*) has the highest diversity in Kijabe and most of it is scattered within the farms. The Red stink wood (*P. africana*) has the highest diversity in terms of trees found within the homestead while dombeya (*D. torrida*) has the highest diversity in terms of trees found within boundary and riverine areas. Most of the trees are concentrated in Mbauni, Bathi and Kijabe subdivisions and very little indigenous trees were found in Magina. Map representation of indigenous tree sites in Kijabe and Kinale Wards.

From the 39 farms visited in Kijabe, the study counted 10,641 indigenous trees. 7,013 indigenous trees were found in the 57 farms visited in Kinale. Some of the indigenous tree compositions found in Lari include *A. abyssinica*, *Ficus thomningii*, *B. hutchinsi*, *A. abyssinicu*, *V. keniensis*, *Prunus Africana*. These trees relative location was majorly homestead, boundary and scattered on farm (Figure 3). There is a high population of indigenous trees found in Mukeu as opposed to Kinale Wards.

Rationale for retaining indigenous trees on farm in Lari Sub-county

There are various reasons as to why indigenous trees are retained on farm in Lari Sub-county. Growing trees can be an induced innovation to help maintain agricultural productivity because they may reduce erosion and enrich the soil (Scherr 1995) or to increase carrying capacity of the shallow soils (Carson 1989). It is a livelihoods’ option often mentioned and increasingly promoted by land-use managers and international development agencies (Zomer et al. 2014). Farmer’s willingness to grow trees depend on many factors (Filius 1997). The research study sought to find out the factors that actually influenced farmers to retain indigenous trees on their farms.

Degree of influence of factors affecting conservation of indigenous trees on farm in Lari Sub-county

Among the factors analyzed on what influences farmers to retain or conserve the indigenous trees on farm included; agricultural and environmental conservation practices, indigenous knowledge on value of tree, benefits derived from having the indigenous species in mixed farming, practicing intensive farming or monoculture and agricultural officer recommendation. The researcher used a Likert scale (0-5) to describe the degree of influence 0 meant to a very low extent while 4 meant to a great extent.
Major factor influencing conservation of indigenous trees on farm in Kinale Ward in Lari Sub-county is due to the benefits derived from having indigenous tree species in mixed farming and knowledge on the value of indigenous trees (Figure 4). The total number of indigenous trees found in Kinale is 7,012 from the farms visited, which was lower than in Kijabe, which could be due to the fact most of the farmers practice horticultural farming including potatoes, French beans, cabbages, kales among others.

In Kijabe, a total of 10,641 indigenous tree species were counted in the 39 farms visited. Similarly, the mixed farming and knowledge of indigenous were was noted as important factors influencing conservation of indigenous trees (Figure 5). In both wards the influence of knowledge on environmental conservation coupled with influence from agriculture contributes to retention of indigenous trees on the farm.

Gender influence on indigenous tree conservation in Lari Sub-county

There are various factors that influence the indigenous tree species on the farm. Household characteristics are one of the factors that influence the presence or absence of indigenous tree species on farm and most often than not dictate where these trees are located on the farm. In the study, men have close to 80% control on deciding which species to have on the farms in Lari Sub-county. Gender and cultural beliefs and taboos play an important role in conservation of tree species on the farm. The socially ascribed gender roles in relation to tree planting activities and use of tree resources can have significant implications for tree planting. For instance, although women provide labor in planting and managing trees, it is the men who decide on use and disposal of tree resources (Ndei 2014). The presence of cultural beliefs and taboos associated with planting can have an impact on conservation of useful tree species on the farm as they inhibit conservation of certain tree species. Traditionally, planting or cutting of certain tree species was prohibited and this helped to conserve some of the endangered indigenous species. Although these cultural beliefs affect men and women, they are more restrictive to women when it comes to participation in conservation of trees. Women in most cases cannot take decisions on issues concerning tree cutting and selling in the community; male permission is usually sought.

![Figure 4. Degree of influence of factors affecting conservation of indigenous trees on farm in Kinale Ward in Lari Sub-county, Kenya](image)

![Figure 5. Degree of influence of factors affecting conservation of indigenous trees on farm in Kijabe Ward in Lari Sub-county, Kenya](image)
study, therefore, echoes Boserup's theory on population agricultural intensification as opposed to tree planting. The food requirement needs are higher and thereby high farm. Therefore most of the farms that had many people the on a farmland may directly affect the economic activity on The study assumes that the higher the population pressure households that had more than 10 persons per household. persons whereas there were no indigenous trees in 1-5 persons and approximately 2% for those having 6-10 10% of the indigenous trees existed in households having the less the indigenous trees that existed on farm. Only the household size the less the conservation of indigenous trees. growth and agricultural intensification. Agriculture is the predominant economic activity within Kiambu county. It is the leading sub-sector in terms of employment, food security, income earnings and overall contribution to the socio-economic wellbeing of the people. The agricultural production system mostly practiced in both Kinale and Kijabe is mixed cropping. Agricultural production systems are mostly influenced by the household sizes. The higher the household size the less the conservation of indigenous trees.

Influence of literacy levels on indigenous tree species diversity

Behavior change in different communities is majorly influenced by the level of education of the constituents. In Lari Sub-county, major household heads had a moderate literacy level of 30.2% and 36.5% at both secondary and upper primary respectively. It is notable that people with university education move out of village in search of jobs, thus lower literacy level in urban areas. From the Table 7, those household heads with no or low literacy level conserve small number of indigenous tree species on farm compared to those with relatively higher level of literacy. This indicates that ingenious education is a part of respondents' cultural and social identities, well-being, sustainable development and intellectual and cultural vitality which plays a crucial role in the successful conservation of the environment.

Agricultural intensification and its influence in indigenous trees conservation in Lari Sub-county

The average household size in both Kinale and Kijabe ranged from 1->10 persons per household. This number depicted the actual number of members living in the households during the study period. From the findings Figure 6 shows that the bigger the household size the less the indigenous trees that existed on farm. Only 10% of the indigenous trees existed in households having 1-5 persons and approximately 2% for those having 6-10 persons whereas there were no indigenous trees in households that had more than 10 persons per household. The study assumes that the higher the population pressure on a farmland may directly affect the economic activity on farm. Therefore most of the farms that had many people the food requirement needs are higher and thereby high agricultural intensification as opposed to tree planting. The study, therefore, echoes the Boserup's theory on population

### Table 7. How level of education influences decision on conserving indigenous trees

| Educational level of household | University | College | Secondary | Upper primary | Lower | Did not go to school | Total |
|-------------------------------|------------|---------|-----------|---------------|-------|----------------------|-------|
| Indigenous trees frequency on farm | 5          | 4        | 29        | 35            | 18    | 5                    | 96    |
| Percentage                    | 5.2        | 4.2      | 30.2      | 36.5          | 18.8  | 5.2                  | 100   |

**Figure 6.** Household size and agricultural intensification

**Uses of indigenous trees vs exotic**

There are various uses of indigenous trees found on farm in Lari constituency. This is one of the rationale why some of the farmers still have indigenous tree species on farm. Some trees have medicinal properties like *Ficus thoorgingii*, *A. abyssinica*, *A. abyssinicus*, *P. africana*, *C. megalocarpus* and *O. usambarensis* these trees can be used to treat diarrhoea, hemorrhage, jaundice, headaches, burns, venereal diseases etc. Other trees are specially used as insect repellants or as acaricides such as *A. abyssinica*. *Podocarpus milanjanus*, *V. keniensis*, *A. abyssinica* and *P. africana* makes very good timber for construction. Indigenous trees also make very good fodder for animal and can therefore be used as feed e.g. the *A. abyssinica* and *M. volkensii*. Others have cultural values such as *Ficus thooringii* (Mugumo) that were used sacred sites traditionally and up to now community avoids cutting it waiting for it to fall on its own.

The low levels of likelihood of farmers to plant and retain trees in Lari Sub-county may be attributed to small land holdings due to high population especially in Kijabe where the land sizes are significantly smaller. In Kinale, the nature of their farming activities was dairy, horticultural and subsistence crops. This may have delineated them from active participation in tree farming as most of the land was needed for pasture and food crops. This was in contrast with Kijabe where the farm sizes were smaller and the major motivation of planting indigenous trees on farm was due to the sensitization efforts by KENVO (Kijabe Environmental Volunteers) and also the presence of the ministry of agriculture within the ward that encourage tree planting. Discussions held with farmers during data collection in this region pointed out that majority of them viewed indigenous tree growing as a long-term investment with no immediate cash to offset household needs, hence lowly prioritized. Therefore, chances of finding indigenous trees on farm of varied sizes were small reflecting less retention. There is high market for poles in Lari Sub-county, therefore, farmers resort to planting more and more exotic trees.
Figure 7. Benefits of indigenous trees on farm in Kinale and Kijabe Wards in Lari Sub-county, Kenya

**Effect of indigenous trees on farm**

Trees in farming systems are found either in forest fallows within shifting cultivation systems; as relics from land clearance by slash-and-burn, or as a result of deliberate management and/or planting. The integration of indigenous trees in farming systems to provide environmental services and/or products that are either traded or used domestically to confer multiple livelihood benefits, especially for smallholder farmers in the tropics beset with poverty, malnutrition, and hunger. The most important factor was decreased vulnerability to climate change and weather variability along with enhanced food security (Figure 7). It is important to note that the numbers of trees in farmland can contribute to the restoration of lost productive capacity in farmland, especially infertile degraded land, through the rehabilitation of agroecosystem functions. Other values of the trees on farm include the creation of new opportunities for greater and more diversified production with enhanced utility and profitability through the domestication of indigenous tree species conferring nutritional and health benefits. In addition to promotion of local enterprise, value-addition, entrepreneurship and job creation in rural communities through commercialization.

In conclusion, there are indigenous tree species found in Lari Sub-county. Their presence is influenced by gender, education levels, socioeconomic activity, and agricultural production system practiced based on household sizes. There are more indigenous trees in Kijabe than Kinale Wards. Most of the indigenous tree species in Lari Sub-county are found scattered on the farm and this can be attributed to their importance of regulating nutrients, build organic matter of topsoil, fix nitrogen and create habitat for beneficial micro-organisms. There are very few indigenous tree species growing on riverine areas and homestead.

Indigenous trees are still retained in Lari Sub-county and the reasons for this is attributed to their effect on the environment as a buffer for food security and decreased vulnerability to climate change. They are also retained due to major efforts that have been put in place by the ministry of agriculture through agricultural extension officers. Residents in Lari recognize that there are very many benefits from indigenous trees that range from medicinal to timber and it's important to preserve these trees for the future generations. This study, therefore, recommends sensitization campaigns among the farming community to promote indigenous tree conservation so as to contribute towards the country target of 10% tree cover.

**REFERENCES**

Altieri M, Nicholls C. 2005. A Rapid, Farmer-Friendly Agro Ecological Method to Estimate Soil Quality and Crop Health in Vineyard Systems. Agroecology and the Search for a Truly Sustainable Agriculture. PNUMA, 277, 290.

Filius AM. 1997. Factors changing farmers' willingness to grow trees in Gunung Kidul (Java, Indonesia). Netherlands J Agric Sci 45: 329-345.

Ndei C. 2014. Gendered Perspective of Cultural Factors that Influence Conservation of Useful Tree Species in Igembe South Sub-county, Upper Eastern Region, [Thesis]. University of Nairobi, Kenya.

Oeba VO, Otor SCJ, Kungu JB, Muchiri MN. 2012. Modelling determinants of tree planting and retention on farm for improvement of forest cover in Central Kenya. ISRN Forestry 2012, Article ID 867249, 14 pages. DOI: 10.5402/2012/867249

Scherr. SJ. 1995. Meeting household needs: farmer tree-growing strategies in western Kenya. In: Arnold JEM, Dewees PA (eds.). Tree Management in Farmer Strategies: Responses to agricultural intensification. Oxford University Press, Oxford.

UNEP. 2012. The Role and Contribution of Montane Forests and Related Ecosystem Services to the Kenyan Economy. United Nations Environmental Programme, Nairobi, Kenya.

