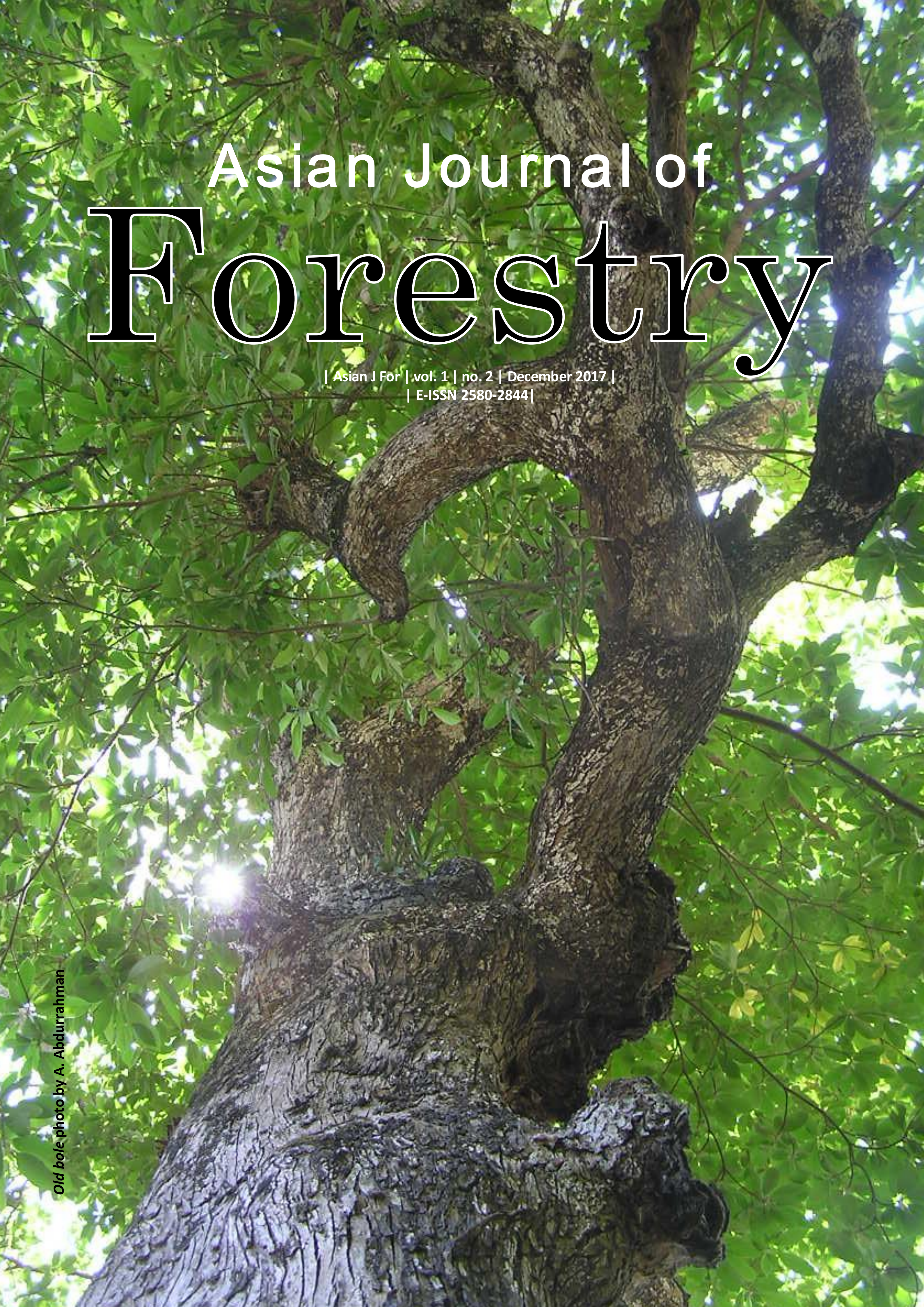
Asian Journal of Forestry

| Asian J For | vol. 1 | no. 2 | December 2017 |
| E-ISSN 2580-2844|



Old bole photo by A. Abdurrahman

Asian Journal of Forestry

| Asian J For | vol. 1 | no. 2 | December 2017| E-ISSN 2580-2844|

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**
Ice Nucleation Active Bacteria in Mount Lawu forest, Indonesia: 1. Isolation and estimation of bacterial populations on lichens KHUSNUL FU'ADAH, SITI LUSI ARUM SARI, ARI SUSILOWATI	83-92

Published semianually **PRINTED IN INDONESIA**

E-ISSN: 2580-2844

9 772580 284026

Asian Journal of Forestry

| Asian J For | vol. 1 | no. 2 | December 2017 |

ONLINE
http://smujo.id/ajf

e-ISSN
2580-2844

PUBLISHER
Society for Indonesian Biodiversity

CO-PUBLISHER
Universitas Sumatera Utara, Medan, Indonesia

OFFICE ADDRESS
Faculty of Forestry, Universitas Sumatera Utara. Jl. Tri Darma Ujung No. 1, Kampus USU Padang Bulan, Medan 20155, Sumatera Utara, Indonesia. Tel.: +62-61-8211633, email: ajf@smujo.id, asianjfor@gmail.com

PERIOD OF ISSUANCE
June, December

Society for Indonesian Biodiversity

Universitas Sumatera Utara Medan, Indonesia

Published by Smujo International for The Society for Indonesian Biodiversity and Universitas Sumatera Utara Medan, Indonesia

GUIDANCE FOR AUTHORS

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, forest fires, small-scale forestry and 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 in this publication 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 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.

Acceptance The only 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 as *.doc* or *.rtf* files for checking and correcting of typographical errors. To 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 obedient 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 purposes. For the new invention, authors are suggested to manage its patent before published.

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.

A charge The journal is committed to free of charge for submission and publication of non-institutional funded research (waiver).

Reprints The sample journal reprint is only available by special request. Additional copies may be purchased when ordering by sending back the uncorrected proofs by email.

Manuscript preparation Manuscript is typed on A4 (210x297 mm^2) 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 figure (9 pt). Word processing program or additional software can be used, however, it must be PC compatible and Microsoft Word based (*.doc* or *.rtf*; **not *.docx***). **Scientific names** of species (incl. subspecies, variety, etc.) should be written in italic, except for italic sentence. Scientific name (genera, species, author), and cultivar or strain should be mentioned completely for the first time mentioning it in the body text, especially for taxonomic manuscripts. Name of genera can be shortened after first mentioning, except generating confusion. Name of the author can be eliminated after first mentioning. For example, *Rhizopus oryzae* L. UICC 524, hereinafter can be written as *R. oryzae* UICC 524. Using trivial name should be avoided, otherwise generating confusion. **Biochemical and chemical nomenclature** should follow the order of the IUPAC - IUB. For DNA sequence, it is better used Courier New font. Symbols of standard chemical and abbreviation of chemistry name can be applied for common and clear used, for example, completely written butilic hydroxyl toluene (BHT) to be BHT herein after. **Metric measurement** use IS denomination, usage other system should follow the value of equivalent with the denomination of IS first mentioning. Abbreviations set of, like g, mg, mL, etc. do not follow by dot. Minus index (m^{-2}, L^{-1}, h^{-1}) suggested to be used, except in things like "per-plant" or "per-plot". **Equation of mathematics** does not always can be written down in one column with text, in that case can be written separately. **Number** one to ten are expressed with words, except if it relates to measurement, while values above them written in number, except in early sentence. The fraction should be expressed in decimal. In the text, it should be used "%" rather than "percent". Avoid expressing ideas with complicated sentence and verbiage, and used efficient and effective sentence.

Title of the article should be written in compact, clear, and informative sentence, preferably not more than 20 words. Name of author(s) should be completely written. **Name and institution** address should also be completely written with street name and number (location), postal code, telephone number (O), facsimile number (O), and personal email address. For Indonesian universities, use local name. Manuscript written by a group, author for correspondence along with address is required. First page of the manuscript is used for writing above information.

Abstract should not be more than 200 words. **Keywords** is about five words, covering scientific and local name (if any), research theme, and special methods which used; and sorted from A to Z. All important **abbreviations** must be defined at their first mention. **Running title** is about five words. **Introduction** is about 400-600 words, covering the background and aims of the research. **Materials and Methods** should emphasize on the procedures and data analysis. **Results and Discussion** should be written as a series of connecting sentences, however, for manuscript with long discussion should be divided into subtitles. Thorough discussion represents the causal effect mainly explains for why and how the results of the research were taken place, and do not only re-express the mentioned results in the form of sentences. **Concluding** sentence should be given at the end of the discussion. **Acknowledgments** are expressed in a brief; all sources of institutional, private and corporate financial support for the work must be fully acknowledged, and any potential conflicts of interest are noted.

Figures and Tables of maximum of three pages should be clearly presented. Title of a picture is written down below the picture, while title of a table is written above the table. 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. **There is no appendix**, all data or data analysis are incorporated into Results and Discussions. For broad data, it can be displayed on the website as a supplement.

References Author-year citations are required. In the text give the authors name followed by the year of publication and arrange 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: Saharjo 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 only (e.g., Rifai MA 2007, pers. com. (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.issn.org/2-22661-LTWA-online.php). The following examples are for guidance.

Journal:

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

Book:

Rai MK, Carpinella 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 rainforest tree communities. In: Carson W, Schnitzer S (eds) Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.) Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm 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:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. www.molecularsystemsbiology.com. DOI:10.1038/msb.2008.24

THIS PAGE INTENTIONALLY LEFT BLANK

ASIAN JOURNAL OF FORESTRY
Volume 1, Number 2, December 2017
Pages: 55-63
E-ISSN: 2580-2844
DOI: 10.13057/asianjfor/r010201

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 a typical land-use system in Kenya, especially in the humid and sub-humid regions. This research aimed to assess the types of indigenous trees, where they are grown, and why they are retained in agricultural production systems in Lari Sub-county, Kiambu County, Kenya. The results showed that various indigenous tree species were retained on-farm including *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 57.4% along the boundary, 38.9% around the homestead, 2.6% inside the farm and 1.1% on riverine areas. Soil conservation, and timber and fuelwood provision were given as the main reasons for conserving indigenous tree species on the farm. While the main reason for planting exotic trees on-farm include economic purposes like income, fuelwood, and decreased land sizes, according to 60% of respondents. Overall, the findings indicate significant decrease in indigenous trees conservation on-farm due to longer maturity span compared to exotic trees. There is a 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. The products derived from them, such as food, medicine, cooking fuel, animal fodder and construction materials, are critical for the subsistence living of hundreds of millions of people throughout the world. Trees also have protective functions at site, landscape and global levels. They prevent soil erosion, store water underground, maintain soil fertility, allow more efficient water and nutrient resource use, 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.

Around 13 million hectares of forest in the world 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.

Removal of trees from agricultural landscapes has for long been seen as a sign of intensification and progress, especially where mechanization of agriculture was involved (Zomer et al. 2014). 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).

Nonetheless, there is an increasing concern about setting aside tree cover in agricultural landscape. 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 increases by 3%, or more than 828,000 km^2. 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 km^2: 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, the increase was at 2%, while both Northern and Central Asia showed a decrease of 2.9%.

A study by Zomer et al. (2014) showed the importance of trees outside forests on 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 on a national scale.

Kenya is among developing countries in sub-Saharan Africa that share problems of deforestation with other eastern Africa nations due to conversion of forests to other land uses, especially agriculture and settlement, to meet the needs of ever-increasing human population. In Kenya, limited studies have been carried out to assess factors associated with indigenous tree planting and retention of trees 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.

Farmlands in Lari Sub-county, Kenya are dotted with remnants of indigenous trees, providing an excellent context for a study of tree cover within agricultural landscapes. Therefore, 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 km^2 with elevation ranging between 2415 and 2591 m above sea level (a.s.l) and receives precipitation between 1,150 and 1,276 mm. The study area covered two wards, first is Kinale Ward, which has an area of 112.3 km^2 with a population density of 130 persons per km^2 (Figure 1). In this area, the agro-ecological zone supports sheep and dairy farming, tea farming and forestry. The other is Kijabe Ward which has an area of 29.8 km^2 with a population density of 711 persons per km^2 while the associated agro-ecological zone supports wheat-maize-barley-pyrethrum farming tea and dairy zone.

Majority of the people in the study area depend 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 quality, 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.

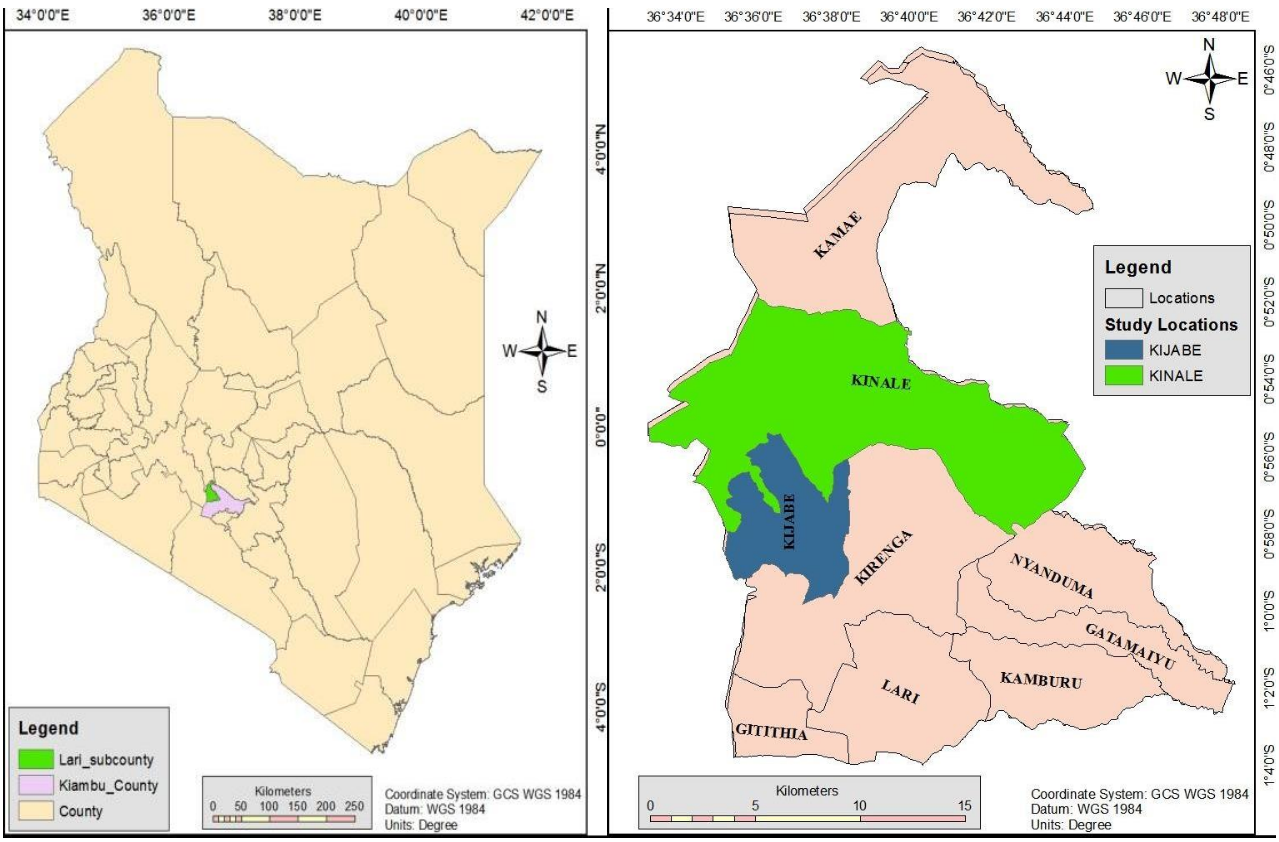


Figure 1. Map showing the study areas in Kinale and Kijabe, Lari Sub-county, Kenya

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 across the road. A total of 96 farms were sampled based on population with Kinale having 60% of the sample population (57 households) and Kijabe 40% of the population (39 households). 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 farm understudy 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 to be combined with tree inventory observation schedule. Data collected included relative position, height, breadth and reasons for maintaining 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 richness

Several species of indigenous tree species were found on farm in both Kinale and Kijabe Wards, Lari Sub-county, Kenya (Table 1). These included trees such as Mukeu-Kikuyu or dombeya (*Dombeya torrida*), croton tree (*Croton megalocarpus*), melia (*Melia volkensii*), etc.

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

Local name	Common name	Scientific name
Murera	Thorn tree	*Acacia abyssinica*
Mokumo/mugumo	Strangler fig	*Ficus thonningii*
Mubuu	Silk oak	*Brachylaena hutchinsii*
Muchami	Allophylus	*Allophylus abyssinicus*
Muhoro/muhoru	Meru oak	*Vitex keniensis*
Muiri	Red stinkwood	*Prunus africana*
Mukau	Melia	*Melia volkensii*
Mukeu	Dombeya	*Dombeya torrida*
Mukindori	Croton	*Croton megalocarpus*
Mutamaiyu	African olive	*Olea europeana*
Mutarakwa	African juniper	*Juniperus procera*
Mutati	Parasol tree	*Polyscias kikuyuensis*
Muthai	Schefflera	*Schefflera volkensii*
Muthegera	Podo	*Podocarpus milanjianus*
Mugaita	Rapanea	*Rapanea ralanophloes / Myrisna melanophloes*

Tree diversity

Table 2 and 3 show a diversity index of the indigenous tree species 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 was a high highest diversity of indigenous tree species in Kijabe than Kinale Ward. Meru Oak (*Vitex keniensis*) dominated in Kijabe while the African juniper (*Juniperus procera*) tree dominated the Kinale Wards farms.

The lowest diversity was the silk oak (*Brachylaena hutchinsii*) and rapanea (*Rapanea melanophloeos*) in both Kinale and Kijabe Wards. There was no strangler fig, silk oak and rapanea tree species in Kijabe and in Kinale there was no allophylus (*Allophylus abyssinicus*), croton (*Croton megalocarpus*), schefflera (*Schefflera volkensii*) and thorn trees (*Acacia abyssinica*) recorded on farm. While the parasol and podo trees occurred in both Kijabe and Kinale Ward.

The location of indigenous trees species on farm

The study analyzed where these indigenous trees grew 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. Boundary trees (B): these trees are those that were grown purposively as fences to mark the boundary between one farm and the other. Homestead (H): this showed the trees that grew near the homestead area but not where the farmer was practicing agriculture. Riverine (R): these are the trees that grew along streams/rivers that were passing via the farms.

Overall, most of the trees in Lari Sub-county were scattered on farm (57.4%) (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.

The highest numbers of indigenous trees in Kinale Ward were mostly located at the boundary and some of these trees included African juniper (*J. procera*), dombeya (*D. torrida*) and podo (*P. milanjianus*) (Table 5; Figure 2). All the indigenous trees found in Kinale were also found at the homesteads. Dombeya (*D. torrida*) had the highest number of trees scattered on various farms in Kinale Ward. The Red stinkwood (*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 Kinale Ward, Lari Sub-county, Kenya

Name of tree	African juniper	African olive	Dombeya	Meru oak	Parasol tree	Podo	Rapanea	Red stinkwood	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 Kijabe Ward, Lari Sub-county, Kenya

Name of tree	African Juniper	African Olive	Dombeya	Meru Oak	Parasol tree	Podo	Red stinkwood	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 in the two locations (Kinale and Kijabe Wards) in Lari Sub-county, Kenya

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, Lari Sub-county, Kenya

Relative location of tree	Name of indigenous trees										
	African juniper	African olive	Dombeya	Meru oak	Parasol tree	Podo	Rapanea	Red stinkwood	Silk oak	Strangler fig	Total
Boundary	6608	2	22	6				3			6641
Scattered on farm		5	36	5	6	5		1	15		73
Riverine		60	5	5	3		1	70			143
Homestead	4	22	7	16		89		15		2	156
Total	6612	89	70	32	9	94	1	89	15	2	7013

Table 6. Relative position of indigenous trees in Kijabe Ward, Lari Sub-county, Kenya

Relative location of tree	Name of indigenous trees											
	African juniper	African olive	Dombeya	Meru oak	Parasol tree	Podo	Red stinkwood	Allophylus	Croton	Schefflera	Thorn tree	Total
Boundary	26	16	143		5	12	23				10	235
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

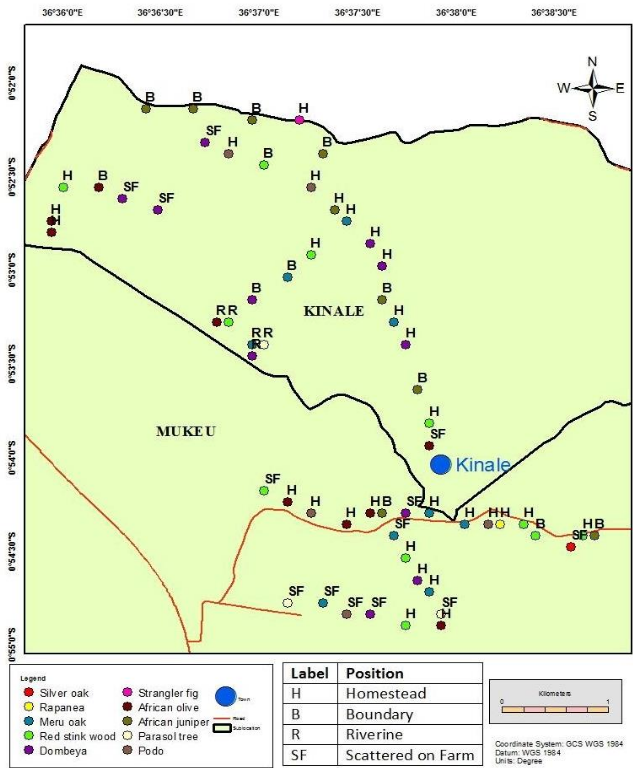


Figure 2. Indigenous tree sites in Kinale Ward, Lari Sub-county, Kenya

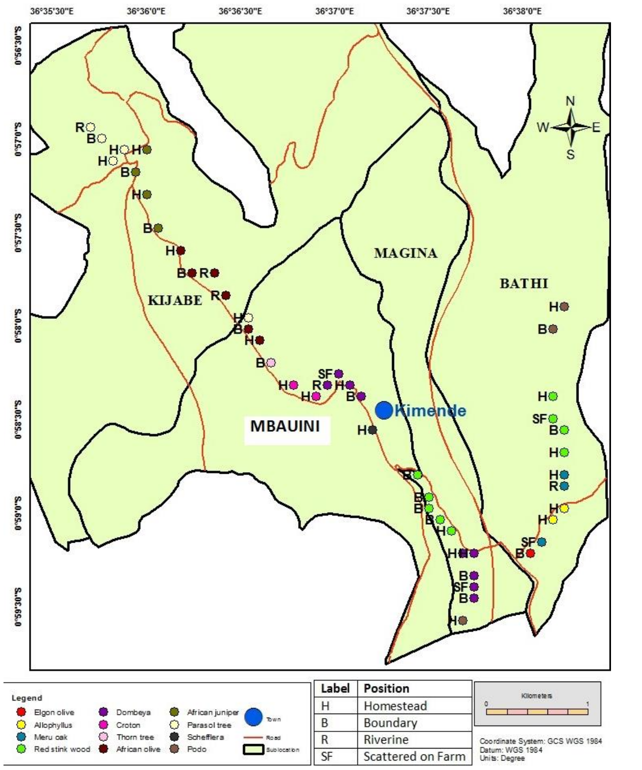


Figure 3. Indigenous tree sites in Kijabe Ward, Lari Sub-county, Kenya

Figure 3 and Table 6 show the relative position of indigenous trees in Kijabe Ward and it shows that Meru oak (*V. keniensis*) had the highest diversity in Kijabe and most of it is scattered within the farms. The Red stink wood (*P. africana*) had the highest diversity in terms of trees found within the homestead while dombeya (*D. torrida*) had the highest diversity in terms of trees found within boundary and riverine areas. Most of the trees were concentrated in Mbauini, Bathi and Kijabe subdivisions and very little indigenous trees were found in Magina.

From the 39 farms visited in Kijabe, the study counted 10,641 indigenous trees. On the other hand, 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 thonningii*, *B. hutchinsii*, *A. abyssinicus*, *V. keniensis*, *Prunus africana*. These trees relative location was majorly homestead, boundary and scattered on farm. There is a high population of indigenous trees found in Mukeu as opposed to Kinale Wards. The reason for fewer indigenous tree species on farm in Kinale was primarily because most of the farms practiced horticultural farming. This system of production mainly requires specialization of either crop mainly cabbages, potatoes, carrots, beetroot, cucumber to name a few and fruit trees.

Rationale for retaining indigenous trees on farm

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 soil erosion and enrich the soil (Scherr 1995) or 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 depends 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

We 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. 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.

Major factor influencing the 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 the knowledge on the value of indigenous trees (Figure 4). The total number of indigenous trees found in Kinale was 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 and kales among others.

In Kijabe, a total of 10,641 indigenous tree species were counted in the 39 farms visited. Similarly, mixed farming and knowledge of indigenous trees were 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 contributed to the retention of indigenous trees on the farm.

Gender influence on indigenous tree conservation

There were various factors that influence the indigenous tree species on the farm. Household characteristics were 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 were 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 was usually sought.

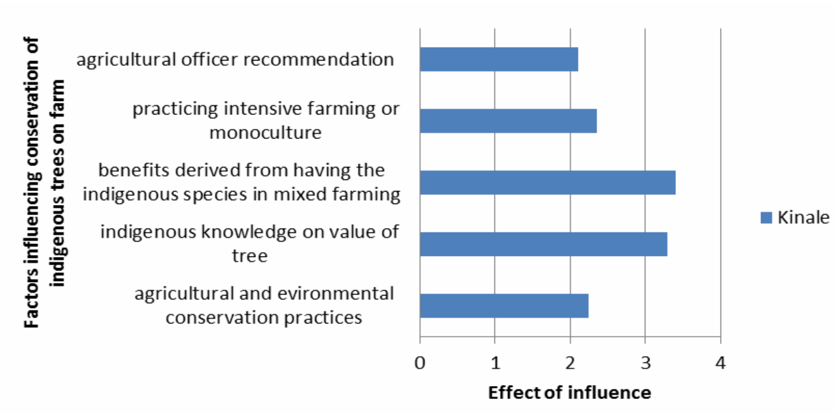


Figure 4. Degree of influence of factors affecting conservation of indigenous trees on farm in Kinale Ward, Lari Sub-county, Kenya

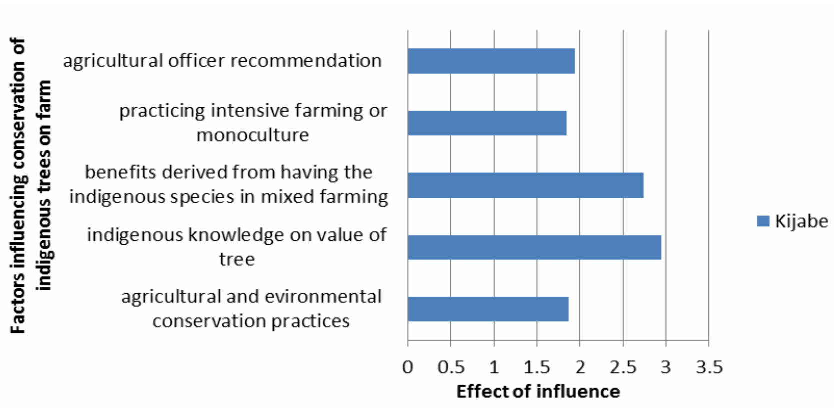


Figure 5. Degree of influence of factors affecting conservation of indigenous trees on farm in Kijabe Ward, Lari Sub-county, Kenya

Table 7. Level of education of respondents conserving indigenous trees in Lari Sub-county, Kenya

	Educational level of household						
Highest level of education	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

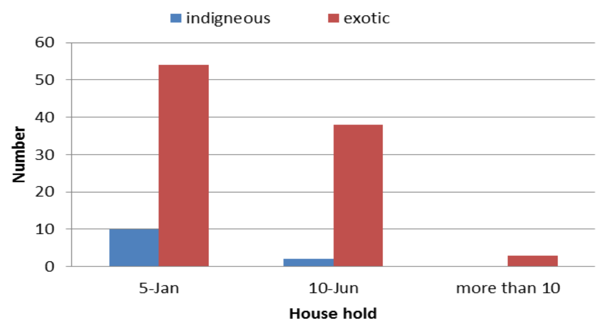


Figure 6. Household size and agricultural intensification

Influence of education levels on indigenous tree species diversity

Behavior change in different communities is primarily influenced by the level of education of the constituents. In Lari Sub-county, major household heads had a moderate education 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. From Table 7, those household heads with no or low education levels conserved 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

The household size in both Kinale and Kijabe ranged from 1 to 10 persons per household. This number depicted the actual number of members living in the households during the study period. 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 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 Boserup's theory on population 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 household sizes. The higher the household size the less the conservation of indigenous trees.

Uses of indigenous trees vs exotic

There were various uses of indigenous trees documented 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 *Octea usambarensis*. These trees can be used to treat diarrhea, 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* make 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 thonningii* (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 landholdings 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.