Wretenberg JTP, Berg A. 2010. Changes in local species richness of farmland birds in relation to land-use changes and landscape structure. Biol Conserv 143: 375-381.

Zomer R J, Trabucco A, Coe R, Place F, Van-Noordwijk M, Xu JC. 2014. Trees on farms: an update and reanalysis of agroforestry’s global extent and socio-ecological characteristics. Working Paper 179. World Agroforestry Centre (ICRAF) Southeast Asia Regional Program, Bogor, Indonesia.
Trends of land cover change in a key biological corridor in Central Nepal

KRIPA NEUPANE1,*, AMBIKA P. GAUTAM1, ARUN REGMI2
1Kathmandu Forestry College, Tribhuvan University, Kathmandu, Nepal. *Email: nr.kripa@gmail.com
2Department of Forestry, Mississippi State University, Starkville, MS, USA

Manuscript received: 20 November 2017. Revision accepted: 3 December 2017.

Abstract. Neupane K, Gautam AP, Regmi A. 2017. Trends of land cover change in a key biological corridor in Central Nepal. Asian J For 1: 64-69. The study analyzed changes in land cover in one of a key biological corridor in Central Nepal, the Barandabhar Corridor located in Chitwan District, during the last two decades (i.e. 1991 to 2013). The study is based on analysis of satellite imageries (Landsat 5 TM of 1991 and Landsat 8 OLI_TIRS of 2013) and primary data on drivers of land cover change, collected from the field. Supervised Maximum Likelihood method of image classification was used to produce the land cover maps for 1991 and 2013. The result showed that forest cover in the corridor increased by 7.03% while the coverage of shrubland, water bodies and other land cover types (open lands, sand and roads) decreased during the study period. Implementation of community based forest management programs, low dependency on forest resources, and increase in conservation awareness among the local people are found to be the main causes of the increase in forest cover.

Keywords: Barandabhar corridor, Land cover change, Landsat, Nepal, Supervised classification

INTRODUCTION

Several regions around the world are facing land cover change at alarming rate. Concern about change in biophysical attributes of the earth's surface has highly increased on global environmental change research (Lambin et al. 2003). Land cover change analysis has been recognized as an essential aspect for identifying the impact of change on the environment and associated ecosystems (Turner et al. 1995; William et al. 1994). Land cover change occurs in both human activities and natural process. Land use practices such as agricultural expansion, infrastructure developments, deforestation, and encroachment are expected to have the largest impact on land cover change (Lambin et al. 2003). In addition, population growth (Geist and Lambin 2002) and climate change (Fischlin and Midgley 2007) have been considered as a major driving force of land cover change.

Remote sensing and Geographic Information Systems (GIS) are the most feasible and efficient tools that provide updated information on temporal trends and spatial distribution for change detection and land-use planning (Lambin et al. 2003; Serra et al. 2008). Satellite imageries have been widely used for the change detection over time (Balla et al. 2007) along with the visual assessment of physical features and natural resources dynamics that occur at a particular time and place (Awasthi 2004). Analysis of satellite images of the same area taken on different times is a widely used method for determining the temporal dynamics of land use (Mulders 2001). Since the past two decades trend of using satellite remote sensing data for change detection has been considerably increased in Nepal (Sharma 2002). For example, several studies (e.g., Balla et al. 2000; Gardner and Gerrard 2001; Gautam et al. 2003) have been carried out to analyze land use land cover change, deforestation and forest degradation using remote sensing data.

The Barandabhar Corridor is an only remaining natural forest that connects the Chitwan National Park (CNP) and Siwalik range with the Mahabharat range (Dhakal and Yadava 2011), thereby allowing the endangered one-horned rhinoceros, and Royal Bengal tiger, and many other species of wild animals and birds access to refuge at higher altitudes during monsoon floods (Tiwari et al. 2007) and other periods of adverse climatic conditions. Approximately 75% of Barandabhar corridor was previously forested, supporting a rich diversity of flora and fauna (Joshi 2002; Bennet 2004). However, the anthropocentric pressure on Barandabhar Corridor has increased substantially over the period (Thakur 2012) resulting the area in deforestation, destruction of natural habitats and conversion of forest land into agricultural land (Shrestha 2001). Since the study of land cover change in Barandabhar corridor is lacking, limited past studies were focused on investigating deforestation and forest degradation (Panta et al. 2008; WWF 2013) and few others were done in floral diversity (Subedi, 1994; Dangol and Shivakoti 2001; Shrestha 2003). Therefore, the present study aims to fill this gap in knowledge with the aim of understanding the trends of land cover changes along with its driving forces by monitoring, assessing and documenting the changes taken in past two decades (1991-2013).
MATERIALS AND METHODS

Study area
The Barandabhar Corridor is located within the Terai Arc Landscape of Nepal between Chitwan National Park (CNP) and the Mahabharat Range, within 27°33'30" to 27°44'30"N Latitude and 84°22'30" to 84°34'00"E Longitude (Figure 1) and covering 11,155.77 hectares (ha). The elevation ranges from 172m to 390m above the mean sea level. The climate is subtropical, with distinct winter (November-February), spring (May-September) and monsoon (June-September) seasons. The average annual rainfall is recorded 2000mm during the monsoon season. Rapti, Budhi-Rapti, and Khageri are the main rivers that flow through the forest. A Ramsar-enlisted wetland called the Bishazari Tal, lies in the center of the forest.

The Corridor is divided by the East-West Highway into two parts. The northern part covers an area of 3,184 ha, which is managed by 15 community forestry users groups (Aryal et al. 2012). The southern part has been declared as the buffer zone of CNP and is managed by six buffer zone community forest users groups (CNP 2013). Sal (Shorea robusta) is the dominant tree species throughout the corridor forest. Riverine, tall grassland and short grassland, occupies part of the corridor area. The area is a key habitat for some endangered species, including the Royal Bengal tiger (Panthera tigris tigris) and one-horned rhino (Rhinoceros unicornis) (CNP 2013).

Data collection
Two types of satellite imageries namely; Landsat 5 TM of 1991, and Landsat 8 OLI_TIRS of 2013 were used for the detection of changes in land cover during the study period. These images were downloaded free of cost from the Earth Resource Observation System Data Centre of the USGS (http://www.glovis.usgs.gov). A brief description of the satellite images used is shown in Table 1. Topographic map of the scale 1: 25,000, which was acquired from the Department of Survey, Government of Nepal, was digitized for creating a spatial database and classifying 1991 TM image. Data of the different land cover classes obtained from field study (GPS location) was used as training samples.

Non-spatial data were collected through the questionnaire survey, key informant interviews, focus group discussions, and direct field observations in order to identify the major driving forces responsible for the land cover changes. A total of 80 households around the forest corridor were selected based on stratified random sampling method for the questionnaire survey. Focus group discussion was conducted with different communities and users groups.

Figure 1. Location map of the study area (the Barandabhar corridor in Chitwan District, Nepal)
Table 1. Satellite images used in land cover classification

| Satellite image | Sensor | Number of bands | Spatial resolution (meter) | Date of acquisition |
|-----------------|--------|-----------------|---------------------------|---------------------|
| Landsat 5 TM    | 1-7    | 30*30           | 1991-10-12                |
| Landsat 8 OLI_TIRS| 1-11  | 30*30           | 2013-11-18                |

In addition, local government forestry officials, CFUG’s and BZCFUG’s committee members, and environmental NGOs were also consulted. Secondary data and information were obtained from governmental offices; CNP, DNPWC, literature review, research articles and internet browsing.

Data analysis
The analyses of the remote sensing data were carried out in ArcGIS, and ERDAS Imagine environments. Images were extracted from the same source and already ortho-rectified, so rectification was not needed (ERDAS 2002). Images were reprojected to the UTM 44 N by using nearest neighborhood re-sampling. Area of Interest (AOI) was separated by using subset tool of ERDAS Imagine to match the satellite image for the topo-sheet compatible. The digitized map was re-projected to UTM/WGS 84, Zone 44 N to match with satellite images.

Maximum likelihood algorithm of supervised classification method was used for the classification of two imageries. GPS locations corresponding to each LULC classes were collected from the field and used as training samples for the image classification and accuracy assessment. Four land cover classes were considered in image classification for producing land cover maps and detecting changes that occurred during the period 1991-2013: (i) forest, (ii) shrubland, (iii) water bodies, iv) others (open lands, sand and roads). Description of these land cover classes is presented in Table 2. The digitized topographic map was used to classify 1991 TM image whereas 2013 OLI_TIRS image were classified based on training samples collected during the field visit.

Land cover changes were calculated using raster calculator tool in Arc GIS. Similarly, quantitative and qualitative data were analyzed by using descriptive statistical tools such as frequency, percentage and mean in SPSS and MS-Excel software.

Accuracy assessment
Error matrix, the most common way to present accuracy of the classified digital image (Fan et al. 2007), was used for assessing the accuracy of classified images. The overall accuracy of the 1991 image classification was 88.5% with Kappa coefficient of 84.6%, and that of the 2013 image was 92.78% with Kappa coefficient of 90.3%.

RESULTS AND DISCUSSION
Change in land use and land cover of Barandabhar Corridor during 1991-2013
From the comparison of land cover maps of 1991 and 2013, it is found that forest area has increased by 7.03%, whereas the coverage of shrubland, water bodies and other land cover types (open lands, sand and roads) decreased by 2.88%, 0.59%, and 3.55% respectively. The forest cover was 7,650 ha (68.57%) in 1991, which increased at the rate of 0.44% per year to 8433.72 ha (75.60%) in 2013. Shrubland, water bodies and other land cover types (open lands, sand and roads) have decreased by 321.75 ha, 65.43 ha, and 396.54 ha respectively, at the rate of 0.86%, 1.5% and 1.48% per year. Net forest gain during this period was 783.72 ha (7.03%) (Table 3; Figure 2-5). The similar trend was observed in the previous land use land cover studies conducted in different locations across Nepal, e.g., (Gautam et al. 2003; Balla et al. 2007; Pokhrel and Shah 2008).

Table 2. Categories of land cover classes considered in the analysis

| Land cover class | Description                        |
|------------------|------------------------------------|
| Forest           | Area covered by trees, poles, and saplings of different species |
| Shrubland        | Area consisting of shrubs, bushes and young regeneration of tree species. |
| Water bodies     | Lake, river                        |
| Others           | Areas with no vegetation cover, stony areas, open lands, sand, roads |

Table 3. Land covers changes in Barandabhar corridor, Chitwan District, Nepal between 1991-2013

| Land cover class        | 2013 Area (ha) | % cover | 1991 Area (ha) | % cover | Change Area (ha) | % Cover |
|-------------------------|----------------|---------|----------------|---------|------------------|---------|
| Forest                  | 8,433.7        | 75.6    | 7,650          | 68.5    | 783.7            | 7.0     | 0.4             |
| Shrubland               | 1,534.9        | 13.7    | 1,856.7        | 16.6    | -321.7           | -2.8    | -0.8            |
| Water bodies            | 166.4          | 1.4     | 231.8          | 2.0     | -65.4            | -0.5    | -1.5            |
| Others                  | 1,020.6        | 9.1     | 1,417.2        | 12.7    | -396.5           | -3.5    | -1.4            |
| Total                   | 11,155.7       | 100     | 11,155.7       | 100     |                  |         |                 |

Rate of Change (%)
Factors contributing to the changes in land cover

Implementation of the Community Forestry (CF) and Buffer Zone Community Forestry (BZCF) programs are found to be the major direct drivers responsible for the increase in forest cover in the corridor. Effective law enforcement in the BZCF by the Chitwan National Park office and conservation of their respective forest blocks by the local community forest user groups led to increase in the forest area. Decreased dependency of the local people on forest products such as fuelwood, timber, and fodder due to easy availability of alternatives like LP gas, kerosene, fuel oil, biogas, improved cooking stoves etc., alongside improved economic well-being of the people living around the corridor have reduced the biotic pressure on the corridor forest, contributing to forest cover increase.

Figure 2. Land cover change (1991-2013) in the Barandabhar corridor, Chitwan District, Nepal

Figure 3. Land cover of the Barandabhar corridor, Chitwan District, Nepal in 1991

Figure 4. Land cover of the Barandabhar corridor, Chitwan District, Nepal in 2013

Figure 5. Land cover change map (1991-2013) of the Barandabhar corridor, Chitwan District, Nepal
Furthermore, control in grazing by the CFUGs, decrease in the number of livestock and fodder demand from forest due to the promotion of stall-feeding also have had a positive impact on vegetative cover. Plantation establishment by the Department of Forests, FUGs, and BZFUUGs on degraded forestlands, barren lands, and grasslands with external assistance has contributed to the forest cover increase. Different national and international organizations (such as NTNC, WWF Nepal) are also involved in the conservation and management of the corridor. Currently, the Corridors and Bottlenecks Restoration Project (CBRP) and Protected Area and Buffer Zone (PABZ) projects are being implemented under TAL program. Increasing awareness among local people about the ecological benefits of protecting and sustainably managing forests also had has a positive impact on the forest cover change.

Invasion by alien plant species has been found to be an important driving agent for decrease in the area of lakes. The Ramsar-enlisted Bishazari Lake is infested with invasive alien plants such as Eichhornia crassipes (water hyacinth), Pistia stratoites (water lettuce), Alternanthera philoxeroides (alligator weed), Ipomoea carnea (bush morning glory), Ageratina adenophora (Crofton weed) and Leersia hexandra (southern cut grass). Sedimentation is found to be another factor responsible for reducing lake surface area. Change in the course of flow by Rapti River has resulted in the conversion of riverbed into grassland. Construction of East-west Mahendra highway within the forest land, new towns, high voltage electric transmission lines around the forest corridor, and the newly constructed road connecting from new Padampur to Bhojad by VDC also have a direct contribution towards land cover change throughout the study area.

The findings of this study are similar to some other previous studies conducted in different parts of Nepal in recent years. For example, the forest cover change analysis carried out in 20 districts of Nepal during 1990/91 to 2000/2001 by the Department of Forests showed that forest cover increased at annual rate of 0.06% during the period (DoF 2005). In the study of land cover change in watershed level, Gautam et al. (2003) found increase in forest cover mainly due to the conversion of shrublands into forests after implementation of the community forestry program.

Conclusions

The study analyzed the trends of changes in land cover of Barandabhar corridor using Landsat satellite images and GIS. The results show that forest area is the major land cover and has increased by the rate of 0.44% per annum during the period 1991-2013. In contrary, shrubland, water bodies and other land cover types (open lands, sand and roads) have decreased by the rate of 0.86%, 1.5% and 1.48% per annum respectively. The findings of this study indicate that successful implementation of community-based forest management (CBFM) programs have contributed positively toward restoring the forest cover in the corridor.

Formation of community forest, active participation of CFUGs, the involvement of different national and international organizations for the conservation and management of corridor and low dependency on forest resources are the major drivers of increasing forest cover. Control of illegal felling and grazing, protection of severely degraded forest land and plantation in the barren land have increased regeneration growth which is being converted into dense forest cover. On the other hand, expansion of invasive alien plant species, sedimentation, changes in the flow of Rapti River, infrastructures development are found to be the major drivers for decreasing shrubland, water bodies and other land cover types (open lands, sand and roads). The positive impact of community-based institutions in improving forest cover in the study area provides an important basis for implementing community-based strategies in the management of protected area buffer zones and biological corridors in other locations in Nepal and other countries with similar socio-economic and ecological contexts.

ACKNOWLEDGEMENTS

We would like to express our profound thankfulness and appreciation to World Wildlife Fund (WWF), Hariyo Ban Small grant program, Nepal for granting us financial support for this research work.

REFERENCES

Aryal A, Brunton D, Pandit et al. 2012. Biological diversity and management regimes of the northern Barandabhar Forest Corridor: an essential habitat for ecological connectivity in Nepal. Trop Conserv Sci 5 (1): 38-49.

Awasthi K. 2004. Land use change effects on soil degradation, carbon and nutrient stocks and greenhouse gas emission in mountain watersheds: Department of Plant and Environmental Sciences, Agricultural University of Norway, Oslo.

Ball M, Awasthi K, Shrestha P, Shcheren D, Poudel D. 2000. Degraded Lands in Mid-hills of Central Nepal: A GIS appraisal in quantifying and planning for sustainable rehabilitation. LI-BIRD, Pokhara, Nepal

Bennett G. 2004. Integrating Biodiversity Conservation and Sustainable Use: Lessons Learned from Ecological Networks. IUCN, Gland.

CBS. 2012. National population and housing census 2011 National Report. Central Bureau of Statistics National Planning Commission Secretariat, Government of Nepal, Kathmandu, Nepal.

CNP. 2013. Management Plan for Chitwan National Park and It’s Buffer Zone 2013-2017. Chitwan National Park Office, Chitwan, Nepal.

Dangol D, Shivakoti G. 2001. Species composition and dominance of plant communities in western Chitwan, Nepal. Nepal Journal of Science and Technology 5 (1): 69-78.

DFRS/FRA. 2014. Terai Forests of Nepal (2010-2012). Forest Resource Assessment Nepal Project/Department of Forest Research and Survey, Babarmahal, Kathmandu.

Dhakal RR, Yadava JN. 2011. Comparative assessment of floristic diversity in a buffer zone community forest and a community forest of Barandabhar corridor, Chitwan, Nepal. J Hortic For 3 (8): 244-250.

DoF. 2005. Forest Cover Change Analysis of the Terai Districts 1990/91-2000/01. Department of Forests (DoF), Kathmandu, Nepal.

ERDAS L. 2002. ERDAS Imagine Field Guide. Erdas Inc., Atlanta, Georgia.

Fan F, Weng Q, Wang Y. 2007. Land use and land cover change in Guangzhou, China, from 1998 to 2003, based on Landsat TM/ETM+ imagery. Sensors 7 (7): 1323-1342.
Fischlin A, Midgley G. 2007. Ecosystems, their properties, goods and services. In: IPCC, climate change 2007—the working group II contribution to the IPCC fourth assessment report. Cambridge University Press, Cambridge.

Gardner R, Gerrard J. 2001. Soil loss on noncultivated land in the Middle Hills of Nepal. Physic Geogr 22 (5): 376-393.

Gautam AP, Webb EL, Shivakoti GP, Zoebisch MA. 2003. Land use dynamics and landscape change pattern in a mountain watershed in Nepal. Agric Ecosys Environ 99 (1): 83-96.

Geist HJ, Lambin EF. 2002. Proximate causes and underlying driving forces of tropical deforestation: Tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. BioScience 52 (2): 143-150.

Joshi A. 2002. Establishing Biological Monitoring System for Terai Arc Landscape. World Wildlife Fund (WWF) Nepal Program. Kathmandu, Nepal.

Lambin EF, Geist HJ, Lepers E. 2003. Dynamics of land-use and land-cover change in tropical regions. Ann Rev Environ Resour 28 (1): 205-241.

Mulders MA. 2001. Advances in the application of remote sensing and GIS for surveying mountainous land. Intl J Appl Earth Observ Geoinform 3 (1): 3-10.

Panta M, Kim K, Joshi C. 2008. Temporal mapping of deforestation and forest degradation in Nepal: applications to forest conservation. For Ecol Manag 256 (9): 1587-1595.

Pokhrel GK, Shah KB. 2008. Role of community forests in faunal diversity conservation: a case study of community forests within Satbariya Range Post of Dang District. Nepal J Sci Technol 9: 111-117.

Serra P, Pons X, Saun’ D. 2008. Land-cover and land-use change in a Mediterranean landscape: a spatial analysis of driving forces integrating biophysical and human factors. Appl Geogr 28: 189-209.

Sharma RR. 2002. Monitoring Forest Resources Using Remote Sensing Data. www.gisdevelopment.net/aars/acrs/2002/for/167.pdf [September 2015].

Shrestha B. 2003. Phytoecology of Barandabhar Forest, Chitwan, Nepal. [Thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Shrestha N. 2001. The political economy of land, landlessness and migration in Nepal. Nirala, New Delhi.

Subedi M. 1994. Structure, composition and general characteristics of some major forest types surveyed on natural and semi-natural forest stand in Nepal Proceeding of II National Conference on Science and Technology, Kathmandu.

Thakur R. B. 2012. Assessment of the land use land cover change in the forest corridor of Lamahi bottleneck area of Terai Arc Landscape Nepal. [Thesis]. Department of Natural Resources, TERI University, New Delhi.

Tiwari S, Regmi R, Green M. 2007. Tiger-rhino conservation project: landscape-scale conservation of the endangered tiger and rhino population in and around Chitwan National Park. Report of the final evaluation mission. United Nations Development Programme, UK.

Turner II BL, Skole D, Sanderson S, Fischer G, Fresco L, Leemans R. 1995. Land-Use and Land-Cover Change Science/Research Plan. IGBP Report No. 35. International Geosphere-Biosphere Programme, Stockholm.

William ER, William BM, Turner II BL. 1994. Modeling land use and land cover as part of global environmental change. Climat Ch 28: 45-64.
Short Communication: Survival and growth of mono and mixed species plantations on the Coromandel coast of India

M. ANBARASHAN*, A. PADMAVATHY, R. ALEXANDAR
Department of Ecology and Environmental Sciences, Pondicherry University, Puducherry, India. *email : anbupu@gmail.com

Abstract. Anbarashan M, Padmavathy A, Alexandar R. 2017. Short Communication: Survival and growth of mono and mixed species plantations on the Coromandel coast of India. Asian J For 1: 70-76. There exists very little information on the growth of autochthonous tree species autochthonous in the tropics and on the experiences in conducting mono and mixed species plantations. The aim of this study was to compare the variation in growth parameter between the mixed species plantation and mono species plantation. The growth, survival, and height of 82 autochthonous mixed species plantations were compared with Casuarina equisetifolia, an exotic species broadly planted in this region after over a decade (2006 to 2016). In the mixed species plantation, seven species showed 100 % survival rate and 19 species were not survived after 10-year intervals. In the mono species plantation, Casuarina equisetifolia had 92 % of the survival rate. When it is compared to the mono plantation, the growth rate of mixed species plantation showed highly significant differences (P < 0.05) values. Simple linear regression between annual girth increment and height produced very strong positive relations (R² 0.759). Plantations of Casuarina equisetifolia seem to be well adapted to the coastal region. On the other hand, mixed plantation with autochthonous species would contribute more to sustainable management because they provide a greater range of ecological goods and ecosystem services than the single species plantations.

Keywords: Exotic species, growth, mortality, autochthonous tree species, plantation, survival

INTRODUCTION

In the tropical countries, there is an increasing interest in establishing mixed autochthonous species plantation for a wide range of economic, silvicultural and sustainability objectives (Nguyen et al. 2016). This is in contrast to the dominance of monoculture in 'industrial' plantation practices in the tropics and temperate regions, largely because of the association with economic benefits. Mixed plantation system provide autochthonous broader range of option for the restoration of autochthonous species in degraded areas, protection and biodiversity conservation (Montagnini et al. 1995; Keenan et al. 1995; Guariguata et al. 1995; Parrotta and Knowles 1999). Vietnam, China, and the Philippines encourage landholders to plant mixtures by their national reforestation programs (Lamb et al. 2005); in several countries, smallholder and community forestry (mostly of autochthonous species) (Herbohn et al. 2014) and there is often little comprehensive information. In certain situations, Mixed species plantations are found to be more successful in terms of biomass production and carbon sequestration (Lawson and Michler 2014; Puettmann and Tappeiner 2014), improved nutrient cycling (Forrester et al 2010; le Maire et al 2013), reduced damage from pest or disease (Nichols et al 2006; Hung et al 2011), than monocultures. Ecological disturbance and climate change impacts can be balanced and more resilient forests can be provided for localities, when mixtures of different species with different traits are established (Rodrigues et al. 2011). Lamb and Lawrance 1993 stated that the complete utilization of soil and water resources as well as different soil strata could be attained by roots of different species during plantation. Plantation of different species tends to observe more solar energy and the light requirements are broadly distributed in the vertical plane (Guariguata et al. 1995).