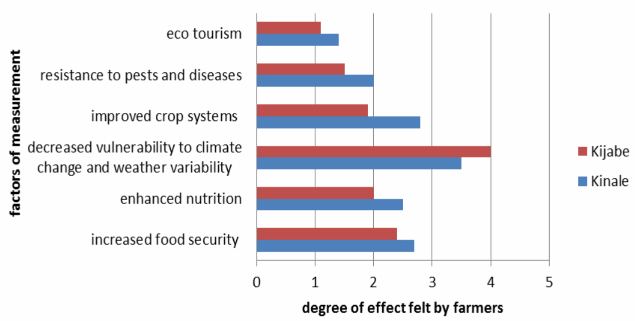


Figure 7. Benefits of indigenous trees on farm in Kinale and Kijabe Wards, Lari Sub-county, Kenya

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 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, entrepreneurism and job creation in rural communities through commercialization.

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

Indigenous trees were still retained in Lari Sub-county and the reasons for this are attributed to their effect on the environment as a buffer for food security and decreased vulnerability to climate change. They were also retained due to major efforts that have been put in place by the Ministry of Agriculture through agricultural extension officers. Residents in Lari recognized that there are very many benefits from indigenous trees, ranging from medicinal to timber, and it is important to preserve these trees for future generations. This study, therefore, recommends sensitization campaigns among the farming community to promote indigenous tree conservation so as to contribute towards the country's 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. DOI: 10.18174/njas.v45i2.521

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: 867249. 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.

ASIAN JOURNAL OF FORESTRY
Volume 1, Number 2, December 2017
Pages: 64-69
E-ISSN: 2580-2844
DOI: 10.13057/asianjfor/r010202

Trends of land cover change in a key biological corridor in Central Nepal

KRIPA NEUPANE[1,♥], AMBIKA P. GAUTAM[1], ARUN REGMI[2]
[1]Kathmandu Forestry College, Tribhuvan University. Kathmandu, Nepal. ♥email: nr.kripa@gmail.com
[2]Department 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.* Monitoring changes in biophysical features of the earth is useful to assess the impacts of human activities on the environment. This effort is essential to evaluate, for example, the outcome of policy implementation. This study analyzed changes in land cover in one of the key biological corridors in Central Nepal, the Barandabhar Corridor located in Chitwan District, during the last two decades (i.e. 1991 to 2013). The study used satellite imageries (Landsat 5 TM of 1991 and Landsat 8 OLI_TIRS of 2013) and the results were cross-checked with primary data collected from the field to investigate the drivers of land cover change. 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. The implementation of community-based forest management programs, decreasing dependency of local communities on forest resources, and increasing awareness in conservation 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 an alarming rate. The concern on this issue has increased research on global environmental change (Lambin et al. 2003). Land cover change analysis has been recognized as a key proxy for identifying the impact of change on the environment and associated ecosystems (Turner et al. 1995; William et al. 1994). Land cover change occurs because of human activities and/or natural processes. Land use practices, such as agricultural expansion, infrastructure developments, deforestation and encroachment, 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) are also considered as other major driving forces of land cover change.

Remote sensing and Geographic Information Systems (GIS) are the most feasible and efficient tools to monitor land cover change, both spatially and temporally (Lambin et al. 2003; Serra et al. 2008). Satellite imageries have been widely used to detect physical features and natural resource dynamics over time (Balla et al. 2007) along with the visual assessment that occurs at a particular time and place (Awasthi 2004). Analysis of satellite images of the same area taken at different times is a widely used method for determining the temporal dynamics of land use (Mulders 2001).

Since the past two decades, the trends in using satellite remote sensing data to detect earth features have been considerably increasing 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 and land cover change, deforestation, and forest degradation using remote sensing data.

The Barandabhar Corridor is the only remaining natural forest that connects the Chitwan National Park (CNP) and Siwalik Range with the Mahabharat Range (Dhakal and Yadava 2011). The existence of this corridor is important to facilitate the endangered one-horned rhinoceros (*Rhinoceros unicornis*), Royal Bengal tiger (*Panthera tigris tigris*), and many other species of wild animals and birds to move to refuge areas 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 with a rich diversity of flora and fauna (Joshi 2002; Bennett 2004). However, the anthropocentric pressures on Barandabhar Corridor have increased substantially (Thakur 2012), resulting in deforestation, destruction of natural habitats and conversion of the forested area into agricultural land (Shrestha 2001).

Studies of land cover change in Barandabhar Corridor are lacking and such studies only 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 assess land cover changes in Barandabhar Corridor in the past two decades (1991-2013) along with the driving forces of such changes.

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. It has coordinates of 27°33'30" to 27°44'30"N Latitude and 84°22'30" to 84°34'00"E Longitude (Figure 1) and covers 11,155.77 hectares (ha). The elevation ranges from 172 m to 390 m above sea level. The climate is subtropical with distinct winter (November-February), spring (May-September) and monsoon (June-September) seasons. The average annual rainfall is 2000 mm 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 user 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 user groups (CNP 2013). Sal (*Shorea robusta*) is the dominant tree species throughout the corridor forest. Riverine, tall grassland and short grassland occupy 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).

Agriculture represents the main source of livelihood of the local people (CBS 2012). The local inhabitants comprise many ethnic groups, including Brahmin, Chhetri, Tharus, and other ethnic groups. Most of the people are migrated to this area from the hilly regions of Nepal.

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 to create a spatial database and classify 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 using a stratified random sampling method for the questionnaire survey. Focus group discussion was conducted with different communities and user groups.

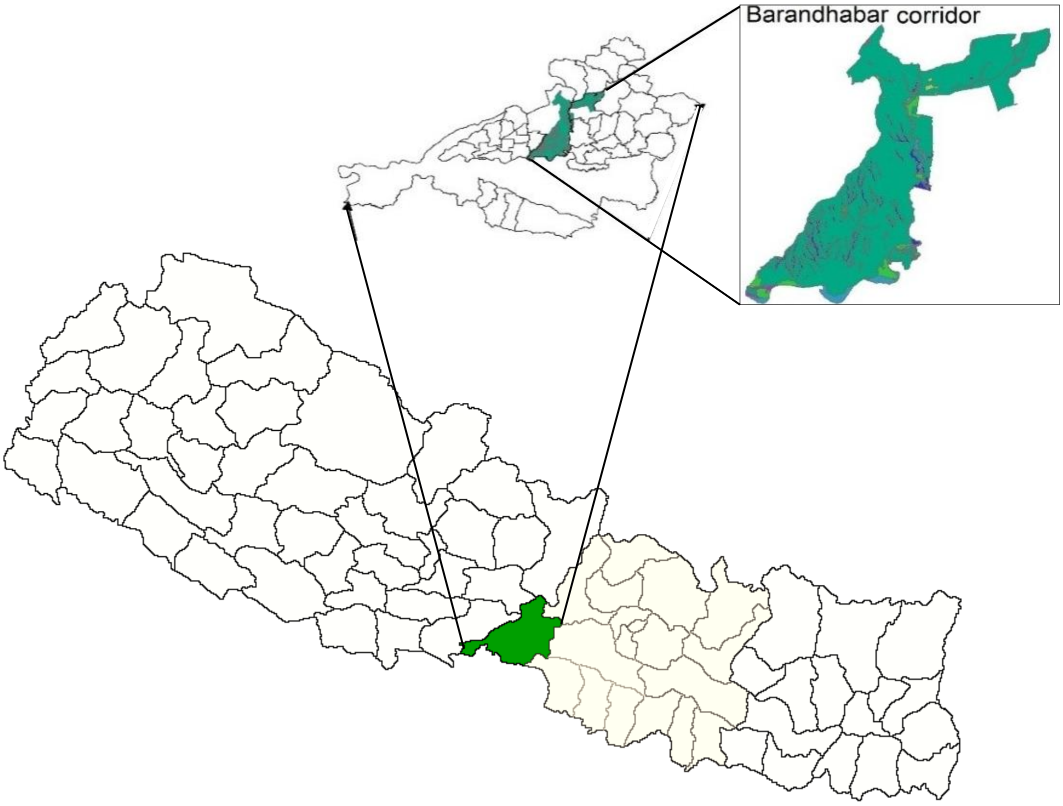


Figure 1. Map of the study area in the Barandabhar Corridor, Chitwan District, Nepal

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 Land Use and Land Cover (LULC) class 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 to produce land cover maps and to detect 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 was 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

By comparing 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). A similar trend was observed in the previous land use and land cover (LULC) 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		1991		Change		Rate of Change
	Area (ha)	% cover	Area (ha)	% cover	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			

Factors contributing to the changes in land cover

The 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 has reduced the biotic pressure on the corridor forest, contributing to forest cover increase.

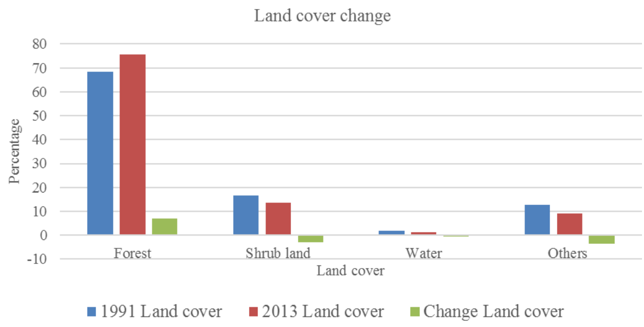


Figure 2. Land cover change during 1991 and 2013 in the Barandabhar Corridor, Chitwan District, Nepal

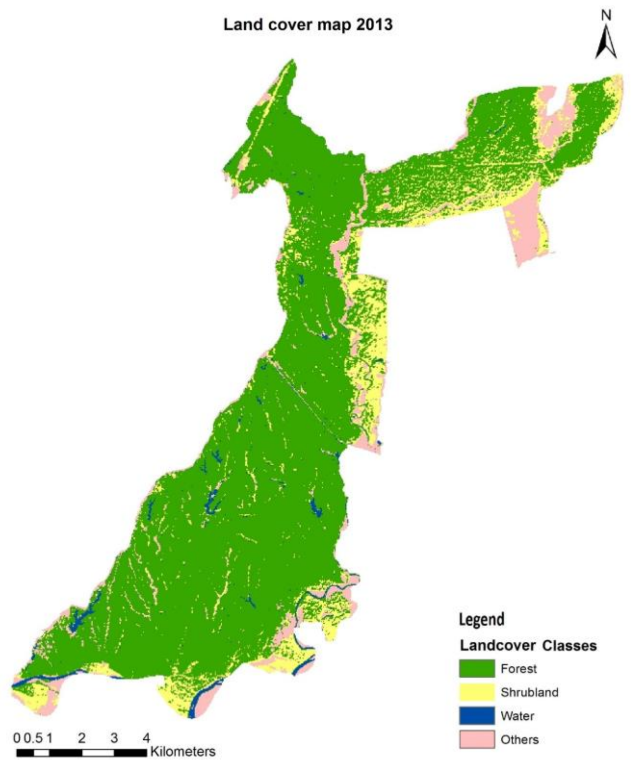


Figure 4. Land cover of the Barandabhar Corridor, Chitwan District, Nepal in 2013

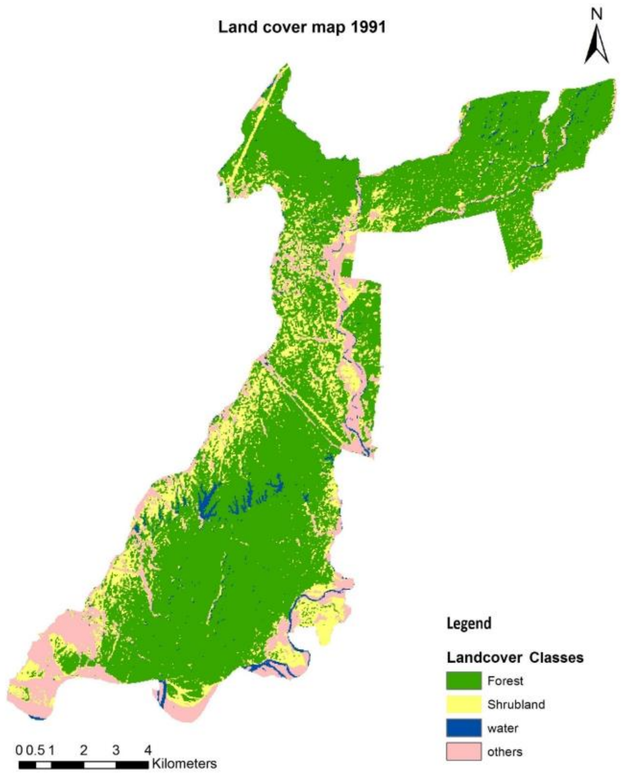


Figure 3. Land cover of the Barandabhar Corridor, Chitwan District, Nepal in 1991

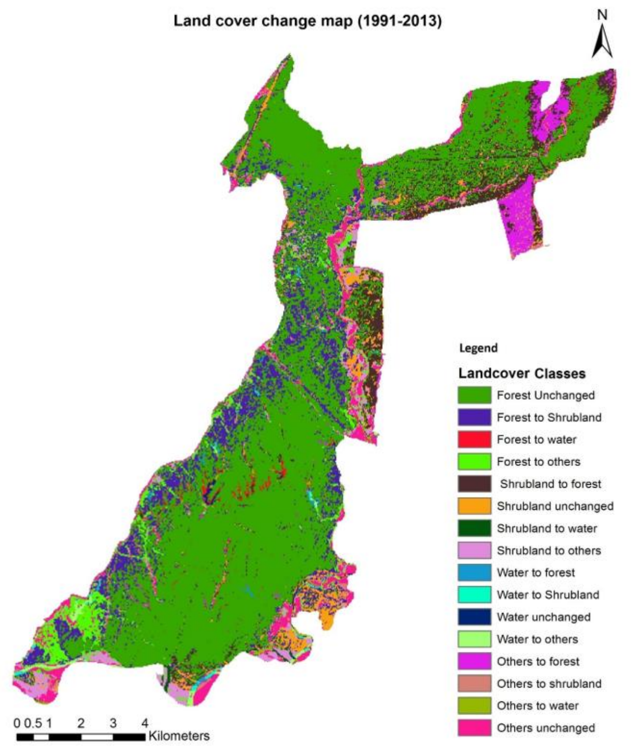


Figure 5. Land cover change map (1991-2013) of the Barandabhar Corridor, Chitwan District, Nepal

Furthermore, the control in grazing by the CFUGs and the 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 BZFUGs on degraded forestlands, barren lands, and grasslands with external assistance has contributed to the forest cover increase. Various 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 has had 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 stratiotes* (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 riverbeds 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 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. On the 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 corridors 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 forest regeneration, resulting in dense forest cover. On the other hand, expansion of invasive alien plant species, sedimentation, changes in the flow of Rapti River, infrastructure 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. DOI: 10.1177/194008291200500105

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.

Balla M, Awasthi K, Shrestha P, Sherchan 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

Balla M, Awasthi K, Singh B, Sitaula B, Pradhan B. 2007. Land Use Changes and Geomorphometric Analyses in Galaundu and Pokhare Khola Watersheds in Mid-hill Region of Nepal. Intl J Ecol Environ Sci 33 (2-3): 171-182.

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 3 (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. DOI: 10.1080/02723646.2001.10642750

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. DOI: 10.1016/S0167-8809(03)00148-8

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. DOI: 10.1641/0006-3568(2002)052[0143:PCAUDF]2.0.CO;2

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. DOI: 10.1146/annurev.energy.28.050302.105459

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. DOI: 10.1016/S0303-2434(01)85015-7

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. DOI: 10.1016/j.foreco.2008.07.023

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. DOI: 10.3126/njst.v9i0.3174

Serra P, Pons X, Saurı´ 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. DOI: 10.1016/j.apgeog.2008.02.001

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. DOI: 10.1007/BF01094100

ASIAN JOURNAL OF FORESTRY
Volume 1, Number 2, December 2017
Pages: 70-76

E-ISSN: 2580-2844
DOI: 10.13057/asianjfor/r010203

Short Communication: Survival and growth of monoculture and mixed-species plantations on the Coromandel coast of India

MUNYSAMY ANBARASHAN♥, ANBARASHAN PADMAVATHY, RAMADOSS ALEXANDAR
Department of Ecology and Environmental Sciences, Pondicherry University. Puducherry, India. ♥email: anbupu@gmail.com

Manuscript received: 19 November 2017. Revision accepted: 7 December 2017.

Abstract. *Anbarashan M, Padmavathy A, Alexandar R. 2017. Short Communication: Survival and growth of monoculture 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 in the tropics, and when it is compared to monoculture plantations. The aim of this study was to compare the variation in growth parameters between the mixed-species plantation and mono species plantation. The survival and growth in terms of height and girth 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% survival rate. When it is compared to the monoculture 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 (R^2 0.759). Plantations of *Casuarina equisetifolia* seem to be well adapted to the coastal region, especially in the Coromandel coast of India. On the other hand, mixed plantations with autochthonous species would contribute more to sustainable management because they provide a greater range of ecological goods and ecosystem services than single-species plantations.

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

INTRODUCTION

In tropical countries, there is an increasing interest in establishing mixed autochthonous species plantations for a wide range of economic, silvicultural and sustainability objectives (Nguyen et al. 2016). This is in contrast to the dominance of monoculture plantation at an industrial scale practiced in the sub-tropics and temperate regions, largely because of the association with economic benefits. Mixed plantation systems provide a broader range of options for the restoration of degraded areas, protection and biodiversity conservation (Montagnini et al. 1995; Keenan et al. 1995; Guariguata et al. 1995; Parrotta and Knowles 1999). For example, Vietnam, China, and the Philippines encourage landholders to plant a mixture of tree species in their national reforestation programs (Lamb et al. 2005; Herbohn et al. 2014).

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 mitigated and more resilient forests can be developed when mixtures of different species with different traits are established (Rodrigues et al. 2011). Lamb and Lawrence (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 in ecological management and 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 forests and their diversity (Vivek et al. 2016).

In the prediction of forest dynamics, 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 is indicated by its 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 plant functional traits (Baker et al. 2004; Nguyen et al. 2016).

However, the success of the establishment of mixed-species 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 in the tropics, and on the comparison between mono and mixed-species plantations. Therefore, this study aimed to determine the growth and survival of 82 autochthonous species in the mixed plantations in the coastal sand dunes compared with *Casuarina equisetifolia* monoculture 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-species plantations 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. The mean annual maximum and minimum temperatures are 33ºC and 24.5ºC. The mean annual rainfall is 1282 mm year with a six-month dry period (2006 to 2016). In general, coastal sandy soils with poor nutrients prevail in the region.

Preparation of plant materials

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.

Research design

A total of 2055 individuals of 82 autochthonous tree species and 1500 individuals of *Casuarina equisetifolia* were planted on two hectares in 2006. Table 1 shows 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.

Table 1. List of species observed in this study with families and ecological importance

Species	Family	Ecological values
Mixed species		
Aegle marmelos (L.) Correa	Rutaceae	Medicinal, economic
Aglaia elaeagnoidea (Juss.) Benth.	Meliaceae	Ecological
Alangium salvifolium (L.f.) Wangerin	Alangiaceae	Medicinal
Albizia amara (Roxb.) Boivin	Mimosaceae	Medicinal, commercial
Atalantia monophylla (L.) Correa	Rutaceae	Medicinal, ecological
Azadirachta indica A. Juss.	Meliaceae	Medicinal, cultural
Barringtonia acutangula (L.) Gaertner	Barringtoniaceae	Ecological
Bauhinia purpurea Lam.	Leguminosae	Medicinal
Bauhinia racemosa Lam.	Leguminosae	Timber, ecological
Benkara malabarica (Lam.) Tirven.	Rubiaceae	Ecological
Calophyllum inophyllum L.	Calophyllaceae	Medicinal
Calotropis gigantea L.	Apocynaceae	Medicinal, cultural
Carmona retusa (Vahl) Masm	Boraginaceae	Ecological
Canthium dicoccum (Gaertn.) Merr.	Rubiaceae	Medicinal
Cassia auriculata L.	Fabaceae	Medicinal
Cassia fistula L.	Fabaceae	Ecological
Cassine glauca Rottb. Kuntze.	Celastraceae	Ecological
Chloroxylon swietenia DC.	Rutaceae	Timber
Coccoloba uvifera L.	Polygonaceae	Fruit, ecological
Commiphora berryi (Arn.) Engl.	Burseraceae	Ecological
Dalbergia latifolia Roxb.	Fabaceae	Timber
Delonix elata Gamble.	Fabaceae	Medicinal, aesthetic
Diospyros ebenum J. Koenig ex Retz.	Ebenaceae	Timber

Diospyros ferrea (Willd.) Bakh.	Ebenaceae	Ecological
Diospyros montana Roxb.	Ebenaceae	Ecological
Dolichandrone falcata Seem.	Bignoniaceae	Ecological
Drypetes sepiaria (Wight and Arn.) Pax and Hoffm.	Euphorbiaceae	Ecological
Ehretia pubescens Benth.	Boraginaceae	Ecological
Erythrina indica L.	Fabaceae	Medicinal
Eugenia bracteata (Willd.) Roxb. ex DC.	Myrtaceae	Ecological
Ficus benghalensis L.	Moraceae	Cultural, medicinal
Ficus hispida Lf.	Moraceae	Medicinal
Ficus religiosa L.	Moraceae	Cultural, medicinal
Garcinia spicata (Wight and Arn.) J.D. Hook.	Clusiaceae	Ecological
Glycosmis mauritiana (Lam.) Tanaka	Rutaceae	Fruit, ecological
Gliricidia sepium (Jacq.) Kunth ex Walp.	Fabaceae	Medicinal
Gmelina asiatica L.	Verbenaceae	Medicinal, aesthetic
Helicteres isora L.	Malvaceae	Medicinal, aesthetic
Holoptelea integrifolia Planch.	Ulmaceae	Timber
Ixora pavetta T. Anderson	Rubiaceae	Cultural, aesthetic
Lawsonia inermis L.	Lythraceae	Cultural, medicinal
Lepisanthes tetraphylla (Vahl.) Radlk.	Anacardiaceae	Cultural
Limonia acidissima L.	Rutaceae	Cultural, medicinal
Madhuca longifolia (L.) Macbr.	Sapotaceae	Oil, cultural
Maerua oblongifolia Forssk.	Capparaceae	Ecological
Mallotus rhamnifolius Muell.-Arg.	Euphorbiaceae	Cultural, aesthetic
Manilkara hexandra (Roxb.) Dubard	Sapotaceae	Fruit, ecological
Melia azedarach L.	Meliaceae	Medicinal
Memecylon umbellatum Burm.f.	Melastomataceae	Ecological, aesthetic
Mimusops elengi L.	Sapotaceae	Medicinal, cultural
Mitragyna parviflora (Roxb.)Korth.	Rubiaceae	Timber
Murraya paniculata (L) Jack	Rutaceae	Aesthetic
Ochna obtusata DC.	Ochnaceae	Ecological, aesthetic
Ormocarpum sennoides (Willd.)DC.	Leguminosae	Medicinal
Pamburus missionis (Wight) Swingle	Rutaceae	Ecological
Pandanus oddaratissimus L.f.	Pandanaceae	*Ecological*
Phyllanthus reticulatus Poir.	Euphorbiaceae	Ecological, medicinal
Pleiospermium alatum (Wall. ex Wight. & Arn.) Swingle	Rutaceae	Ecological, medicinal
Polyalthia suberosa (Dunal) Thw.	Annonaceae	Ecological, aesthetic
Pongamia pinnata (L.) Pierre	Fabaceae	Oil, cultural
Pterocarpus marsupium Roxb.	Combretaceae	Timber, medicinal
Pterospermum canescens Roxb.	Sterculiaceae	Ecological
Pterospermum xylocarpum (Gaertn.) Sant. & Wagh.	Sterculiaceae	Ecological
Salacia chinensis L.	Celastraceae	Medicinal
Salvadora persica L.	Salvadoraceae	Medicinal, economic
Sapindus emarginatus Vahl	Sapindaceae	Medicinal, economic
Streblus asper Lour.	Moraceae	Ecological
Strychnos nux-vomica L.	Loganiaceae	Medicinal
Strychnos potatorum Lf.	Loganiaceae	Ecological, medicinal
Suregada angustifolia (Baill. ex. Muell-Arg.) Airy Shaw	Meliaceae	Ecological
Syzygium cumini (L.) Skeels	Myrtaceae	Medicinal, fruit
Tarenna asiatica (L.) Kuntze.	Rubiaceae	Medicinal, cultural
Terminalia arjuna (DC.) Wight & Arn.	Combretaceae	Medicinal, timber
Terminalia bellirica (Gaertner) Roxb.	Combretaceae	Medicinal, timber
Terminalia catappa L.	Combretaceae	Ecological, fruit
Thespesia populnea (L.)Sol.	Malvaceae	Timber, cultural
Tricalysia sphaerocarpa (Dalz.) Gamble	Rubiaceae	Timber, cultural
Vitex leucoxylon Lf.	Lamiaceae	Timber, ecological
Vitex negundo L.	Lamiaceae	Medicinal, cultural
Walsura trifolia (A..Juss.) Harms	Rubiaceae	Ecological
Wrightia tinctoria (Roxb.) R.Br.	Apocynaceae	Medicinal
Ziziphus mauritina Lam.	Rhamnaceae	Ecological
Monoculture plantation		
Casuarina equisetifolia L.	Casuarinaceae	Fuel wood

RESULTS AND DISCUSSION

Measurements in the mixed-species plantation at 10 years of age showed that *Albizia amara*, *Lepisanthes tetraphylla*, *Diospyros ferrea*, *Eugenia bracteata*, *Mimusops elengi*, *Sapindus emarginata*, and *Terminalia bellerica* exhibited the highest rate of survival (100%), followed by *Wrightia tinctoria*, *Mitragyna parviflora*, *Streblus asper*, *Pleiospermium alatum*, *Gmelina asiatica*, *Ixora pavetta* and *Coccoloba uvifera* showing 99% of the survival rate (Table 2). In total, 19 species were not survived for over a decade. No species exhibited significant differences ($P < 0.05$) in survival between the mixed species and monoculture plantation plots. Species such as *Bauhinia purpurea*, *Benkara malabarica*, *Calophyllum inophyllum*, *Limonia acidissima*, *Polyalthia suberosa*, *Pterospermum xylocarpum*, *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 missionis* and *Pterocarpus marsupium* demonstrated less than 20% survival rates. Comparing monoculture to mixed-species plantations, in general, species in the monoculture plantation demonstrated better survival rates. Notably, in the single species plot, *Casuarina equisetifolia* exhibited high survival and growth rates. 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 pests 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 that environmental conditions may have strong effects 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 later after some pioneer plants or extant nurse trees.

In the mixed-species plantation, the measurements taken at 10 years intervals 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 monoculture and mixed autochthonous species plantations. In the monoculture plantation, *C. equisetifolia* showed moderate growth of height and girth. Simple linear regression between annual girth increment and height produced very strong positive relation (R^2 0.759) (Figure 1).

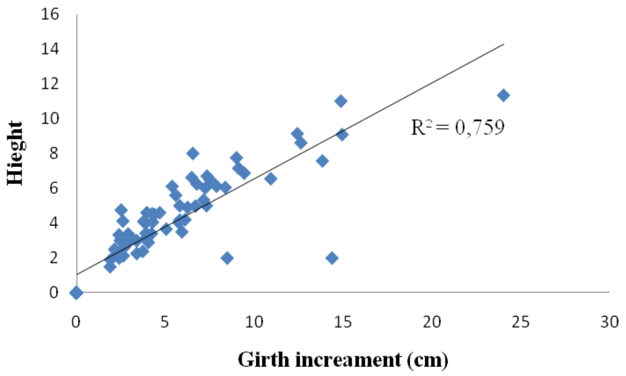


Figure 1. Simple linear regression between annual girth increment and average height of mixed-species plantation (2 ha).

Table 2. Number of individuals of each species with survival and growth rate after 10 year period of intervals

Species	Planted in 2006	Survived 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 elaeagnoidea (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±4.608
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

Canthium 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. Kuntze.	30	28	6.275±3.750
Chloroxylon swietenia DC.	10	2	4.4±1.414
Coccoloba uvifera L.	30	29	5.786±4.142
Commiphora berryi (Arn.) Engl.	100	81	7.907±3.142
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 sepiaria (Wight and Arn.) Pax and Hoffm.	28	26	3.419±1.808
Ehretia pubescens Benth.	10	0	0
Erythrina indica 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.) Tanaka	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
Ixora 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
Limonia acidissima 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 azedarach 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
Mitragyna parviflora (Roxb.)Korth.	15	15	4.233±2.135
Murraya paniculata (L) Jack	10	7	2.471±0.449
Ochna obtusata DC.	10	7	7.525±3.224
Ormocarpum sennoides (Willd.)DC.	10	1	3.4
Pamburus missionis (Wight) Swingle	5	0	0
Pandanus oddaratissimus L.f.	10	9	3.177±0.440
Phyllanthus reticulatus Poir.	20	0	0
Pleiospermium alatum (Wall. ex Wight. & Arn.) Swingle	100	88	8.396±5.134
Polyalthia suberosa (Dunal) Thw.	5	0	0
Pongamia pinnata (L.) Pierre	5	0	0
Pterocarpus marsupium Roxb.	5	1	8.5
Pterospermum canescens Roxb.	50	42	7.269±4.281
Pterospermum xylocarpum (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±4.617
Tarenna asiatica (L.) Kuntze.	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
Tricalysia sphaerocarpa (Dalz.) Gamble	5	3	2.4±0.866
Vitex leucoxylon Lf.	15	14	13.864±5.607
Vitex negundo L.	10	8	9.025±2.100
Walsura trifolia (A..Juss.) Harms	50	48	4.29±4.16
Wrightia tinctoria (Roxb.) R.Br.	70	69	9.146±3.860
Ziziphus mauritina 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 in the mixed-species plots. When compared to the monoculture plantation, it showed highly significant differences (P < 0.05) values. In the monoculture 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. *Casuarina equisetifolia* had the highest basal area, showing significant differences (P < 0.05) compared to all species and the mixture of autochthonous species plantations. The present study revealed that the variation in 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 factors, plant growth process, internal growth property, and physiological process. On the other hand, the soil parameters, microclimatic factors, and response plants 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 monoculture 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 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 result 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 monoculture plantations.