The primary goal of ecological research in tropical forests is about comprehending the patterns of highly dynamic plant growth. Forest growth function is important for determining the size and multitude of ecology management applications (Vivek et al. 2016). Providing practical and meaningful classification of tropical forest species is needed by foresters in modeling the growth and yield factors, whereas the ecologists explain the life history of tropical forest and their diversity (Vivek et al. 2016). In the prediction of forest dynamics understanding of tree, mortality is inevitable, and its center to any long-term dynamics of woody plants as their biomass is regulated by the difference between gains through individual growth and losses through mortality (Scherer-Lorenzen et al. 2005). The growth and mortality of saplings of trees are dependent on impacts of various factors such as species-specific, tree vigor and size, and environmental conditions on the interactions and processes in stands (Scherer-Lorenzen et al. 2005; Radosevich et al. 2006). Differences in mortality rates among species are the major determinants of ecological succession (Schneider et al. 2014) and forest stand structure (Semwal et al. 2013). Performance of a tree
species was indicated by their vigor and size, as it partially reflects the competitive ability of a tree (Nakashizuka 2001). Growth-mortality trade-off can also be predicted by their relationship to plants functional traits (Baker et al. 2004; Nguyen et al. 2016).

However, the success of the establishment of mixed forest plantations depends on plantation design and an appropriate definition of the species to be used, taking into consideration ecological and silvicultural aspects (Wormald 1992). There is very little information on the growth of autochthonous tree species autochthonous in the tropics and on the experiences on comparing mono and mixed species plantations. However, in the present study, we tested if the mixed forest tree species can grow/survive in the coastal sand dunes. The main objective of the present study is to determine the growth and survival of 82 autochthonous species in the mixed plantations when they were compared with *Casuarina equisetifolia* mono plantation after over a decade (2006-2016). The hypotheses tested were: there is variation in growth and survival among species, and the growth and survival of autochthonous species are higher in mixed plantation than that in mono-species plantations.

**MATERIALS AND METHODS**

**Study site**

The study plots were developed in 2006 in Koonimedu Coastal village on the Coromandel Coast of southern India.

**Table 1.** List of species with families and ecological importance

| Species                          | Family          | Ecological values                      |
|----------------------------------|-----------------|----------------------------------------|
| **Mixed species**                |                 |                                        |
| *Aegle marmelos* (L.) Correa     | Rutaceae        | Medicinal, economic                    |
| *Aglaia elaeagnoidae* (Juss.) Benth. | Meilaceae      | Ecological                             |
| *Alangium salvifolium* (L.f.) Wangerin | Alangiaceae   | Medicinal                              |
| *Albizia amara* (Roxb.) Boivin   | Mimosaceae      | Medicinal, commercial                  |
| *Atalantia monophylla* (L.) Correa | Rutaceae       | Medicinal, ecological                  |
| *Atadira beta indica* A. Juss.    | Rutaceae        | Medicinal, cultural                    |
| *Barringtonia acutangula* (L.) Gaertner | Barringtoniaceae | Ecological                             |
| *Bauhinia purpurea* Lam.          | Rutaceae        | Medicinal                              |
| *Bauhinia racemosa* Lam.          | Rutaceae        | Medicinal                              |
| *Benkara malabarica* (Lam.) Tirven. | Apocynaceae  | Medicinal, cultural                    |
| *Calophyllum inophyllum* L.       | Calophyllaceae  | Medicinal, ecological                  |
| *Calotropis gigantea* L.          | Rubiaceae       | Medicinal                              |
| *Carmona retusa* (Vahl) Masm      | Burseraceae     | Medicinal, cultural                    |
| *Cassia auriculata* (L.)          | Fabaceae        | Medicinal                              |
| *Cassina glauca* Roth. Kuntze.    | Fabaceae        | Medicinal                              |
| *Chloroxylon swietenia* DC.       | *Ebenaceae*     | Medicinal, ecological                  |
| *Coccoloba uvifera* L.            | Polygonaceae    | Fruit, ecological                      |
| *Commiphora burnii* (Arn.) Engl.  | Burseraceae     | Ecological                             |
| *Dalbergia latifolia* Roxb.       | Fabaceae        | Medicinal                              |
| *Delonix elata* Gamble.           | Fabaceae        | Medicinal, aesthetic                   |
| *Diospyros ebenum* J. Koenig ex Retz. | *Ebenaceae*   | Timber                                 |
| *Diospyros ferrua* (Wild.) Bakh.   | *Ebenaceae*     | Timber                                 |

The saplings were produced in the onsite nursery, under a standard white polyethylene nursery bag system. Seeds were collected from the local Tropical Dry Evergreen forests in the region. Weeding became the primary maintenance activity after field planting of trees, and pruning of secondary apical shoots was conducted in the first year. The mean annual maximum and minimum temperature are 33° C and 24.5°C. The mean annual rainfall is 1282 mm per year with a six-month dry period (2006 to 2016). In general, coastal sandy soils prevail in the region, with poor nutrient.

**Methods**

A total of 2055 individuals of 82 autochthonous trees and 1500 *Casuarina equisetifolia* were planted in two hectares in 2006. Table 1 includes the list of species, families, and ecological importance. Species choice was based on growth rate, timber, ecological significance. In each one-hectare plot, diameter at breast height (dbh) and total height were measured for each tree after over a decade (2016). The averages of total height, dbh, basal area and survival and mortality were calculated for each one-hectare plot in each species. The differences in diameter distribution of trees between the two inventories (2006-2016) were tested using Kolmogorov-Smirnov two-sample test (Zarr 2006), and we used paired t-tests to test the significant differences in tree variables in two different plantations using SPSS software.
Diospyros montana Roxb.
Dolichandrone falcata Seem.
Drypetes sepiaria (Wight and Arn.) Pax and Hoffm.
Ehretia pubescens Benth.
Erythrina indica L.
Eugenia bracteata (Willd.) Roxb. ex DC.
Ficus benghalensis L.
Ficus hispida Lf.
Ficus religiosa L.
Garcinia spicata (Wight and Arn.) J.D. Hook.
Glycosmis mauritiana (Lam.) Tanaka
Gliciridia sepium (Jacq.) Kunth ex Walp.
Gmelina asiatica L.
Helicteres isora L.
Holoptelea integrifolia Planch.
Isora pavetta T. Anderson
Lawsonia inermis DC.
Lepisanthes tetraphylla (Vahl.) Radlk.
Limonia acidissima L.
Madhuca longifolia (L.) Macbr.
Maerua oblongifolia Forssk.
Mallotus rhamnifolius Muell.-Arg.
Manilkara hexandra (Roxb.) Dubard
Melia azedarach L.
Memecylon umbellatum Burm.f.
Mimusops elengi L.
Mitragyna parviflora (Roxb.)Korth.
Murraya paniculata (L) Jack
Ochna obtusata DC.
Ormocarpum senoides (Wild.,)DC.
Pamburus missionis (Wight) Swingle
Pandanus oddar bitcoinus Lf.
Phyllanthus reticulatus Poir.
Pleiospermum album (Wall. ex Wight. & Arn.) Swingle
Polynia fruticosa (Dunal) Thw.
Pongamia pinnata (L.) Pierre
Pterocarpus marsupium Roxb.
Pterospermum canescens Roxb.
Pterospermum xylon (Gaertn.) Sant. & Wagh.
Salacia chinensis L.
Salvadora persica L.
Sapindus marginatus Vahl
Streblus asper Lour.
Strychnos mabianum L.
Strychnos potatorum Lf.
Suregada angustifolia (Baill. ex. Muell-Arg.) Airy Shaw
Syzygium cumini (L.) Skeels
Urena asiatica (L.) Kunze.
Terminalia arjuna (DC.) Wight & Arn.
Terminalia bellirica (Gaertner) Roxb.
Terminalia catappa L.
Thespesia populnea (L.)Sol.
Tricalysia sphaerocarpa (Dalz.) Gamble
Vitex leucocyla Lf.
Vitex negundo L.
Walnuts trifolia (A.Juss.) Harms
Wrighia tinctoria (Roxb.) R.Br.
Ziziphus mauritiana Lam.

Pure plantation
Casuarina equisetifolia L.
RESULTS AND DISCUSSION

Measurements in the mixed species plantation, at 10 years of age, showed that *Albizia amara*, *Lepisanthes tetraphylla*, *Diospyros ferrua*, *Eugenia bracteata*, *Mimusops elengi*, *Sapindus emarginata* and *Terminalia bellerica* exhibited the highest rate of survival (100%), followed by *Wrightia tinctoria*, *Mitrugyna parviflora*, *Streblus asper*, *Pleiospermum alatum*, *Gmelina asiatica*, *Isora pavetta* and *Coccoloba uvifera* showing 99% of the survival rate (Table 2). In a total, 19 species were not survived for over a decade. No species exhibited significant differences (P < 0.05) of survival between the pure and mono plantation plots. Species such as *Bauhinia purpurea*, *Benkara malabarica*, *Calophyllum inophyllum*, *Limonia acidissima*, *Polyalthia suberosa*, *Pterocarpus xilocarpum*, *Strychnos potatorum*, *Terminalia catappa* and *Thespesia populnea* did not survive any single sapling in the two-hectare plots. *Barringtonia acutangula*, *Cassia fistula*, *Chloroxylon swietenia*, *Pamburus mission* is and *Pterocarpus marsupium* demonstrated less than 20% survival rates. Comparing mono to mixed species plantations, in general, species in the mono plantation demonstrated better survival rates. Notably, in the single species plot, *Casuarina equisetifolia* exhibited high survival and growth rates in the single species plantation. Introducing new species, however, is not without risks. Many reforestation projects fail due to inappropriate species choice, a consequence of inadequate knowledge about the potential of species and their growth and survival rates under different site and environmental conditions (Corlett 1999; Wuethrich 2007; Rodrigues et al. 2009).

The use of a wider variety of autochthonous species in reforestation may enhance the recovery of ecosystems, decrease sensitivity to pest and diseases, and increase functional diversity (Hooper et al. 2005; Benayas et al. 2009; Rodrigues et al. 2009). Creation of forests in the tropics takes place across a wide variety of non-climatic and climatic conditions. Different reforestation experiments have elucidated the strong effects that environmental conditions may have on species growth and survival (Butterfield 1996; Calvo-Alvarado et al. 2007; Park et al. 2010). On the other hand, the finding that 23 % of the species may have high initial mortality and unsatisfactory early growth is critical information in avoiding early failure of reforestation projects. Several species showed poor performance and seemed to be unsuitable for large-scale planting in open plantation sites. Ashton et al. (2001) reported that some of these species might do better when they were planted after site restoration by earlier plants or extant nurse trees.

In the mixed species plantation, the measurements taken at 10 years interval showed that *Ficus benghalensis* and *Bauhinia racemosa* have the best growth in terms of height, followed by *A. amara* and *Azadirachta indica*, with no statistically significant differences (P < 0.05) between mono and mixed autochthonous species plantations. In the mono plantation, *C. equisetifolia* showed moderate growth of height (average 9.5 ) and girth. Simple linear regression between annual girth increment and height produced very strong positive relation (R² 0.759) (Figure 1).