ACKNOWLEDGEMENTS

The 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, Singhakumara 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. DOI: 10.1016/S0378-1127(01)00512-6.

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. DOI: 10.1111/j.1365-2486.2004.00751.x.

Benayas JMR, Newton AC, Diaz A., Bullock JM. 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. Science 325: 1121-1124. DOI: 10.1126/science.1172460.

Butterfield R. 1996. Early species selection for tropical reforestation: a consideration of stability. For Ecol Manag 81: 161-168. DOI: 10.1016/0378-1127(95)03649-0.

Calvo-Alvarado JC, Arias D, Richter DD. 2007. Early growth performance of autochthonous and introduced fast-growing tree species in wet to sub-humid climates of the Southern region of Costa Rica. For Ecol Manag 242: 227-235. DOI: 10.1016/j.foreco.2007.01.034.

Corlett RT. 1999. Environmental forestry in Hong Kong: 1871-1997. For Ecol Manag 116: 93-105. DOI: 10.1016/S0378-1127(98)00443-5.

Forrester DI, Theiveyanathan S, Collopy JJ, Marcar NE. 2010. Enhanced water use efficiency in a mixed Eucalyptus globulus and Acacia mearnsii plantation. For Ecol Manag 259 (9): 1761-1770. DOI: 10.1016/j.foreco.2009.07.036.

Guariguata MR, Rheingans R, Montagnini F. 1995. Early woody invasion under tree plantations in Costa Rica: implications for forest restoration. Restor Ecol 3: 252-260. DOI: 10.1111/j.1526-100X.1995.tb00092.x.

Herbohn JL, Vanclay J, Nguyen H, Le HD, Baynes JR, Harrison S, Cedamon E, Smith C, Firn J, Gregorio NO, Mangaoang E, Lamarre E. 2104. Inventory Procedures for Smallholder and Community Woodlots in the Philippines: Methods, Initial Findings and Insights. Small-scale For 13: 79-100. DOI: 10.1007/s11842-013-9242-6.

Hooper DU, Chapin FS, Ewel JJ, Hector A, Inchausti P, Lavorel S, Lawton JH, Lodge DM, Loreau M, Naeem S, Schmid B, Setälä H, Symstad AJ, Vandermeer J, Wardle DA. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecol Monogr 75: 3-35. DOI: 10.1890/04-0922.

Hung TD, Herbohn JL, Lamb D, Nhan HD. 2011. Growth and production varies between pair-wise mixtures and monoculture plantations in North Viet Nam. For Ecol Manag 262 (3): 440-448. DOI: 10.1016/j.foreco.2011.04.010.

Keeling HC, Baker TR, Martinez RV, Monteagudo A, Phillips OL. 2008. Contrasting patterns of diameter and biomass increment across tree functional groups in Amazonian forests. Oecologia 158: 521-534. Doi: 10.1007/s00442-008-1161-4.

Lamb D, Erskine PD, Parrotta JA. 2005. Restoration of degraded tropical forest landscapes. Science. 310 (5754): 1628. DOI: 10.1126/science.1111773.

Lamb D, Lawrence P. 1993. Mixed species plantations using high-value rainforest trees in Australia. In: Lieth, H., Lohmann, M. (Eds.), Restoration of Tropical Forest Ecosystems. Kluwer Academic Publishers, Nederland.

Lawson SS, Michler CH. 2014. Afforestation, restoration and regeneration — Not all trees are created equal. J For Res 25 (1): 3-20. DOI: 10.1007/s11676-014-0426-5.

Le Maire G, Nouvellon Y, Christina M, Ponzoni FJ, GoncËalves JLM, 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. DOI: 10.1016/j.foreco.2012.03.005.

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. DOI: 10.1016/j.foreco.2010.08.019.

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. DOI: 10.1007/s10310-009-0136-6.

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. DOI: 10.1016/S0169-5347(01)02117-6.

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. DOI: 10.1371/journal.pone.0164957.

Nichols JD, Bristow M, Vanclay JK. 2006. Mixed-species plantations: Prospects and challenges. For Ecol Manag 233 (23): 383-390. DOI: 10.1016/j.foreco.2006.07.018.

Park A, van Breugel M, Ashton, PMS, Mariscal E, Deago J, Ibarra D, Cede˜no 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. DOI: 10.1016/j.foreco.2010.03.021.

Parrotta JA, Knowles OH. 1999. Restoration of Tropical Moist Forests on Bauxite-Mined Lands in the Brazilian Amazon. Restor Ecol 7 (2): 103-116. DOI: 10.1046/j.1526-100X.1999.72001.x

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. DOI: 10.1093/forestry/cpt050.

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. DOI: 10.1139/x05-280.

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. DOI: 10.1016/j.jspi.2009.04.014.

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. DOI: 10.1016/j.foreco.2010.07.005

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, KoÈrner 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. Doi: 10.1007/s11056-013-9393-5.

Semwal RL, Nautiyal 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. DOI: 10.1016/j.foreco.2013.08.023.

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. DOI: 10.1126/science.315.5815.1070

ASIAN JOURNAL OF FORESTRY
Volume 1, Number 2, December 2017
Pages: 77-82

E-ISSN: 2580-2844
DOI: 10.13057/asianjfor/r010204

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

Manuscript received: 21 November 2018. Revision accepted: 26 December 2017.

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 the country that have several benefits for society. It constitutes various social, economic, and other uses. This review identified that forests are an important part of the environment and economy of a nation. When managed well, forests provide clean air and water, homes for wildlife, beautiful scenery, places for recreation and more than 5,000 products that are used every day. Forest resources and forest lands should be managed and used on sustainable basis to fulfill the social, economic, cultural and spiritual needs of the present and future generations. 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 some constraints in forest conservation and management, including addressing poverty and forest governance by promoting forest ownership and access rights; promoting greater recognition of the rights of local and indigenous groups; and giving greater attention to land tenure, ownership, and rights-to-resource. Conversely, the greatest opportunities in forest management lie in forest and land restoration.

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

INTRODUCTION

Forests are home to at least 80 percent of the world’s remaining terrestrial biodiversity and are a major carbon sink to mitigate 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.

Forests contribute to the livelihoods of more than 1.6 billion people globally. Forests and forest products industries are important sources of economic growth and employment, with the value of global forest products traded internationally 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. Covering 26 percent of the Earth's land surface, forests play a significant role in realizing the Millennium Development Goals (MDGs) of halving the number of people living in absolute poverty by 2015. 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).

Unfortunately, rural development strategies often neglect forests because forests have been mistakenly viewed as being outside the mainstream of agricultural development. This situation is worsened by the increasing rate of destruction of remaining forests across the world. The continuing global deforestation and degradation threaten biodiversity, forest-related ecological services, and rural livelihoods.

Multiple-use forest management (MFM) for timber, non-timber forest products, and environmental services is envisioned by many as a preferable alternative to timber-focused regime. It is praised as a more equitable strategy of satisfying the demands from multiple stakeholders, ecologically more friendly harvesting approach, and a way of adding more value to forests. 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 the country. It is one of the natural resources that have several benefits for 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). Forest land is also important for watershed protection, soil and water conservation, wildlife conservation and recreational value (Eshetu 2004). This paper review forest management and conservation in Ethiopia with focus on the constraints and opportunities in the practice.

FOREST RESOURCE MANAGEMENT AND ITS PURPOSES

Forest resources provide 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 on sustainable basis to fulfill the social, economic, cultural and spiritual needs of the present and future generations. By its nature, forestry is concerned with maintaining the quality of various non-market benefits (Wang 2004).

Many tropical forests have been fragmented into small patches, and forest structure and regeneration have been disturbed due to this fragmentation (Cabin et al. 2002). Human-induced disturbances, mainly via 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.

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.

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). 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 (Jylhä 2007).

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 systems (FAO 2006). The management system must be multiuse-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 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).

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 experts and low education level of the community to understand and promote the conservation and management policies.

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 of people "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 people 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 that 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 humans. Forests give us many things like fuel, food, wood, etc. in which are very important sources of energy. Forests are sources of food (Jackson and Baker 2010). Wild food is important for food security to 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, climate change policy is creating incentives to preserve and restore forests, while on the other hand 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 inadequate appreciation of the role and value of forest, and inadequate investment in forestry sector under the state plan, etc.

FOREST CONSERVATION

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). Threats to biodiversity from poor forest management practices are diverse and widespread. 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.

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 forms in the tropical, temperate and boreal zone of the world. 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 made the conservation and management activity very difficult (Fischer et al. 2010).

Management systems 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.

There are some emerging practices of forest conservation. For example, 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 and Todo 2013). Although Rainforest Alliances originally worked primarily with producers of larger plantations (Méndez et al. 2010), they 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). However, the significance of the conservation efforts of certification programs remains unclear because of a lack of empirical evidence.

CONSTRAINTS OF FOREST RESOURCES IN ETHIOPIA

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

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).

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 Tikkanen 2011). The high increase 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 problems. 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 forests among the community. They are not well-informed and convinced about the biological, ecological, social and economic importance of forests (Belcher 2005).

In Ethiopia, the poverty and forest governance problems need to be addressed by promoting forest ownership and access rights. This is to 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. In doing so, it is important to 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

The role of forests as an engine of economic growth and development needs to be enhanced. This can be done by increasing investments in plantations (especially in tropical countries), expanding forest certification and overall forest management, and encouraging responsible private sector investments, including community-company partnerships for on-site forest enterprise development, and for market access.

This is also essential to protect vital local and global environmental services and values. Furthermore, creating markets for local ecosystem services such as carbon storage might seize the potentially enormous financing opportunities emerging in the context of global climate change to increase investments for carbon sequestration and avoid deforestation to reduce emissions from deforestation and forest degradation.

In policy context, there is a gap in assisting countries to integrate the global forest agenda into their own national strategies and policies and to harness the development opportunities available. The World Bank's leadership position can be used 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. Integrating forest interdependencies into the design of agriculture, rural development, and natural resources rural poverty alleviation is also as important as the management projects to ensure sustainable economic growth.

OPPORTUNITIES OF FOREST RESOURCES IN ETHIOPIA

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 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 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 nontimber 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).

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 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 center on the negative effects of monocultures, i.e. low stability, low resource use efficiency, low level of biodiversity, the tendency to use exotics that were 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 points 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).

CONCLUSION AND RECOMMENDATION

In general anthropogenic (human-caused) and lack of goods management policy are the main constraints of forest resource management. 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 a 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. Intl For Rev 4 (3): 231-233.

Bardhan P. 1987. The new institutional economics and development theory. World Dev 17 (9): 1389-1395. DOI: 10.1016/0305-750X(89)90080-6

Beierle TC, Konisky DM. 2000. Values, conflict, and trust in participatory environmental planning. J Pol Anal Manag 19: 587-602. DOI: 10.1002/1520-6688(200023)19:4<587::AID-PAM4>3.0.CO;2-Q

Belcher BM. 2005. Forest product markets, forests and poverty reduction. Intl For Rev 7 (2): 82-89. DOI: 10.1505/ifor.2005.7.2.82

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. DOI: 10.1016/S0006-3207(01)00163-X

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, Chamela watershed, Mexico. Catena 65: 107-117. DOI: 10.1016/j.catena.2005.11.004

Dove MR. 1993. A revisionist view of tropical deforestation and development. Environ Conserv 20: 17-24. DOI: 10.1017/S0376892900037188

EFAP. 1994. The challenge for development report. Volume 2. Addis Abeba, Ethiopia.

Eshetu Z. 2004. N abundance in soils under young-growth forests in Ethiopia. For Ecol Manag 187: 139-47. DOI: 10.1016/S0378-1127(03)00315-3

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. DOI: 10.1126/science.1152747
Fischer AP, Bliss J, Ingemarson F, Lidestav G, Lo ¨nnstedt 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. DOI: 10.1080/02827581.2010.498386
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. DOI: 10.1088/1748-9326/3/3/034001
Hujala T, Jukka T. 2011. Change in forest planner ' S Advisory Role." Scandinavian J For Res 26: 466. DOI: 10.1080/02827581.2011.579996
Jackson RB, Justin SB. 2010. Opportunities and constraints for forest climate mitigation. Bioscience 60: 9: 698-707. DOI: 10.1525/bio.2010.60.9.7
Johnson N, Ravnborg HM, Westermann O, Probst K. 2002. Use participation in watershed management and research. Water Pol 3 (6): 507-520. DOI: 10.1016/S1366-7017(02)00014-4
Jylhä L. 2007. Forest management associations-Value from Cooperation for forest owners. Unasylva 58 (228): 44-47.
Kant S. 2003. Extending the boundaries of forest economics. For Pol Econ 5: 39-56. DOI: 10.1016/S1389-9341(02)00045-X
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. DOI: 10.1016/j.forpol.2005.11.003
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. DOI: 10.1007/s11842-006-0012-6
Leskinen P, Hujala T, Tikkanen J, Kainulainen T, Kangas A, Kurttila M. 2009. Adaptive decision analysis in forest management planning. For Sci 55: 95-108. DOI: 10.1093/forestscience/55.2.95
Mas AH, Dietsch TV. 2004. Linking shade coffee certification to biodiversity conservation: butterflies and birds in Chiapas, Mexico. Ecol Appl 14: 642-654. DOI: 10.1890/02-5225
Méndez VE, Bacon CM, Olson M, Morris KS, Shattuck A. 2010. Agrobiodiversity and shade coffee smallholder livelihoods: a review and synthesis of ten years of research in Central America. Prof. Geogr 62: 357-376. DOI: 10.1080/00330124.2010.483638
Pearce D, Putz FE, Vanclay JK. 2003. Sustainable forestry in the tropics: panacea or folly? For Ecol Manag 172: 229-247. DOI: 10.1016/S0378-1127(01)00798-8
Philpott SM, Bichier P, Rice R, Greenberg R. 2007. Field-testing ecological and economic benefits of coffee certification programs. Conserv Biol 21: 975-985. DOI: 10.1111/j.1523-1739.2007.00728.x
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. DOI: 10.1890/08-0645.1
Powers RF. 1999: On the sustainable productivity of planted forests. New For 17: 253-306. DOI: 10.1023/A:1006555219130
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, Gautam K, Hersch Martinez P, De Jong W, Kusters K, Kutty M, López C, Martinez FUM, Nair M,Ndoye TKR, Ocampo O, Rai R, Ricker N, Schreckenberg M, Shackleton K, Shanley S, Sunderland P, Youn Y. 2004. Markets drive the specialization strategies of forest peoples. Ecol Soc 9 (2): 4. DOI: 10.5751/ES-00655-090204
Sanoff H. 2000. Community participation methods in design and planning. John Wiley and Sons, New York.
Searchinger T, Heimlich R, Houghton RA, Dong F, Elobeid A, 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. DOI: 10.1126/science.1151861
Southgate DD, Graham D, Tweeten D. 2007. The World Food Economy. Wiley, New York.
Takahashi R, Yasuyuki 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. DOI: 10.1016/j.jenvman.2013.08.025
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. DOI: 10.1016/j.forpol.2004.03.004
WCED.1987. Our Common Future. Oxford University Press, Oxford.
WCFSD. 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. For Ecol Manag 256: 1468-1476. DOI: 10.1016/j.foreco.2008.04.029

ASIAN JOURNAL OF FORESTRY
Volume 1, Number 2, December 2017
Pages: 83-91
E-ISSN: 2580-2844
DOI: 10.13057/asianjfor/r010205

Ice Nucleation Active bacteria in Mount Lawu forest, Indonesia: 1. Isolation and estimation of bacterial populations on lichens

KHUSNUL FU'ADAH, SITI LUSI ARUM SARI, ARI SUSILOWATI♥
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret. Jl. Ir. Sutami 36A Surakarta 57126, Central Java, Indonesia. Tel./fax.: +62-271-663375, ♥email: arisusilowati@staff.uns.ac.id

Manuscript received: 19 October 2017. Revision accepted: 30 December 2017.