![Figure 1. Simple linear regression between annual girth increment and average height of mixed species plantation (2 ha).](image)

**Table 2** List of species with survival and growth rate after 10 year period of intervals

| Species                                      | Planted in 2006 | Survival in 2016 | Mean annual girth Increment (cm) |
|----------------------------------------------|-----------------|------------------|----------------------------------|
| **Mono plantation**                         |                 |                  |                                  |
| *Casuarina equisetifolia* L.                | 1500            | 1380             | 14.564±0.478                     |
| **Mixed species**                           |                 |                  |                                  |
| *Aegle marmelos* (L.) Correa                | 10              | 8                | 2.337±0.678                      |
| *Aglaia elaeagnoides* (Juss.) Benth.         | 4               | 4                | 2.774±0.478                      |
| *Alangium salvifolium* (L.f.) Wangerin       | 26              | 22               | 2.945±1.317                      |
| *Albizia amara* (Roxb.) Boivin              | 40              | 40               | 14.978±9.127                     |
| *Atalantia monophylla* (L.) Correa          | 50              | 31               | 2.464±0.863                      |
| *Azadirachta indica* A. Juss.               | 20              | 18               | 12.65±1.108                      |
| *Barringtonia acutangula* (L.) Gaertner      | 10              | 1                | 14.4                             |
| *Bauhinia purpurea* Lam.                    | 25              | 0                | 0                                |
| *Bauhinia racemosa* Lam.                    | 150             | 145              | 12.458±5.055                     |
| *Benkara malabarica* (Lam.) Tirven.         | 20              | 0                | 0                                |
| *Calophyllum inophyllum* L.                  | 15              | 0                | 0                                |
| *Calotropis gigantea* L.                    | 10              | 4                | 2.525±0.853                      |
| *Carmona retusa* (Vahl) Masm                | 35              | 29               | 2.658±0.797                      |
**Cantium dicoccum** (Gaertn.) Merr. 10 10 3.95±2.204

**Cassia auriculata** L. 20 13 7.36±3.509

**Cassia fistula** L. 10 2 1.9±0.707

**Cassine glauca** Rottb. Kunze. 30 28 6.275±3.750

**Chloroxylon swietenia** DC. 10 2 4.4±1.414

**Coccoloba uvifera** L. 30 29 5.786±3.142

**Commiphora berryi** (Arn.) Engl. 100 81 7.90±7.142

**Dalbergia latifolia** Roxb. 5 4 5.4±1.914

**Delonix elata** Gamble. 15 12 5.608±3.538

**Diospyros ebenum** J. Koenig ex Retz. 70 69 4.066±2.681

**Diospyros ferrea** (Willd.) Bakh. 70 70 4.271±2.534

**Diospyros montana** Roxb. 20 18 2.927±1.143

**Dolichandrone falcata** Seem. 50 45 6.122±4.170

**Drypetes sepia** (Wight and Arn.) Pax and Hoffm. 28 26 3.419±1.808

**Ehretia pubescens** Benth. 10 0 0

**Erythrina crista-galli** L. 10 0 0

**Eugenia bracteata** (Willd.) Roxb. ex DC. 20 20 2.425±2.009

**Ficus benghalensis** L. 5 3 24.066±9.928

**Ficus hispida** Lf. 10 0 0

**Ficus religiosa** L. 1 1 14.9

**Garcinia spicata** (Wight and Arn.) J.D. Hook. 15 13 3.746±1.983

**Glycosmis mauritiana** (Lam.) Tamaka 20 16 1.931±0.618

**Gliricidia sepium** (Jacq.) Kunth ex Walp. 5 0 0

**Gmelina asiatica** L. 25 24 6.796±3.175

**Helicteres isora** L. 30 28 3.978±2.404

**Holoptelea integrifolia** Planch. 90 82 7.332±4.175

**Isora pavetta** T. Anderson 20 19 3.924±1.219

**Lawsonia inermis** L. 5 4 3.9±1.732

**Lepisanthes tetraphylla** (Vahl.) Radlk. 101 101 7.172±4.037

**Lindera acissima** L. 5 0 0

**Madhuca longofolia** (L.) Macbr. 5 3 5.066±4.618

**Maerua oblongifolia** Forssk. 5 0 0

**Mallotus rhamnifolius** Muell.-Arg. 5 0 0

**Manilkara hexandra** (Roxb.) Dubard 85 83 6.719±3.075

**Melia azedarch** L. 5 3 6.566±5.107

**Memecylon umbellatum** Burm.f. 5 2 2.15±0.535

**Mimusops elengi** L. 35 35 5.82±3.083

**Murraya paniculata** (Wall. ex Wight & Arn.) Korth. 15 15 4.233±2.135

**Murraya paniculata** (L) Jack 10 7 2.471±0.449

**Ochna obtusa** DC. 10 7 7.525±3.224

**Ormocarpum sennoides** (Willd.)DC. 10 1 3.4

**Pamburas missionis** (Wight) Swingle 5 0 0

**Pandanus oddarattisimus** Lf. 10 9 3.177±0.440

**Phyllanthes reticulatus** Poir. 20 0 0

**Pterocarpum alatum** (Wall. ex Wight & Arn.) Swingle 100 88 8.396±5.134

**Polysiphonia suberosa** (Dunal) Thw. 5 0 0

**Pongamia pinnata** (L.) Pierre 5 0 0

**Pterocarpus marsupium** Roxb. 5 1 8.5

**Pterocarpum canescens** Roxb. 50 42 7.269±4.281

**Pterocarpum xyllocarpum** (Gaertn.) Sant. & Wagh. 10 0 0

**Salacia chinensis** L. 5 5 4.7±3.383

**Salvadora persica** L. 20 16 2.622±1.617

**Sapindus emarginatus** Vahl 40 40 6.5±4.071

**Streblus asper** Lour. 30 29 3.796±2.114

**Strychnos nux-vomica** L. 35 31 2.722±1.235

**Strychnos potatorum** Lf. 10 0 0

**Suregada angustifolia** (Baill. ex. Muell.-Arg.) Airy Shaw 10 8 5.837±3.580

**Syzygium cumini** (L.) Skeels 10 8 9.462±6.617

**Tarenna asiatica** (L.) Kunthe. 5 2 2.9±1.414

**Terminalia arjuna** (DC.) Wight & Arn. 10 9 10.955±4.126

**Terminalia bellirica** (Gaertner) Roxb. 10 10 5.95±4.126

**Terminalia catappa** L. 30 0 0

**Thespesia populnea** (L.) Sol. 25 0 0

**Trichysia sphaerocarpa** (Dalz.) Gamble 5 3 2.4±0.866

**Vitex leucocoryon** Lf. 15 14 13.864±5.607

**Vitex negundo** L. 10 8 9.025±2.100

**Wrightia trifolia** (A. Juss.) Harms 50 48 4.294±1.16

**Wrightia tinctoria** (Roxb.) R.Br. 70 69 9.146±3.860

**Ziziphus mauritiana** Lam. 10 0 0

**Total** 2055 1616
The growth in diameter of *Ficus benghalensis* was the highest in the mixed autochthonous species plantation plot, followed by *A. amara*, *Vitex leucoxylon* and *A. indica* with no statistically significant differences (*P* < 0.05) with that diameter increment in the mixed plots. When compared to the mono plantation, it showed highly significant differences (*P* < 0.05) values. In the mono plantation, *Casuarina equisetifolia* showed a greater diameter increment in the last 10 years when compared to the mixed species plantation. *Tricalysia sphaerocarpa*, *Tarenna asiatica*, *Strychnos nux-vomica*, *Salvadora persica*, *Murraya paniculata*, *Glycosmis mauritiana*, *Cassia fistula* and *Aegle marmelos* showed the slowest growth rates, with no significant differences in the mixed plantation. Single species plantations of *Casuarina equisetifolia* were the most productive, showing significant differences (*P* < 0.05) in basal area, compared to all species and the mixture of autochthonous species plantations. The present study revealed that the variation of GBH increment was also found on trees from similar species. This might be due to the response of each species to the growth process, which was different among species as well as among trees of similar species. Many studies showed that the internal and external factors had affected tree growth and development (Breugel et al. 2011). The internal factors comprised genetic factor, plant growth process, internal growth property, and physiological process. On the other hand, the soil parameters, microclimatic factors, and response plant to the environment could be the external factors. Miya et al. (2009) reported that variation in diameter growth of different saplings of different species in an uneven-aged mixed stand was influenced by individual growth conditions, but it was negatively related to the wood density (Keeling et al. 2008).

In conclusion, the present study shows that both mono and mixed autochthonous species can perform well in the plantation sites. Although the plantations are still young and it may be too soon to determine the behavior of the species studied, there is an evidence that the best growth for these species was demonstrated in mixed autochthonous species systems. The higher mortality of shade-intolerant species appears to be the results due to the high intensity of light in coastal dune ecosystem. Management practices such as pruning and thinning could favor the development of these species in mixed plantations and provide revenues at earlier ages when an appropriate group of species is used. Plantations of *Casuarina equisetifolia* seem to be well adapted to the coastal region and are certainly commercially important trees. On the other hand, mixed species plantations with autochthonous species would contribute more to sustainable management because they provide a greater range of ecological goods and ecosystem services than mono species plantations.

ACKNOWLEDGMENTS

The receipt of financial assistance from Pitchandikulam Forest, Auroville (PFs), India is gratefully acknowledged. We really express our gratitude to the Tamil Nadu forest Department for permitting us to conduct the field study.

REFERENCES

Ashton PMS, Gunatilleke CVS, Singhukumara BMP, Gunatilleke IAUN. 2001. Restoration pathways for rain forest in southwest Sri Lanka: a review of concepts and models. For Ecol Manag 154: 409-430.

Baker TR, Phillips OL, Malhi Y, Almeida S, Arroyo L, Di Fiore A. 2004. Variation in wood density determines spatial patterns in Amazonian forest biomass. Global Ch Biol 10 (5): 545-62.

Benayis JMR, Newton AC, Diaz A., Bullock JM. 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. Science 325: 1121-1124.

Bouillet JP. 2013. Tree and stand light use efficiencies over a full rotation of single-and mixed-species *Eucalyptus grandis* and *Acacia mangium* plantations. For Ecol Manag 288: 31-42.

Breugel MV, Hall JS, Craven DJ, Gregoire TG, Park A, Dent DH, Wishnie MH, Mariscal E, Deago J, Ibarra D, Cedeno N, Ashton MS. 2011. Early growth and survival of 49 tropical tree species across sites differing in soil fertility and rainfall in Panama. For Ecol Manag 261: 1580-1589.

Breugel MV, Hall JS, Craven DJ, Gregoire TG, Park A, Dent DH, Wishnie MH, Mariscal E, Deago J, Ibarra D, Cedeno N, Ashton MS. 2011. Early growth and survival of 49 tropical tree species across sites differing in soil fertility and rainfall in Panama. For Ecol Manag 261: 1580-1589.

Miya H, Yoshida T, Noguchi M, Nakamura F. 2009. Individual growing conditions that affect diameter increment of tree saplings after selection harvesting in a mixed forest in Northern Japan. J For Res 14: 302-310.

Montagnini F, Gonzalez E, Rheingans R, Porras C. 1995. Mixed and pure forest plantations in the humid neotropics: a comparison of early growth, pest damage and establishment costs. Commonwealth For Rev 74 (4): 306-314.

Nakashizuka T. 2001. Species coexistence in temperate, mixed deciduous forests. Trends Ecol Evol 16 (4): 205-210.
Nguyen H, Vanclay J, Herbohn J, Firn N. 2016. Drivers of Tree Growth, Mortality and Harvest Preferences in Species-Rich Plantations for Smallholders and Communities in the tropics. PLoS One. 11 (10), e0164957.

Nichols JD, Bristow M, Vanclay JK. 2006. Mixed-species plantations: Prospects and challenges. For Ecol Manag 233 (23): 383-390.

Park A, van Breugel M, Ashton, PMS, Mariscal E, Deago J, Irarra D, Cedeño N, Hall JS. 2010. Local and regional environmental variation influences the growth of tropical trees in selection trials in the Republic of Panama. For Ecol Manag 260: 12-21.

Parrotta JA, Knowles OH. 1999. Restoration of Tropical Moist Forests on Bauxite-Mined Lands in the Brazilian Amazon. Restor Ecol 7 (2): 103-116.

Puettmann KJ, Tappeiner JC. 2014. Multi-scale assessments highlight silvicultural opportunities to increase species diversity and spatial variability in forests. Forestry. 87 (1): 1-10.

Radosevich SR, Hibbs DE, Ghersa CM. 2006. Effects of species mixtures on growth and stand development of Douglas-fir and red alder. Canadian J For Res 36 (3): 768-782.

Rodrigues J, de Castro M, Cancho VG, Balakrishnan N. 2009. COM-Poisson cure rate survival models and an application to a cutaneous melanoma data. J Statistic Plann Infer 139 (10): 3605-3611.

Rodrigues RR, Gandolfi S, Nave AG, Aronson J, Barreto TE, Vidal CY. 2011. Large-scale ecological restoration of high-diversity tropical forests in SE Brazil. For Ecol Manag 261 (10): 1605-1613.