Abstract. *Fu'adah K, Sari SL, Susilowati A. 2017. Ice Nucleation Active bacteria in Mount Lawu forest, Indonesia: 1. Isolation and estimation of bacterial populations on lichens. Asian J For 1: 83-91.* Ice Nucleation Active (INA) bacterias cause frost injury in plants. These bacteria are also predicted to play an important role in bioprecipitation, cloud formation, and rain. Most INA bacteria studies are conducted in subtropical areas. Therefore, studies on INA bacteria from tropical areas, especially Indonesia, need to be conducted. This study aimed to isolate and determine the number of INA bacteria in lichenes. samples of lichenes were taken from the hiking pathway of Cemoro Sewu, Mount Lawu forest, Java, Indonesia, at ±2.200, ±2.400, and ±2.600 m asl. INA bacteria were isolated by the spread plate method on the NA medium with 2.5 % glycerol and King's B medium. A tube nucleation test determined ice nucleation activity. A multiple-tube nucleation test estimated the number of INA bacteria. The data were analyzed descriptively based on colony morphology, cell morphology, biochemical tests, and analysis of the numbers of INA bacteria. The result showed that 7 isolates from *Parmelia* sp. at an altitude of 2.532 m asl (station 2) have been known as INA bacterias. The number of INA bacteria in lichenes was 5 x 104/g, which was very low.

Keywords: Bioprecipitation, Ice Nucleation Active bacteria, lichens, Mount Lawu, number of bacteria

INTRODUCTION

Ice Nucleation Active (INA) bacteria is one of the bacteria that can be found on plant surfaces. The population of INA bacteria reached 106 cells/g in plant tissue (Lindow 1993). INA bacterial species are generally epiphytic in plants, and their presence on plant surfaces increases the likelihood of frost injury at temperatures above -5°C (Lindow et al. 1982). Most frost-sensitive plants will experience frost damage between -2 and -5ºC. When the water cools, it turns to ice between and within the cells, causing freeze damage.

INA bacteria can generally initiate ice core formation at temperatures above -10ºC. Some of these species can even form ice cores at -1.5ºC. INA bacteria can naturally initiate ice core formation due to the presence of ice core-forming substances (Lindow 1983). *Pseudomonas syringae* is the most widely distributed and studied INA bacterial species (Lindow 1983; Lindow 1990). The *P. syringae* expresses a certain type of protein on the cell surface, namely ice nucleation protein (INP), which increases the freezing temperature of the water. If there is no ice core, the cold water can become supercooled, and freezing will not occur until the temperature is low enough for the most active ice core to initiate cold water crystallization. Although ice-core activity in bacteria is limited to Gram-negative bacterial species, the presence of these species in plants and other natural habitats is an interesting general phenomenon (Gurian-Sherman and Lindow 1993).

According to Wahyudi (1995), ice cores in bacteria that are active at relatively warm temperatures (≥ -5ºC) have the potential to play an important practical role in making snow, changing weather, freezing certain types of food, and enabling their use to make artificial rain. Therefore, especially in freezing food, it is also necessary to consider bacteria carrying the ice+ gene to be classified as a safe group (Generally Recognized As Safe = GRAS).

In its current development, INA bacteria play a role in bioprecipitation, which can affect cloud and rain formation and climate. As aerosol particles, bacterial cells can act as cloud condensation nuclei to form raindrops. On a larger scale, INA bacteria have been studied in the atmosphere. According to research by Amato et al. (2007) and Morris et al. (2008), INA bacteria have been detected in the rain, snow, and the atmosphere. It suggests that INA bacteria can be propagated through the global water cycle and is an important part of precipitation initiation research.

The hiking pathway of Cemoro Sewu, Mount Lawu, is located on the southern slope of Mount Lawu, Java, Indonesia. According to Setyawan (2000), this location is the most fertile area in the Mount Lawu area because it is a rainwater catchment area. A cloudy southeast wind containing drops of water hits the mountain and is lifted up, causing condensation and drops of water to fall as rain. As a result, the south (southeast) slope gets relatively more rainfall throughout the year than the other slopes. Rainwater is a dominant factor for the growth of epiphytes because these plants generally live far from the soil surface, so the arrival of rain generally fulfills that water need.

The results of Samsali's research in 2008 showed 12 types of epiphytes found along the hiking pathway of Cemoro Sewu. These epiphytes consist of 4 from the

Lichenes division, 1 from the Bryophyta division, 5 from the Pteridophyta division, and 2 from the Spermathophyta division. A study by Kieft (1988) concluded that INA bacteria are found in various lichens in the southwestern United States. This condition allows a great opportunity to find INA bacteria and test their nucleation activity.

Most of the studies on INA bacteria were carried out in the subtropics, while there were very few reports of studies on INA bacteria in the tropics. Given the important role of INA bacteria and the practical use of these bacteria, as well as scientific applications, it is necessary to conduct a study on INA bacteria in tropical mountain areas, one of which is the hiking pathway of Cemoro Sewu, Mount Lawu.

The objectives of this study were: (i) obtaining isolates of INA bacteria from lichenes on the hiking pathway of Cemoro Sewu, Mount Lawu; (ii) determining the number of INA bacteria in lichenes on the hiking pathway of Cemoro Sewu, Mount Lawu.

MATERIALS AND METHODS

Materials

Lichens originated from the hiking pathway of Cemoro Sewu, Mount Lawu, Java, Indonesia. Lichens sampling was carried out on the hiking pathway of Cemoro Sewu. The sampling point is set at as many as three stations based on height differences, namely at an altitude of ± 2,200 m asl (Montana), ± 2,400 m asl (sub-alpine), and ± 2,600 m asl (sub-alpine). There were two sampling points at each station. Lichens are put into a sterile paper coated with plastic bags and immediately carried to the laboratory (<12 hours) for insulation or stored in a refrigerator at 5°C to be isolated for the next few days. Figure 1 shows the location of each station. Lichens identification is carried out using a reference book by van Steenis (1978).

Measurement of abiotic environmental factors

At each sampling point, several environmental factors are measured, namely:

Light intensity. Measurement of light intensity is done with a lux meter. The measurement distance was 50 cm above the ground surface. After 60 seconds of waiting, the size of the light intensity is recorded.

Air temperature and humidity. Measurement of air temperature and humidity is carried out with a hygrometer. The measurement distance was 50 cm above the ground surface. After 60 seconds of waiting, the air temperature and humidity were recorded.

Sterilization of tools and materials

Equipment and materials to be used to isolate must be sterilized in advance to prevent contamination. Equipment that must be sterilized includes petri dishes, test tubes, Erlenmeyer, tips, and Eppendorf tubes. The sterilized materials are aquades, King's B media, NAG media, and phosphate buffer. Wet sterilization is done using an autoclave at 121°C, with a pressure of 1 atm for 20 minutes.

The making of media

King's B (KB)

King's B Media was made by dissolving 20 g of protease peptone, 15 mL of glycerol, 1.5 g of K_2HPO_4; 1.5 g of $MgSO_4.7H_2O$; 20 g of agar in 1000 mL of distilled water. First, Erlenmeyer containing KB media was heated on a hotplate stirrer with a temperature of 350°C for 20 minutes. The clear media was then covered with cotton and coated with aluminum foil, and then it was sterilized using an autoclave at 121°C, with a pressure of 1 atm for 20 minutes. Next, sterile media was poured into each aseptic petri dish for as much as ± 15 mL. After the media was cold, then it was wrapped in paper and placed at room temperature for ± 2 days or until it was dry in an upside-down position with the above position for the media.

Nutrient agar and 2.5 % glycerol (NAG)

Six (6) g of Nutrient Agar was dissolved in 200 mL of distilled water and added 5 mL of glycerol. Erlenmeyer containing Na and glycerol was heated on the hotplate stirrer with a temperature setting of 350°C for 20 minutes. The clear media was then covered with cotton and coated with aluminum foil, and then it was sterilized using an autoclave at 121°C with a pressure of 1 atm for 20 minutes. Sterile media was poured as much as ± 15 mL in each aseptic petri dish. When it was cold, the media was wrapped in paper and placed at room temperature for ± 2 days, or until it was dry in an upside-down position, the media was above.

A B C

Figure 1. Lichens sampling location in Cemoro Sewu, Mount Lawu, Indonesia. A. Montane (sta. 1), B. Sub-alpine (sta. 2), C. Alpine (sta. 3)

To make tilted agar media, after the media became clear, 4 mL of it was poured into a test tube and covered with cotton, then sterilized using an autoclave at 121°C with a pressure of 1 atm for 20 minutes. Sterile media was tilted up to half of the tube. The media was placed at room temperature for ± 2 days or until it was dry. If not contaminated, the media was ready to use.

Phosphate buffer 0.1 M pH 7 and 0.1% peptone meat

Phosphate buffer was made with the composition of 0.6 g of $NaH_2PO_4.2H_2O$ and 1.6 g of $Na_2HPO_4.2H_2O$ dissolved in 1000 mL of distilled water. Then, it was added with 1 g of peptone meat. Furthermore, the phosphate buffer medium was sterilized using an autoclave at a temperature of 121°C with a pressure of 1 atm for 20 minutes.

Isolation and pure culture of INA bacteria

Each 5 g of lichens sample was cut into pieces with a size of about 5 cm^2. Then it was inserted into a 500 mL Erlenmeyer tube containing 200 mL of 0.1 M phosphate buffer with a pH of 7.0 with 0.1% peptone (Difco) (Lindow et al. 1978a). The Erlenmeyer tube containing the buffer solution and the Lichens sample was shaken on a rotary shaker at 150 rpm for 2 hours. Next, 1 mL of sample was taken and put in a test tube containing 9 mL of sterile distilled water. Furthermore, 3 series of dilutions were carried out, namely 10^{-1}, 10^{-2}, and 10^{-3}. Finally, 0.1 mL was taken from each dilution and then spread on NA media containing 2.5% glycerol (NAG) and King's B (KB) media using a spread plate technique. Each dilution series was spread over two petri dishes. After the surface of the media was dry, it was wrapped in paper and incubated at 18º-24ºC in an inverted position for 2 days (Lindow et al. 1982b). Colonies with different morphological appearances were then taken, purified on new media, and stored in a tilted media at 4ºC.

INA test

Ice nucleation activity was determined by the tube nucleation test method (Stephanie and Waturangi 2011). Bacterial colonies aged 4 to 6 days were transferred with an ose loop, suspended in 400 µL sterile phosphate buffer, and tested for ice nucleation activity at -10°C in a circulating alcohol bath for 5 minutes. The freezing of the phosphate buffer indicated a positive test result due to the presence of INA bacteria (Lindow et al. 1978a).

INA protein classification based on freezing temperature

One ose isolates positive for INA bacteria was suspended in 400 µL sterile phosphate buffer and tested for ice nucleation activity at -2°C to -10°C in a circulating alcohol bath (Lindow et al. 1978a).

Characterization of INA bacterial isolates

INA bacterial isolates were characterized based on colony morphology, cell morphology observations, and biochemical tests.

Colony morphological observations

Morphological observations were carried out, including observations of colony color, shape, edge, elevation, and size.

Cell morphological observations

Microscopic observation of bacterial cell morphology was carried out by Gram staining. Gram staining was carried out by taking the INA bacterial isolate aseptically, placing them on a sterile glass object, and then making them into suspension with a drop of sterile distilled water. Preparations fixed over the flame were stained with crystal violet for 1 minute and rinsed with water. Staining was continued with iodine for 2 minutes and rinsed again with water. Next, bleaching was carried out with 95% alcohol and rinsed with water. Then it was stained with safranin for 30 seconds. After washing and drying, observations were made with a microscope to see the type of gram and cell shape (Hadioetomo 1993).

Biochemical test

Biochemical tests carried out include the catalase test and oxidase test.

The catalase test was carried out to detect the presence of the catalase enzyme, which can convert hydrogen peroxide (H_2O_2) into water (H_2O) and oxygen (O_2). The INA bacterial isolate fixed on a glass object was added with one drop of 3% H_2O_2 solution. The gas formation was observed. Furthermore, it gave positive results if air bubbles appeared (Hadioetomo 1993).

An oxidase test was used to determine the oxidation ability in bacteria that produce oxidase enzymes. A total of one ose of the bacterial isolate was streaked on Oxidase Test Strips. The color changes on the trip test paper were observed. A positive test was indicated by the formation of black or blue-violet color.

Estimation of the number of INA bacteria

The number of INA bacteria was estimated using the multiple tube nucleation method (Cazorla et al. 1995). First, the test tube containing 9 mL of sterile phosphate buffer was cooled at -10°C for 30 minutes. Then the tubes were shaken, and all the frozen tubes were separated. Next, the tube containing the unfrozen phosphate buffer was heated to 5°C. Two (2) g of Lichens sample was homogenized in 20 mL of phosphate buffer medium and 0.1% peptone meat. Then 1 mL was taken and put in a test tube containing 9 mL of sterile phosphate buffer.

Furthermore, 3 series of dilutions were carried out, 10^{-1}, 10^{-2}, 10^{-3}, in the tube containing unfrozen phosphate buffer. Each dilution series was carried out in three replications to obtain a series of 3 tubes. Each tube containing unfrozen phosphate buffer and a homogenized sample of Lichens was put into a circulating alcohol bath for 10 minutes so that the temperature reached -3°C to -9°C. The number of INA bacteria per gram of fresh weight of the sample was estimated based on the MPN method. First, the number of frozen test tubes was calculated for each dilution. Then it was compared with the numbers in the MPN series 3 tube table to obtain the table values. Finally, the value obtained is multiplied by the dilution factor of the medium tube to obtain the number of microbial MPNs in the sample (Fardiaz 1993). The results of the microbial MPN calculation were multiplied by 100 because the Lichens sample was classified as a solid sample.

Microbial MPN = MPN value x 1/ Dilution of the middle tube

Data analysis

The obtained data were analyzed descriptively based on the observations of colony morphology, cell morphology, biochemical tests, and analysis of the number of INA bacteria in Lichens living in the hiking pathway of Cemoro Sewu.

RESULTS AND DISCUSSION

Lichens sample

Based on the results of field observations and the identification of Lichens living in the hiking pathway of Cemoro Sewu, it is known that the most common species found at an altitude of 2,200-2,600 m asl are *Usnea* sp. and *Parmelia* sp. (Figure 2). Therefore, in this study, 2 types of Lichens, namely *Usnea* sp. and *Parmelia* sp., were determined to be used as the main source for isolating INA bacteria. The sampling stations and the types of lichenes are presented in Table 1.

Station 1 is located at coordinates 07°.39.067'LS and 111°.11.727'BT with an altitude of 2,207 m asl. The sampling location is in front of post 1, a field with sparse tree vegetation. The light intensity is 7510 Lux because the canopy density is low enough so that most of the sunlight can reach the ground surface.

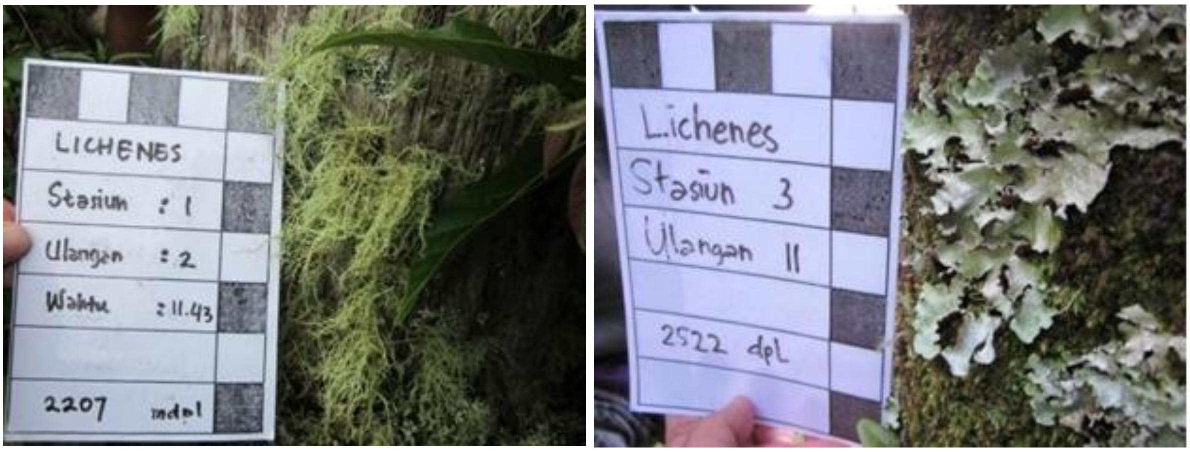
Station 2 is located at coordinates 07°.39.043'LS and 111°.11.660'BT with an altitude of 2,532 m asl. It is dominated by shrubs and large trees with a dense enough canopy so that sunlight is blocked enough to reach plant vegetation. The air temperature is around 20ºC. It can be attributed to the low light intensity of 3676 Lux.

Station 3 is located at coordinates 07°.38.524'LS and 111°.11.714'E with an altitude of 2,601 m asl. The sampling location is near post 2. There is a lot of tree vegetation, but the plant canopy does not block sunlight from reaching the vegetation.

Isolation of INA bacteria from lichenes samples on the hiking pathway of Cemoro Sewu

Isolation of INA bacteria from lichenes was carried out using selective media for INA bacteria isolation, namely King's B (KB) media containing 1.5% glycerol. Another isolation medium used was Nutrient Agar media which was enriched with the addition of 2.5% glycerol (NAG). The content of glycerol was used as a carbon source for bacterial growth.

Lindow (1990) stated that KB media containing glycerol is a common medium used to isolate ice-core-forming bacteria. On the other hand, Lindow et al. (1982a) explained that culture growth in media containing polyalcohols such as glycerol, mannitol, sorbitol, etc., can increase the frequency of ice core formation. Waturangi and Tjhen (2009) also reported that family planning media is a selective medium expected to have almost the same nutritional content as the nutrients in the leaves. Meanwhile, NA media which has been enriched with the addition of 2.5% glycerol (NAG), is also expected to grow INA bacteria.



A B

Figure 2. Lichens living on the hiking pathway of Cemoro Sewu, Mount Lawu, Indonesia. A. *Usnea* sp., B. *Parmelia* sp.

Table 1. Lichenes Sampling Station on the hiking pathway of Cemoro Sewu, Mount Lawu, Indonesia

Sampling station	Altitude (m asl.)	Light Intensity (Lux)	Air temperature (°C)	Air humidity (%)	Lichen types
1	2,207	7510	21	71	*Usnea* sp.
2	2,532	3676	20	85	*Parmelia* sp.
3	2,601	4260	20	86	*Parmelia* sp.

The isolation results obtained 37 different isolates based on the appearance of morphology and pigmentation produced. All colonies with different morphological appearances were purified before being tested for ice nucleation activity. All isolates were tested for ice nucleation activity at a temperature of -10°C in a circulating alcohol bath for 5 minutes. In line with Lindow's (1990) opinion, INA bacteria can initiate ice core formation at temperatures above -10ºC. On the other hand, Kieft and Ruscetti (1990) also stated that the formation of an ice core indicated a positive test for INA bacteria after an incubation period of 5 minutes.

The ice nucleation activity test resulted in 7 positive isolates of INA bacteria. They were from *Parmelia* sp., located at an altitude of 2,532 m asl (station 2). The number of bacterial isolates obtained from each station and the results of the ice nucleation activation test is presented in Table 2. Tubes with positive results are shown in Figure 3.

Based on their activity, INA proteins are divided into three main classes, namely class A, B, and C. Class A is active in forming ice cores at temperatures > -2°C to -5°C, class B is active at temperatures > -5°C to -7°C, and class C is active at temperatures -> 7°C to -10°C (Ruggles et al. 1993). Based on the test results, 2 isolates were classified into Class B. The five isolates were classified into the Ice core formation temperature class for each isolate as presented in Table 3.

Characterization of the obtained isolates

The observations result of colony morphology showed differences in the colonies of each isolate, which indicated that the seven isolates were different. Furthermore, this difference was seen in almost all parts of the colony, such as color, shape, margins, and size (Table 4 and Figure 4). Since colony morphology alone was insufficient, cell characterization of each isolate, including microscopic observations and biochemical tests, was needed.

The morphological characterization of bacterial cells was carried out by observing the shape of the cells and the type of gram bacteria. Table 5 shows the morphological characteristics of cells, indicating that there are differences in cell shape, namely, five isolates are rod-shaped, and 2 other isolates are coccobacillus (short stem). The similarity of the morphological characteristics of the cells was indicated by the reaction of the bacterial cells to the same gram staining of the seven isolates, namely Gram-negative, which was indicated by the appearance of pink-colored bacterial cells (Figure 5). According to Hadioetomo (1993), Gram-negative bacteria will be stained with safranin counter-dye at the end of the staining process because they cannot withstand the primary purple dye complex with iodine crystals.

Table 2. Number of bacterial isolates obtained by isolation from lichens on the hiking pathway of Cemoro Sewu, Mount Lawu, Indonesia

Station	Lichen species	Number of obtained isolates	Number of positive isolates of INA bacteria
1	*Usnea* sp.	7	-
2	*Parmelia* sp.	17	7
3	*Parmelia* sp.	13	-

Table 3. Classification of INA proteins based on freezing temperatures isolated from *Parmelia* sp. at Station 2 of Cemoro Sewu, Mount Lawu, Indonesia

Isolation code	Freezing temperature	INA protein class
K21B-5	-10°C	C
N21B-13	-5°C	B
N21B-15	-8°C	C
K22B-2	-5°C	B
K22B-4	-9°C	C
N22B-6	-10°C	C
N22B-7	-10°C	C

Note: K: Growth medium (K: King's B; N: NAG), 2: Sampling Station Number, 1: Repetition Number, B: Lichens Species Names (A: *Usnea*; B: *Parmelia*), 5: Number of isolates

Table 5. Cell morphological characteristics and biochemical test of INA bacteria isolates

Isolate	Morphology of cell		Biochemical test	
	Gram	Shape	Catalase	Oxidase
K21B-5	-	Coccobacillus	+	+
N21B-13	-	Coccobacillus	+	+
N21B-15	-	rod-shaped	-	-
K22B-2	-	rod-shaped	+	+
K22B-4	-	rod-shaped	+	+
N22B-6	-	rod-shaped	+	+
N22B-7	-	rod-shaped	+	+

Note: (+) positive, (-) negative. K: Growth medium (K: King's B; N: NAG), 2: Sampling Station Number, 1: Repetition Number, B: Lichens Species Names (A: *Usnea*; B: *Parmelia*), 5: Number of isolates

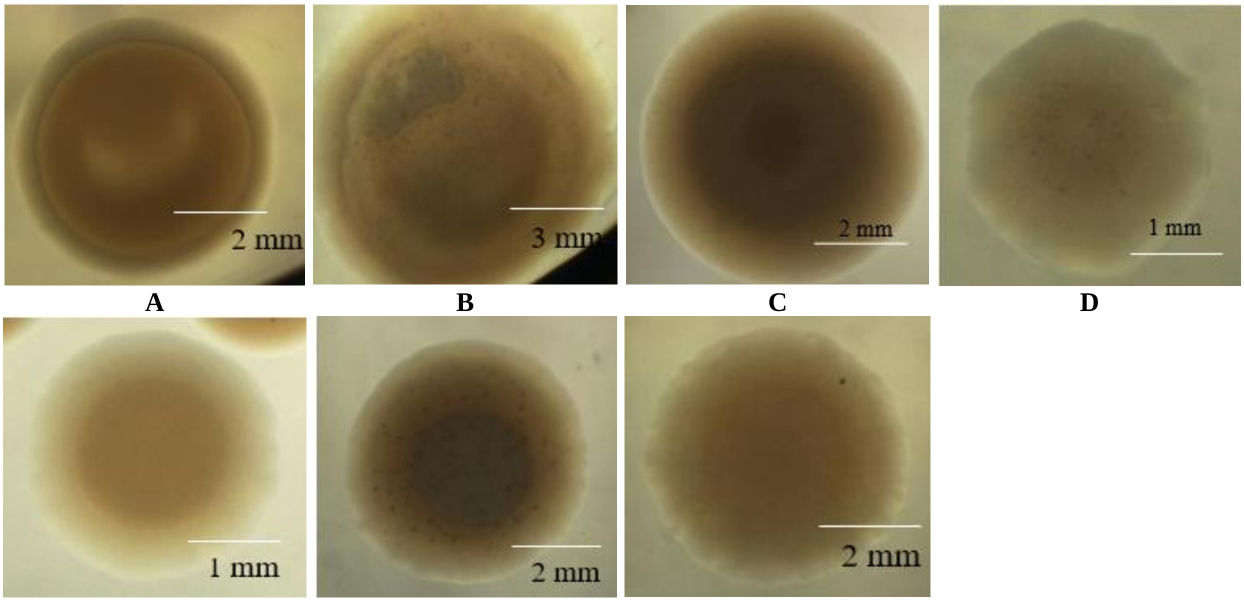
Table 4. Morphological characteristics of INA bacterial isolate colony

Isolate code	Colony morphological character				
	Color	Shape	Edge	Elevation	Size (mm)
K21B-5	Cloudy white	Circular	Entire	Convex	2
N21B-13	White	Irregular	Undulate	Convex	2.5-3.0
N21B-15	Clear yellow	Circular	Entire	Convex	2
K22B-2	Cloudy white	Circular	Undulate	Convex	1
K22B-4	Flash yellow	Circular	Entire	Convex	1
N22B-6	Flash yellow	Circular	Undulate	Convex	2
N22B-7	Flash yellow	Circular	Undulate	Convex	2

Note: Circular (round), Irregular, Entire (slick), Lobate (curvy), Undulate (wavy), K: Growth medium (K: King's B; N: NAG), 2: Sampling Station Number, 1: Repetition Number, B: Lichens Species Names (A: *Usnea*; B: *Parmelia*), 5: Number of isolates

A B C D E F G

Figure 3. Ice nucleation activity isolated from *Parmelia* sp. Note: isolate code: A. K22B-5, B. N21B-13, C. N21B-15, D. K22B-2, E. K22B-4, F. N22B-6, G. N22B-7



E F G

Figure 4. Morphology of colony of INA bacteria isolate from *Parmelia* sp. (40X Magnification). Note: isolate code: A. K22B-5, B. N21B-13, C. N21B-15, D. K22B-2, E.K22B-4, F. N22B-6, G. N22B-7

The morphological characters of bacterial cells isolated from *Parmelia* sp. generally showed Gram-negative characteristics with rod-shaped cells. It is in line with the opinion of Gurian-Sherman and Lindow (1993), which stated that ice core formation activity in bacteria is limited to Gram-negative bacterial species. Still, the presence of these species in plants and other natural habitats is an interesting general phenomenon. The most commonly found ice-core bacteria associated with plants include five species, namely: *P. syringae*, *P. viridiflava*, *P. fluorescens*, *Erwinia herbicola*, and *Xanthomonas campestris* pv translucens. The five species are Gram-negative bacteria. It is supported by the opinion of Lindow et al. (1978b) that *P. syringae* is a Gram-negative bacterium, rod-shaped, does not produce spores, and is oxidase negative. The *E. herbicola* species are Gram-negative bacteria, yellowish in color, motile, can use citrate, and produce H_2S. Members of the *Erwinia* genus are major plant pathogens that cause damage, wilt, and several other plant diseases.

Biochemical tests were carried out to determine the metabolism of isolated bacteria, which strengthened the different characteristics of each bacterium. The biochemical tests were: the catalase test and oxidase test. The different reactions of 7 bacterial isolates to biochemical tests can be seen in Table 5, which shows physiological differences between the isolates obtained. Each different microorganism has its biochemical characteristics called biochemical fingerprints. This device is controlled by the enzymatic activity of the cell and is responsible for biosynthesis and biodegradation (Cappucino and Sherman 1987).