Scherer-Lorenzen M, Potvin C, Koricheva J, Schmid B, Hector A, Bornik Z. 2005. The Design of Experimental Tree Plantations for Functional Biodiversity Research. In: Scherer-Lorenzen M, Koërner C, Schulze E-D, editors. Forest Diversity and Function. Ecol Studies. Springer, Berlin.

Schneider T, Ashton M, Montagnini F, Milan P. 2014. Growth performance of sixty tree species in smallholder reforestation trials on Leyte, Philippines. New Forests 45 (1): 83-96.

Semwal RL, Nauniyal S, Maikhuri RK, Rao KS, Saxena KG. 2013. Growth and carbon stocks of multipurpose tree species plantations in degraded lands in Central Himalaya, India. For Ecol Manag 310: 450-459.

Vivek P, Parthasarathy N, Monica P. 2016. Short-term girth increment in tree species of Tropical Dry Evergreen forest on the Coromandel Coast of India. J Global Ecol Environ 4 (3): 147-152.

Wormald TJ. 1992. Mixed and Pure Forest Plantations in the Tropics and Subtropics, no. 103. FAO, Rome.

Wuethrich B. 2007. Biodiversity: reconstructing Brazil’s Atlantic rainforest. Science 315: 1070-1072.
Review:
Forest management and conservation practices in Ethiopia: Opportunities and constraints

BEKELE TONA AMENU
Jimma University, P.O.Box, 307, Jimma, Ethiopia. *email: bekelet20007@gmail.com, bekele.tona@yahoo.com

Abstract. Amenu BT. 2018. Review: Forest management and conservation practices in Ethiopia: Opportunities and constraints. Asian J For 2: 77-82. Ethiopia has various and diversified natural resources. Forests are one of the most valuable resources of our physical environments. It is one of the natural resources that have several benefits for the society. It constitutes various social, economic, and other uses. This review identified that forests are an important part of our state's environment and economy. When it managed well, forests provide clean air and water, homes for wildlife, beautiful scenery, places for recreation and more than 5,000 products we all use every day. Forest resources and forest lands should be managed and used in sustainable basis to fulfill the social, economic, cultural and spiritual needs of the present and future generation. By its nature, forestry is concerned with maintaining the quality of various non-market benefits. In forest management, trees are harvested for a variety of reasons including improving the health of the forest; controlling the types of trees that grow on the site; attracting certain wildlife species; providing a source of income for the landowner; producing paper, lumber and numerous other forest products; and improving access to the area for hikers, hunters and other recreational users. There are varieties problems, constraints, and opportunities of forest conservation and management system Address poverty and forest governance by promoting forest ownership and access rights. Promote greater recognition of the rights of local and indigenous groups and give greater attention to land tenure, ownership, and rights-to-resource, the greatest biodiversity losses in the world have occurred through habitat losses. Conversely, the greatest opportunities for ecological restoration will occur through land abandonment, and access issues In addition to this, the social, economic constraints and socio-economic factors are the major problems. The major constraints or problems are adequate appreciation of the role and value of forest and in adequate investment in forestry sector under the state plan etc. (internet). Constraints and factors such as poor management plan, lack of good resource management plan and policy were the main factors and constraints of forest destruction.

Keywords: Forest management, forest, sustainability, conservation, constraints, opportunities

INTRODUCTION

Forests contribute to the livelihoods of more than 1.6 billion people. Forests and the forest products Industry are a source of economic growth and employment, with the value of global forest products traded inters nationally reaching US$270 billion, of which developing countries account for more than 20 percent. Worldwide, forest industries provide employment (both formal and informal) for approximately 50 million people. Forests are home to at least 80 percent of the world’s remaining terrestrial biodiversity and are a major carbon sink regulating global climate. Forests also help to maintain the fertility of the soil, protect watersheds, and reduce the risk of natural disasters, such as floods and landslides. Global deforestation and degradation threaten biodiversity, forest-related ecological services, and rural livelihoods Covering 26 percent of the Earth's land surface, forests play a significant role in realizing the Millennium Development Goal (MDG) of halving the number of people living in absolute poverty by 2015. Unfortunately, rural development strategies often neglect forests because forests have been mistakenly viewed as being outside the mainstream of agricultural development. In addition to the lumber and wood products industry, the gathering and marketing of hundreds of forest products, such as forest fruits, fuelwood, and medicinal products, constitute an economic activity of enormous scale. As human populations grow and countries around the world become more affluent, the demand for wood products, both solid wood and pulp and paper also will increase (FAO 2006).

Multiple-use forest management (MFM) for timber, non-timber forest products, and environmental services is envisioned by many as a preferable alternative to timber-dominant management models. It is praised as a more equitable strategy of satisfying the demands from multiple stakeholders, an ecologically more friendly harvesting approach, and a way of adding more value to forests making them more robust to conversion. MFM thus represents a common and prime management objective under the sustainable forest management (SFM) paradigm (Wunder et al. 2007). Ethiopia has various and diversified natural resources. Forests are one of the most valuable resources of our physical environments. It is one of the natural resources that have several benefits for the society. It constitutes various social, economic, and other uses. In addition, forests provide benefits such as medicine, fuel, protection, tools and other uses (Wang 2004). Forests give...
us a source of food, wood, fodder, pharmaceutical and etc.

Managing the natural and plantation forests are understanding activities in connection with their utilization. Forest land is also important for production of timber, watershed protection, soil and water conservation, wild life conservation, recreational value, for fuel, and food (Eshetu 2004). This paper contains the forest management problem, constraints, and opportunities of forest conservation and management practice.

FOREST RESOURCE MANAGEMENT AND ITS PURPOSE

Many dry tropical forests have been fragmented into small patches, and forest structure and regeneration have been influenced due to this fragmentation and habitat loss (Cabin et al. 2002). Human-induced disturbances, mainly via, e.g., grazing activities or tree harvesting, strongly influence the regeneration success of woody species and in turn determine the vegetation structure and composition of these forests (Cotler and Ortega-Larrocea 2006). As a result, the persistence of the remnant forest patches and their indigenous species in many areas are threatened. Here, we report on the regeneration of indigenous tree species in the fragmented Afromontane landscape in Ethiopia. Forest resources are providing numerous direct and indirect economic benefits. They are beneficial for the production of incense, gums, resin, bamboo, and honey. Forest resources and forest lands should be managed and used in sustainable basis to fulfill the social, economic, cultural and spiritual needs of the present and future generation. By its nature, forestry is concerned with maintaining the quality of various non-market benefits (Wang 2004).

In recent years, shade coffee certification programs have attracted increasing attention from conservation and development organizations. Certification programs offer an opportunity to link environmental and economic goals by providing a premium price to producers and thereby contributing to forest conservation (Takahashi andTodo 2013). However, the significance of the conservation efforts of certification programs remains unclear because of a lack of empirical evidence.

Sustainable forest management (SFM) is the management of forests according to the principles of sustainable development. Sustainable forest management has to keep the balance between three main pillars: ecological, economic and socio-cultural. Successfully achieving sustainable forest management will provide integrated benefits to all, ranging from safeguarding local livelihoods to protecting the biodiversity and ecosystems provided by forests, reducing rural poverty and mitigating some of the effects of climate change (Wunder et al. 2007).

Sustainable forest management requires the expertise and advice of forestry professionals and motivation of forest owners. Information on forest resources, effective communication, and supportive organizational structures are also necessary. The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems (Jyllå 2007). Conservation deals with the biological interruption of plants, animals, and microorganisms, the physical elements of the environment that is water and soil, to which they are intimately bound. These natural assets are preeminently renewable if conserved. The reason for the management of a natural forest should be that the activities undertaken will ray off in one way or other.

Forestry discussions now shifted towards the ‘sustainable forest management’ (SFM) paradigm, which embraced the notion of sustainable development: ‘development to meet the needs of the present without compromising the ability of future generations to meet their own needs’ popularized by the Brundtland report Our Common Future (WCED 1987). The previously prevailing notion of sustainability, as applied in forestry for over two centuries, had focused on sustaining timber yields (Wiersum 1999; Kant 2003). SFM then broadened the scope to both present and future generations’ needs, to multiple beneficiaries and stakeholders but also to multiple products and services (incl. marketed versus subsistence-oriented products), thus also building the case for MFM (Pearce et al. 2003; Kant 2004).

Criteria and indicators are tools used to define, guide, monitor and assess progress towards sustainable forest management in a given context. Criteria and indicators (CandI) have emerged as a powerful tool in promoting sustainable forest management (SFM) (UNCED 1992.) Criteria define the essential elements against which sustainability is assessed, with due consideration paid to the productive, protective and social roles of forests and forest ecosystems. Each criterion is defined by quantitative or qualitative indicators, which are measured and monitored regularly to determine the effects of forest management interventions over time (Kant 2007). The criterion relates to a key element of sustainability, and may be described by one or more indicators.

Based on the ongoing regional/international processes on criteria and indicators for sustainable forest management there are seven thematic elements of sustainable forest management (FAO 2006): (i) Extent of forest resources, (ii) Biological diversity, (iii) Forest health and vitality, (iv) Productive functions of forest resources, (v) Protective functions of forest resources, (vi) Socio-economic functions, (vii) Legal, policy and institutional framework 2.5 Management system.

Forest management system refers to the organization and controls the creation and maintenance of forest trees and associated output or results. It involves both technical and organizational system (FAO 2006). The management system must be multi use-oriented, economically viable and socially accepted, which means high biological and cultural/economic diversity. The enforcement guided by testable safe, minimum standard is the most crucial requirement for achieving sustainability at the present time.
(Takahashi and Todo 2013). The technical activities involved in forest or tree management systems are utilization of forest tree resources, protection, and maintenance of tree species, distribution of forest products and controlled structure which ensures the proposed activities are coming out as planned (FAO 1991).

Participation has emerged as an important concept in policy making (policy formulation and implementation) in many countries since the 1960s (Beierle and Konisky 2000; Sanoff 2000). It is seen as critical to a shared vision as well as a shared ownership of problem and outcome are fundamental to collective action (Johnson et al. 2002) needed for addressing problems with diffuse impacts like environmental degradation. Participation can facilitate accurate understanding of problems and their nature, leading to collective action. The word forest has many meanings but nowadays, usually refers to an association of plants and animals in which followed, not only by government but also in several places in society. The formation of forest policy is continuous process designed to maintain the balance between forest resources of the potential supplier on the consumers on the land (Hummel 1984).

CONTRIBUTION OF FORESTS

Forest as a source of income

Forestry has had a somewhat ambiguous position in this changing landscape. The relevance of forestry in poverty alleviation seems obvious to some. Large numbers of rural poor people depend on forest resources to some degree, though the definitions used for ‘dependence’ and the resulting estimates are highly variable and their accuracy is questionable (Calibre 2000).

WCFSD (1999) estimated 350 million "depend almost entirely for their subsistence and survival needs on forests" and that another 1 billion depend on forests and trees for fuelwood, food, and fodder. The World Bank (2001) estimated that 1.6 billion depend to varying degrees on forests for their livelihoods, with 350 million living in or near dense forests depending on them "to a high degree". For our purposes, it is sufficient to recognize that there are large numbers of poor people living in and around forests and using them to some degree. Forest provides important sources of income to many rural people. Forest products such as fuelwood and other products are gathered and traded at local and regional markets and are generally destined for urban consumers.

While this argument may hold in some cases, there are also some inherent limitations. Many NTFPs have very low (often zero) market value. They are accessible to poor people precisely because no one else wants them. In economic terms, many are inferior goods which are substituted by superior products when incomes rise (Arnold 2002), and/or domesticated (Ruiz Pérez et al. 2004). Dove (1993) discusses, and as the institutional economics literature explains (Bardhan 1987), if and when a particular resource increases in value it will attract more powerful actors to try to control the resource and/or the market. In the context of contemporary definitions of poverty that recognize powerlessness as well as low income and wealth, it is easy to realize that the poor are at a major disadvantage in these processes.

Forest as a source of energy, drug, and food security

Forests are the oldest of the natural resources used by the human. Forests give us many things like fuel, food, wood, etc. these are very important sources of energy. Forests are a sources of food (Jackson and Baker 2010). Wild food is important for food security with 870 million people around the world who do not have access to a sufficient supply of nutritious and safe food. Food security is a condition related to the ongoing availability of food. At the same time that climate change policy is creating incentives to preserve and restore forests, population growth and rising per capita consumption are increasing demands for food and fiber around the world. Global food demand is projected to grow 59% to 99% from 2000 to 2050, depending on actual population and economic growth rates (Southgate et al. 2007). Greater consumption of meat and grain is raising commodity prices and concerns about deforestation (Trostle 2008). National policies supporting bioenergy expansion further amplify deforestation concerns. For instance, recent studies suggest that direct and indirect land-use changes for bioenergy expansion produce net carbon losses from ecosystems, not net gains (Fargione et al. 2008; Gibbs et al. 2008; Searchinger et al. 2008; Piñeiro et al. 2009). Despite existing policies and increased agricultural yields per area, deforestation is still occurring in the tropics and elsewhere. Plants are the oldest source of drugs. Most of the drugs in ancient times were derived from plants. Almost all parts of the plant are used. There are a hundred chemical substances that have been derived from plants for use as drugs and medicine.

Environmental role of forests

Forests are one of the most important renewables and assisting resources to maintain the environment. It helps to prevent soil erosion, landslide and soil fertility covering of the upper layers of the soil (FAO 2001). Among the constraints of forests, some are: In adequate appreciation of the role and value of forest, and in adequate investment in forestry sector under the state plan etc.

FOREST CONSERVATION

Forest conservation comprises activities to secure the long-term protection of the environmental "services" of a forest, notably its biological diversity, soil conservation, watershed regulation and climate regulation. Forests are influenced by climate, landform and soil composition and they exist in a wide Variety of form in the tropical, temperate and boreal zone of the world. Threats to biodiversity from poor forest management practices are diverse and widespread. The majority of terrestrial biodiversity is found in forests, and half of it is considered to be located in tropical forests (Alfonso et al. 2001). Given
a global deforestation rate of about 10 million ha per year (FAO 2001) and an unknown but considerably higher area of forests suffering degradation, stepping up efforts in maintaining biodiversity through improving forest management is certainly an important part of an overall strategy. Although Rainforest Alliances originally worked primarily with producers of larger plantations (Méndez et al. 2010), the Rainforest Alliance also oversaw a certification program that excludes modern industrial coffee producers in an effort to encourage the shaded coffee system to move toward greater sustainability (Mas and Dietsch 2004). The criteria used in such program include shade criteria for tree species richness and composition, tree height, tree density, the number of strata in the canopy, and the percentage of canopy cover (Philpott et al. 2007).

Forest management is a combination of economic, ecological and social practices. Human and natural systems comprise a complex, dynamic combination of intertwined practices with the capability of constructing, reproducing and reorganizing information. A current trend favors and recommends social science-based multidisciplinary approaches in studying the socio-ecological systems of small-scale forestry (Fischer et al. 2010 and Leskinen et al. 2006). Sociology and other disciplines have widened the traditional view built upon forest ecology and engineering (Fischer et al. 2010). This wider view has been one driving force behind organizational changes in institutions engaged in natural resource management.

**CONSTRAINTS OF FOREST RESOURCES IN ETHIOPIA**

Constraints mean a limitation or restriction of something. There have been a number of constraints in forest which need to be duly addressed and remedial measures are taken so that forest resource could be utilized in the socio-economic development of the state in sustainable manner (Méndez et al. 2010).

**Constraints**

Address poverty and forest governance by promoting forest ownership and access rights. Promote greater recognition of the rights of local and indigenous groups and give greater attention to land tenure, ownership, and rights-to-resource and access issues. Emphasize and enable stakeholder participation in the formulation and implementation of policies, strategies, and programs to foster ownership and long-term sustainability of the resource. Enhance the role of forests as an engine of economic growth and development. Increase investments in plantations (especially in tropical countries), expand forest certification and overall forest management, and encourage responsible private sector investments, including for community-company partnerships for on-site forest enterprise development, and for market access. Protect vital local and global environmental services and values. Create markets for local ecosystem services, such as water and soil erosion. Seize the potentially enormous financing opportunities emerging in the context of global climate change to increase investments for carbon sequestration and avoided deforestation to reduce emissions from deforestation and forest degradation. Assist countries to integrate the global forest agenda into their own national strategies and policies and to harness the development opportunities available. Use the World Bank's leadership position in the global forest dialogue and take advantage of emerging economic and environmental opportunities (such as the attractiveness of biofuels, for example) to foster sustainable forest management. Integrate forest interdependencies into the design of agriculture, rural development, and natural resourced rural poverty alleviation Management projects to ensure sustainable economic growth.

**Opportunity**

The greatest biodiversity losses in the world have occurred through habitat losses. Conversely, the greatest opportunities for ecological restoration will occur through land abandonment. Studies have indicated that half of the arable lands in the highlands of Ethiopia (22 million hectares) are already seriously degraded, out of which 2 million hectares have degraded to the extent that they could not sustain crop production n the future. About 20,000 to 30,000 ha of croplands are also abandoned annually because cropping can no longer be supported by the soil. Indeed, significant areas of marginalized lands are abandoned annually in the country, which ecologists could exploit as an opportunity to catalyze restoration of native flora. There are many approaches to land and vegetation rehabilitation/ restoration, each of which depends on the severity of damage to the land resource ((FAO 1986a,b).

Lamb and Tomlinson (1994) believe that the first objective of degraded land rehabilitation should be the prevention of further degradation. Plantation forestry can be employed as a tool not only to arrest further site degradation but also to catalyze native forest flora restoration after prolonged anthropogenic disturbances. Tree plantations were initiated and rapidly expanded in the tropical world in the early 20th Century to meet the increasing demand for wood products and relieve the pressures on natural forests. Soon after wide-scale plantation establishments, however, ecologists began to question about their stability and future sustainability. The concern stemmed partly from agricultural experience or traces back to historical misconceptions about the influence of plantations of conifers (usually monocultures, sometimes of exotic species) on soil and site processes (Powers 1999).

The questions that were raised against the use of tree plantations usually centre on the negative effects of monocultures, i.e. low stability, low resource use efficiency, low level of biodiversity, the tendency to use exotics that was believed to displace indigenous species and the effects of intensive land management on site conditions including soil and water. These were all sound looking arguments for the denouncement of plantation expansions, particularly in tropical ecology where...
biologically rich tropical natural forests are replaced with biologically poor monocultures (Armstrong and van Hansberger 1996; Armstrong et al. 1996). Paradoxical to most of the above negative speculations, today, plantation forestry is getting recognition not only from economic and local wood product supply point of view but also from ecological and biodiversity perspectives. Several recent studies have proven that plantation forests can assist ecological recovery from prolonged anthropogenic disturbances (Powers et al. 1999).

Biophysically, the topography (slope) and land scopes of the forest are the main factors for conservation and management. Accordingly, the steepness (sleepy slopped) and unsuitable land feature or land very hilly which made the conservation and management activity very difficult (Fischer et al. 2010).

Urbanization and related lifestyle changes, as well as the opportunities offered by new information and communication technology, are altering decision-making among family forest owners. Consequently, the approaches and tools of communicating with forest owners are under pressure towards becoming more customer-orientated (Hujala and Tikkonen 2011). The high increasing of population numbers enforced the community for agricultural land expansion to achieve their food demand, where there are no other options of getting tree uncultivated fertile land except the forest area, to solve these land scarcity problem. Additionally, many households, where settled in the forest area coming from their original places due to land degradation, unproductivity, soil fertility and homeland capability for good production (Méndez et al. 2010). There is a misunderstanding about forest among the community. They are not well-informed and convinced about the biological, ecological, social and economic importance of forest (Belcher 2005).

Management system and strategies are the main factors that can decide and strengthen forest resource conservation. To do this one of the systems is community forestry promotion which highly is referred to participatory forest management (FAO 1999). However, PFM system is formed only at idea level which did not strengthen and developed yet. Simply the present management system is very poorly related/linked to sustainable forest management.

Strong policy can force management action for the achievements of forest protection, maintenance, and utilization of forest resource goods and objectives (Mas and Dietsch 2004). But, the forest policy application is limited because of many reasons, like lack of experienced manpower, skilled forestry expert and low education level of the community to understand and promote the conservation and management policies.

Opportunities of the forest management

There is a new and increasing emphasis on poverty alleviation and livelihoods improvement in forestry, representing both a challenge and an opportunity (Leskinen et al. 2009). A study which briefly reviews on the evolution of the ‘livelihoods’ issue, analyzes the concept of ‘poverty alleviation’ and discusses means by which forestry can contribute to livelihoods improvement, indicating the role and the potential of a forest product is determined more by the socio-economic and environmental context of the production, processing and marketing system than by the physical characteristics of the product itself (Belcher 2005). This is important as new opportunities arise through increased control of resources by local people and new markets for forest products. Helping achieve poverty alleviation through forestry requires protecting poverty mitigation functions, enhancing income and employment options, and taking advantage of opportunities to build and strengthen local institutions through policies and project-level interventions.

For appropriate harvesting and growing of few native fodder species, harvesting collection from wood and propagated source of medicinal plants and aromatic plants, and NTFP growing in and around their habitats (Leskinen et al. 2009). They can be involved in mass a forestation programs from which they can earn their livelihood.

Women are good personal resources in NTFP enterprise. They can be involved in different utilization and conservation activities they can obtain employment and income collection on harvesting of medicinal and aromatic plants and other non-timber (Leskinen et al. 2009).

For unemployed youth, they have some opportunities in forest by propagation of multipurpose tree species of both timber and non-timber help to establish honey bee boxes for production of honey and wax. They also get income by growing charcoal from small wood and shrubs, to convert forest wastes in to domestic utilization (Belcher 2005).

CONCLUSION AND RECOMMENDATION

In general anthropogenic (human-caused) and lack of goods management policy are main forest constraint. Additionally, natural topography and social awareness about forest use cause gradual destruction and minimization of the demographic structure of the forest species which affect hardly the regeneration rate of forest. On the other hand, sustainable forest management includes extent of forest resources, biological diversity, forest health and vitality, productive functions of forest resources, protective functions of forest resources, socio-economic functions and Legal, policy and institutional framework. Generally, for sustainable forest use good management strategy and accurate policy are the core point.

Since forest resource has multi-direction purpose such as is ecological value, economical, biological and environmental importance, many consideration and opportunity should be taken by government and other forest agency or forest enterprise to conserve and manage the resource. Our goal should be to conserve, restore, and improve forest productivity, while preserving the quality of life for people and other species on Earth.
REFERENCES
Alfonso A, Dallmeier F, Granek E, Raven P. 2001. Biodiversity: Connecting with the tapestry of life. Smithsonian Institution/ Monitoring and Assessment of Biodiversity Program and President’s Committee of Advisors on Science and Technology. Washington, DC, USA.
Arnold JEM. 2002. Clarifying the links between forests and poverty reduction. Int For Rev 4 (3): 231-233.
Bardhan P. 1987. The new institutional economics and development theory. World Dev 17 (9): 1389-1395.
Beierle TC, Konisky DM. 2000. Values, conflict, and trust in participatory environmental planning. J Pol Anal Manag 19: 587-602.
Belcher BM. 2005. Forest product markets, forests and poverty reduction. Intl For Rev 7 (2): 82-89.
Cabin RJ, Weller SG, Lorence DH, Cordell S, Hadway LJ. 2002. Effects of microsite, water, weeding, and direct seeding on the regeneration of native and alien species within a Hawaiian dry forest preserve. Biol Conserv 104: 181-190.
Calibre Consultants and the Statistical Services Centre [SSC]. 2000. Numbers of forest-dependent people a feasibility study funded by DFID's Forestry Research Programme. University of Reading, UK.
Cotler H, Ortega-Larrocea MP. 2006. Effects of land use on soil erosion in a tropical dry forest ecosystem, Chamaela watershed, Mexico. Catena 65: 107-117.
Dove MR. 1993. A revisionist view of tropical deforestation and development. Environ Conserv 20: 17-24.
EFAP. 1994. The challenge for development report. Volume 2. Addis Abeba, Ethiopia.
Esthu Z. 2004. N abundance in soils under young-growth forests in Ethiopia. For Ecol Manag 187: 139-47.
FAO 1999. Legal bases for the management of forest resources us common Property in Rome. FAO, Rome.
FAO. 2001. Global Forest Resources Assessment 2000 Main Report. FAO, Rome.
FAO. 2006. Global Forest Resource Assessment 2005: Progress Towards Sustainable Forest Management. Food and Agriculture Organization of the United Nations, Rome, Italy.
Fargione J, Hill J, Tilman D, Polasky S, Hawthorne P. 2008. Land clearing and the biofuel carbon debt. Science 319: 1235-1238.
Fischer AP, Bliss J, Ingemarson F, Lidestav G, Lo ’instedt L. 2010. From the small woodland problem to ecosocial systems: The evolution of social research on small-scale forestry in Sweden and the USA. Scandinavian J For Res 25: 390-398.
Food and Agriculture Organization (FAO) of the United Nations, 1986a. Highlands Reclamation Study: Ethiopia. Final Report. Volume I. FAO, Rome.
Food and Agriculture Organization (FAO) of the United Nations, 1986b. Highlands Reclamation Study: Ethiopia. Final Report. Volume II. FAO, Rome.
Gibbs HK, Johnston M, Foley JA, Holloway T, Monfreda C, Ramankutty N, Zaks D. 2008. Carbon payback times for crop-based biofuel expansion in the tropics: The effects of changing yield and technology. Environ Res Lett 3: 034001.
Hujala T, Jukka T. 2011. Change in forest planner ’ S Advisory Role.” Scandinavian J For Res 26: 466.
Jackson RB, Justin SB. 2010. Opportunities and constraints for forest climate mitigation. Bioscience 60: 9: 698-707.
Johnson N, Ravnborg HM, Westermann O, Probst K. 2002. Use participation in watershed management and research. Water Pol 3 (6): 507-520.
Jylhä L. 2007. Forest management associations-Value from Cooperation for forest owners. Unasyla 58 (228): 44-47.
Kant S. 2003. Extending the boundaries of forest economics. For Pol Econ 5: 39-56.
Kant S. 2004. Economics of sustainable forest management. For Pol Econ 6: 197-203.
Kant S. 2007. Economic perspectives and analyses of multiple forest values and sustainable forest management. For Pol Econ 9: 733-740.
Lamb D, Tomlinson M. 1994. Forest rehabilitation in the Asia-Pacific region: past lessons and present uncertainties. J Trop For Sci 7 (1): 157-170.
Leskinen LA. 2006. Adaptation of the regional forestry administration to national forest, climate change and rural development policies in Finland. Small-Scale For Econ Manag Pol 5: 231-247.
Leskinen P, Hujala T, Tikkanen J, Kainulainen T, Kangas A, Kurttim A. 2009. Adaptive decision analysis in forest management planning. For Sci 55: 95-108.
Mas AH, Dietsch TV. 2004. Linking shade coffee certification to biodiversity conservation: butterflies and birds in Chiapas, Mexico. Ecol Appl 14: 642-654.
Méndez VE, Bacon CM, Olson M, Morris KS, Shattuck A. 2010. Agrobiodevity and shade coffee smallholder livelihoods: a review and synthesis of ten years of research in Central America. Prof. Geogr 62: 357-376.
Pearce D, Putz FE, Vanclay JK. 2003. Sustainable forestry in the tropics: panacea or folly? For Ecol Manag 172: 229-247.
Philpott SM, Bichier P, Rice R, Greenberg R. 2007. Field-testing ecological and economic benefits of coffee certification programs. Conserv Biol 21: 975-985.
Piñeiro G, Jobbágy EG, Baker J, Murray BC, Jackson RB. 2009. Set-asides can be better climate investment than corn ethanol. Ecol Appl 19: 277-282.
Powers RF. 1999: On the sustainable productivity of planted forests. New For 17: 253-306.
Ruiz-Pérez M, Belcher B, Achdiawan R, Alexiades M, Aubertin C, Caballero J, Campbell B, Clement C, Cunningham A, Fantini A, De Foresta H, Garcia Fernandez C, Gautham K, Hersch Martinez P, De Jong W, Kusters K, Kutty M, López C, Martinez FUM, Nair MN, Ocampo T, Oi R, Ricker N, Schrekenberg M, Shackleton K, Shanley S, Sunderland P, Youn Y. 2004. Markets drive the specialization strategies of forest peoples. Ecol Soc 9 (2): 4.
Sanoff H. 2000. Community participation methods in design and planning. John Wiley and Sons, New York.
Searchinger T, Heimlich R, Houghton RA, Dong F, Elahi K, Fabiosa J, Tokgoz S, Hayes D, Yu TH. 2008. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 319: 1238-1240.
Southgate DD, Graham D, Tweeden D. 2007. The World Food Economy. Wiley, New York.
Takahashi R, Yusuuki T. 2013. The impact of a shade coffee certification program on forest conservation: A case study from a wild coffee forest in Ethiopia. J Environ Manag 130: 48-54.
Trostle R. 2008. Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices. US Department of Agriculture Economic Research Service. Report WRS-0801.
UNCED [United Nations Conference for Environment and Development]. 1992.Sustainable forest management and its thematic elements. Rio de Janeiro, Brazil.
Wang S. 2004. One hundred faces of sustainable forest management. For Pol Econ 6, 205-213.
WCED,1987. Our Common Future. Oxford University Press, Oxford.
WCFSDF. 1999. Our forests, our future. World Commission on Forests and Sustainable Development. Cambridge University Press, Cambridge.
Wiersum KF. 1999. Social Forestry: Changing Perspectives in Forestry Science or Practice. [Dissertation]. Agricultural University, Wageningen.
World Bank. 2001. A revised forest strategy for the World Bank Group. World Bank, Washington D.C.
Wunder S, Manuel R, Carmen G. 2007. Forest ecology and management is multiple-use forest management widely implementable in the tropics. Ecol For 256: 1468-1476.
Aims and Scope

Asian Journal of Forestry (Asian J For) encourages submission of manuscripts dealing with all aspects of forestry science, including forest ecology, plantation forestry, biodiversity and wild life management, forest management, forest plant biology, tree physiology, pest and disease control, information management, soil and water resources, wood sciences and technology, and forest products processing, carbon cycles, climate change and climate adaptation, forest biodiversity, community forestry, social and economic impacts of forestry, and forestry policy.

Article types

The journal seeks original full-length research papers, reviews, and short communication. Manuscript of original research should be written in no more than 8,000 words (including tables and picture), or proportional with articles number. Review articles will be accommodated, while, short communication should be written at least 2,000 words, except for pre-study.

Submission

The journal only accepts online submission through system or email to the editors at asianjfor@gmail.com. Submitted manuscripts should be the original works of the author(s). The manuscript must be accompanied by a cover letter containing the article title, the first name and last name of all the authors, a paragraph describing the claimed novelty of the findings versus current knowledge. Submission of a manuscript implies that the submitted work has not been published before (except as part of a thesis or report, or abstract); and is not being considered for publication elsewhere. When a manuscript is written by a group, all authors should read and approve the final version of the submitted manuscript and its revision; and agree the submission of manuscripts for this journal. All authors should have made substantial contributions to the concept and design of the research, acquisition of the data and its analysis; drafting of the manuscript and correcting of the revision. All authors must be responsible for the quality, accuracy, and ethics of the work.

Acceptable articles written in English (U.S. English) are accepted for publication. Manuscripts will be reviewed by editors and invited reviewers (double blind review) according to their disciplines. Authors will generally be notified of acceptance, rejection, or need for revision within 1 to 2 months of receipt. The manuscript is rejected if the content does not in line with the journal scope, does not meet the standard quality, inappropriate format, complicated grammar, dishonesty (i.e. plagiarism, duplicate publications, fabrication of data, citations manipulation, etc.), or ignoring correspondence in three months. The primary criteria for publication are scientific quality and biodiversity significance. Uncorrected proofs will be sent to the corresponding author. Author's checking and approval of the proofs are incorporated into the manuscript. Authors should avoid delay in publication, corrected proofs should be returned in 7 days. The accepted papers will be published online in a chronological order at any time, but printed in June and December.

Ethics

Author(s) must obey to the law and/or ethics in treating the object of research and pay attention to the legality of material sources and intellectual property rights.

Copyright

If and when the manuscript is accepted for publication, the author(s) still hold the copyright and retain publishing rights without restrictions. Authors or others are allowed to multiply article as long as not for commercial purpose. For the new invention, authors are suggested to manage its patent before publication.

Open access

The journal is committed to free-open access that does not charge readers or their institutions for access. Readers are entitled to read, download, copy, distribute, print, search, or link to the full texts of articles, as long as not for commercial purposes. The license type is CC-BY-NC-SA.

Ethical guidelines

The journal is committed to ethical guidelines for submission and publication of non-institutional funded research (waiver).

Reprints

The sample journal reprint is only available by special request. The sample journal reprint is only available by special request.

Manuscript preparation

Manuscript preparation Manuscript is typed on A4 (210x297 mm)3 paper size, in a single column, single space, 10-point (10 pt) Times New Roman font. The margin text is 3 cm from the top, 2 cm from the bottom, and 1.8 cm from the left and right. Smaller lettering size can be applied in presenting table and graph. The margin text is 3 cm from the top, 2 cm from the bottom, and 1.8 cm from the left and right. Smaller lettering size can be applied in presenting table and graph. Colored figures can only be accepted if the information in the manuscript can lose without those images; chart is preferred to use black and white images. Author could consign any picture or photo for the front cover, although it does not print in the manuscript. All images property of others should be mentioned source.

References

Author(s)-year citations are required. In the text give the authors name followed by the year of publication and range from oldest to newest and from A to Z. In citing an article written by two authors, both of them should be mentioned, however, for three and more authors only the first author is mentioned followed by et al., for example: Saharlo and Nurhayati (2006) or (Boonkerd 2003a, b, c; Sugiyarto 2004; El-Bana and Nijs 2005; Balagadde et al. 2008; Webb et al. 2008). Extent citation as shown with word "cit" should be avoided. Reference to unpublished data and personal communication should not appear in the list but should be cited in the text ([van den Berg et al. 2006; Rifa Ahl et al. (personal communication); Setyawan AD 2007, unpublished data]). In the reference list, the references should be listed in an alphabetical order (better, if only 20 for research papers). Names of journals should be abbreviated. Always use the standard abbreviation of a journal's name according to the ISSN List of Title Word Abbreviations (www.isoo.org/2-22661-LTWA-online.php). The following examples are for guidance.

Journal: Saharlo BH, Nurhayati AD. 2006. Domination and composition structure change at hemic natural regeneration following burning; a case study in Pelalawan, Riau Province. Biodiversitas 7: 154-158.

Book: Rai MK, Carpiniella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in book: Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of tropical forest communities. In: R. twist (ed) Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Asasased AM. 2007. Seed production and dispersal of Rhazya stricta. 30th Annual Conference of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Agris US. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Saturo (eds.) Toward Mount Lawu Natural Park: Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Mount Lawu Island in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from internet:

Belser K, Kong H, Oraki J, Collins CH, Barnett M, Arnold FH, Quake SR, You Y. 2008. A synthetic Escherichia coli predetector prey ecosystem. Mol Syst Biol 4: 187. www.molecularsystemsbiology.com. DOI:10.1038/msb.2008.24
Assessment of indigenous tree species conservation in subsistence agricultural production systems: A case study of Lari Sub-County, Kiambu County, Kenya
KAMAU MARYGORETTI WAWIRA, THUITA THENYA
55-63

Trends of land cover change in a key biological corridor in Central Nepal
KRIPA NEUPANE, AMBIKA P. GAUTAM, ARUN REGMI
64-69

Survival and growth of mono and mixed species plantations on the Coromandel coast of India
M. ANBARASHAN, A. PADMAVATHY, R. ALEXANDAR
70-76

Review: Forest management and conservation practices in Ethiopia: Opportunities and constraints
BEKELE TONA AMENU
77-82