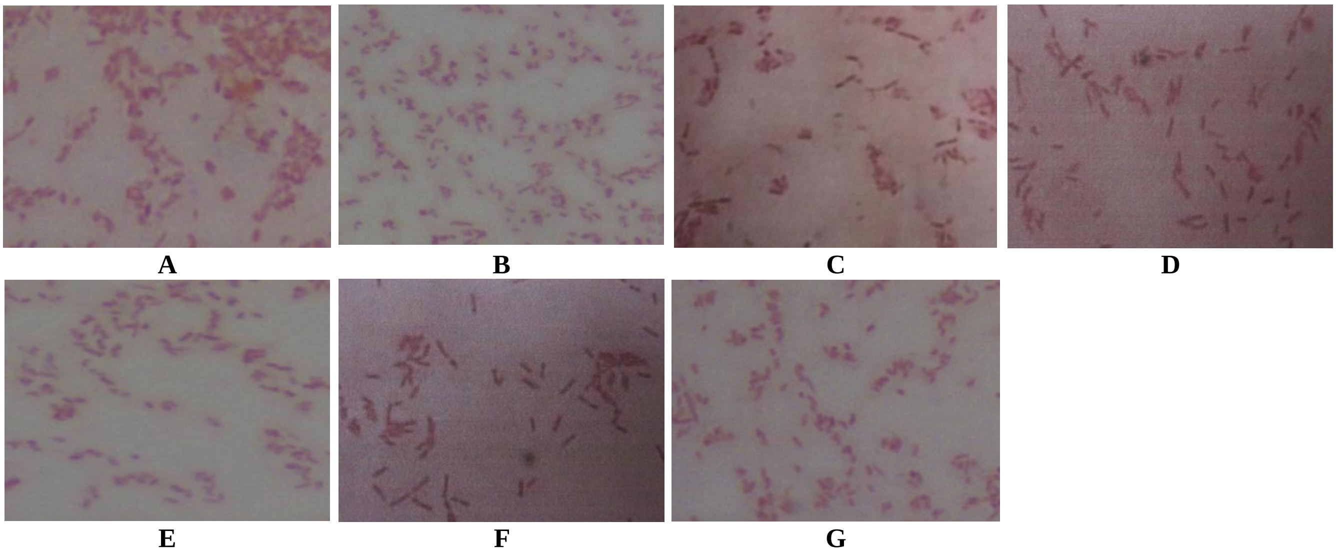


Figure 5. Gram staining of INA bacterial isolates isolated from *Parmelia* sp. (1000X Magnification). Note: Isolate code: A. K22B-5, B. N21B-13, C. N21B-15, D. K22B-2, E. K22B-4, F. N22B-6, G. N22B-7

Differences in the character of each obtained bacterial isolate can be seen in colony morphology, cell morphology and bacterial physiology characteristics. The characteristics of each isolate are as follows:

Isolate K22B-5 had the following characteristics: cloudy white colonies, circular shape (round), entire edge (slippery), convex elevation, 2 mm colony size, and coccobacillus cell shape (short rods). In addition, bacterial cells showed a negative reaction to Gram staining, i.e., cells looked pink and reacted positively to the catalase enzyme indicating that the bacteria were aerobic or facultative anaerobes. Aerobic bacteria and facultative anaerobes can produce the enzyme catalase, which converts hydrogen peroxide into water and oxygen. In the oxidase test, isolate K22B-5 showed a positive reaction indicating that the bacteria were able to produce oxidase enzymes.

Isolate N21B-13 had white colony characteristics, irregular shape (irregular), undulate edges (wavy), convex elevation, colony size of 2.5-3.0 mm, coccobacillus cell shape (short rods), and reacted negatively to Gram staining. Bacteria were aerobic or facultative anaerobes indicated by the formation of bubbles in the catalase test and the positive reaction in the oxidase test.

Isolate N21B-15 had the following characteristics: clear yellow colonies, circular shape (round), entire edge (slippery), convex elevation, colony size of 2 mm, Gram-negative, rod-shaped cell. The biochemical test results showed a negative reaction to the catalase enzyme, indicated by the absence of air bubbles. In addition, the K22B-5 isolate showed a negative reaction in the oxidase test, indicating that the bacteria could not produce the oxidase enzyme.

Isolate K22B-2 with colony character of cloudy white color, circular shape, undulate edge (wavy), convex elevation, 1 mm colony size, rod-shaped cells reacted negatively to Gram staining, i.e., cells looked pink. Positive reactions to the catalase test and the oxidase test indicated that the bacteria were aerobic or facultative anaerobes and the bacteria were able to produce oxidase enzymes.

The K22B-4 isolate had the following characteristics: bright yellow colonies, circular shape, entire edge (slick), convex elevation, 1 mm colony size, reacted negatively to Gram staining, and rod-shaped cells. In addition, K22B-4 isolate produced catalase enzyme, which converts hydrogen peroxide into water and oxygen. In addition, it could oxidize, which produces the enzyme oxidase.

Isolate N22B-6 had morphological characteristics of bright yellow colonies, circular shape (round), undulate edges (wavy), convex elevation, 2 mm colony size, Gram-negative, and rod-shaped cells. In addition, it reacted positively for the catalase test, as indicated by the formation of air bubbles and positive oxidase.

Isolate N22B-7 had a bright yellow colony appearance, circular shape (round), undulate edge (wavy), convex elevation, colony size 2 mm, Gram-negative and rod-shaped cell. It had a positive reaction to the catalase and oxidase tests.

Estimation of INA bacteria

The number of INA bacteria was estimated by the multiple tube nucleation method, which is a method for estimating the number of ice nuclei from bacterial suspensions and the population of INA bacteria on plant parts (Cazorla et al. 1995).

According to Anon (1975), the tube nucleation test is used to calculate the number of INA bacteria associated with plants based on and developed from the multiple-tube or MPN (Most Propable Number) method is a method to determine the number of coliforms in water. According to Montesinos and Viraldell (1991), the use of a tube assay to determine the number of ice cores is based on the number of tubes that freeze in each dilution series. The MPN method assumes that a frozen tube contains at least one ice core (Govindarajan and Lindow 1988).

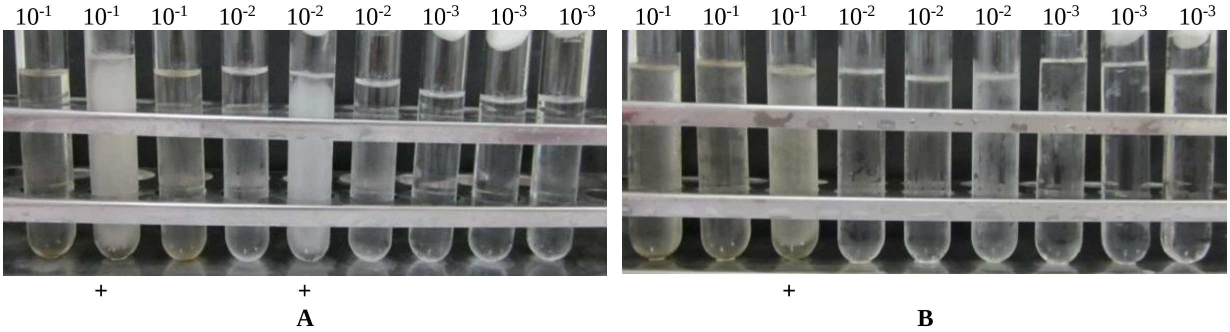


Figure 6. Positive tube (frozen) on the MPN test. A. Tube combination 1-1-0; B. Tube combination 1-0-0

Table 6. Average MPN value based on the 3-tube series MPN table

Station	Lichen types	MPN tabel value (MPN/g)
1	*Usnea* sp.	<3
2	*Parmelia* sp.	5
3	*Parmelia* sp.	<3

Fardiaz (1993) stated that the MPN method is usually used to count the number of microbes in a liquid sample, although it can also be used for solid samples by first making a 1:10 suspension of the sample. The output of the MPN method is the MPN value. The MPN value estimates the number of growth units or colony-forming units in the sample. However, in general, the MPN value is also interpreted as an estimate of the number of individual bacteria.

The number of bacteria was estimated using the multiple tube nucleation test method at a temperature of -5°C for 10 minutes in a circulating alcohol bath. In a study conducted by Cazorla et al. (1995), the optimum temperature for the estimation test is -5ºC. Furthermore, it is supported by the opinion of Hirano et al. (1985) and Baertlein et al. (1992) that a temperature of -5°C is sensitive enough to detect the presence of INA bacteria. On the other hand, Lindow et al. (1982a), Hirano and Upper (1986), Olive and McCarter (1988) used a temperature of -5°C for routine testing to determine INA bacteria.

Based on the test results, the frozen positive tube was only found in sample station 2 (2,532 m asl). In replicate 1, the number of frozen positive tubes with a combination of 1-1-0 was matched with the MPN table, which shows a value of 7 MPN/g. In the second sample, the number of frozen positive tubes was obtained with a combination of 1-0-0, then matched with the MPN table, which shows a value of 4 MPN/g. At stations 1 and 3, the combination of frozen positive tubes is 0-0-0, which indicates a value of <3 MPN/g. Of the three stations, the highest table MPN value came from the sample *Parmelia* sp. at station 2 (2532 m asl.) with an average value of 5 MPN/g (Table 6). The combination of frozen positive tubes can be seen in Figure 6.

Based on the calculation results, the number of INA bacteria in Lichens on the hiking pathway of Cemoro Sewu is 5 x 104/g. This value indicates a low number of bacteria compared to several previous studies. Several studies have been carried out, including by Lindow (1993), which states that the population of INA bacteria reaches 106 cells/g in plant tissue. On the other hand, Kieft (1988) reported that the highest density of ice-core bacteria population in lichenes was between 2.3 x 106 to more than 1 x 108 cells/g at -5ºC. Lindow et al. (1978a,b) also reported that the lowest bacterial population ranged from 102 to 2.4 x 106 cells/g. The low population in plant tissue is between 102 to >104 cells/g. Differences in environmental conditions may be one of the factors that cause the high and the low number of INA bacteria on the plant surface.

This study provides the following conclusions: (i) 7 isolates of INA bacteria can be isolated from lichenes on the hiking pathway of Cemoro Sewu, which were isolated from lichenes type *Parmelia* sp. at an altitude of 2,532 m asl; (ii) the number of INA bacteria in Lichens on the hiking pathway of Cemoro Sewu is 5 x 104/g, indicating a low number of bacteria.

REFERENCES

Amato P, Parazols M, Sancelme M, Laj P, Mailhot G, Delort AM. 2007. Microorganisms isolated from the water phase of tropospheric clouds at the Puy de Dome: major groups and growth abilities at low temperatures. FEMS Microbiol Ecol 59: 242-254. DOI: 10.1111/j.1574-6941.2006.00199.x.

Anon. 1975. Standard Methods for the Examination of Water and Wastewater, 14th edn. American Public Health Association, Washington, DC.

Baertlein DA, Lindow SE, Panopoulos NJ, Lee SP, Min-drinos MN, Chen THH. 1992. Expression of bacterial ice nucleation gene in plants. Plant Physiol 100: 1730-1736. DOI: 10.1104/pp.100.4.1730.

Cappucino JG, Sherman N. 1978. Microbiology: A Laboratory Manual. The Benjamin Cummings Publishing Company Inc., California, USA.

Cazorla FM, Olalla L, Tores JA, Perez-Garcia A, Codina JC, de Vicente A. 1995. A method for estimation of population densities of ice nucleation active *Pseudomonas syringae* in buds and leaves of mango. J Appl Bacteriol 79: 341-346. DOI: 10.1111/j.1365-2672.1995.tb03146.x.

Fardiaz S. 1993. Analisis Mikrobiologi Pangan. PT. Raja Grafindo, Jakarta. [Indonesian]

Govindarajan AG, Lindow SE. 1988. Size of bacterial Ice Nucleation sites measured in situ low radiation inactivtion analysis. Proc Natl Acad Sci USA 58: 1334-1338. DOI: 10.1073/pnas.85.5.1334.

Gurian-Sherman D, Lindow SE. 1993. Bacterial Ice Nucleation: Significance and moleculer basis. FASEB J 7: 1338-1343. DOI: 10.1096/fasebj.7.14.8224607.

Hadioetomo RS. 1993. Mikrobiologi Dasar Dalam Praktek (Teknik dan Prosedur Dasar Laboratorium). PT. Gramedia, Jakarta. [Indonesian]

Hirano SS, Baker LS, Upper C.D. 1985. Ice nucleation temperature of individual leaves in relation to population sizes of ice nucleation active bacteria and frost injury. Plant Physiol 77: 259-265. DOI: 10.1104/pp.77.2.259.

Hirano SS, Upper CD. 1986. Bacterial nucleation of ice in plant leaves. Methods Enzymol 27: 730-738. DOI: 10.1016/0076-6879(86)27057-3.

Kieft TL, Ruscetti T. 1990. Characterization of biological ice nuclei from a lichen. J Bacteriol 172: 3519-3523. DOI: 10.1128/jb.172.6.3519-3523.1990.

Kieft TL. 1988. Ice Nucleation Activity in lichens. Appl Environ Microbiol 54 (7): 1678-1681. DOI: 10.1128/aem.54.7.1678-1681.1988.

Lindow SE, Aray DC, Upper CD 1978a. Distribusition of Ice Nucleation Active bacteria on plants in nature. Appl Environ Microbiol 36: 831-838. DOI: 10.1128/aem.36.6.831-838.1978.

Lindow SE, Aray DC, Upper CD 1982a. Bacterial Ice Nucleation: A factor in frost injury to plants. Plant Physiol 70: 1084-1089. DOI: 10.1104/pp.70.4.1084.

Lindow SE, Arny DC, Upper CD 1978b. *Erwinia herbicola*: A bacterial Ice Nucleus Active in increasing frost injury to corn. Phytopathol J 68: 523-527. DOI: 10.1094/Phyto-68-523.

Lindow SE, Hirano SS, Barchet WR, Arny DC, Upper CD. 1982b. Relation between Ice Nucleation Frequency of bacteria and frost injury. Plant Physiol 70: 1090-1093. DOI: 10.1104/pp.70.4.1090.

Lindow SE. 1983. The role of bacterial Ice Nucleation in frost injury to plant. Ann Rev Phytopathol 21: 363-384. DOI: 10.1104/pp.70.4.1084.

Lindow SE. 1990. Bacterial Ice Nucleation Activity. In: Klement Z, Rudolp K, Sand DC (eds). Methods in Phytobacteriology. Academiai Kiodo, Budapest.

Lindow SE. 1993. Novel Method for identifying bacterial mutant with reduced epiphytic fitness. Appl Environ Microbiol 59: 1586-1592. DOI: 10.1128/aem.59.5.1586-1592.1993.

Montesinos E, Vilardell P. 1991. Relationships among population levels of *Pseudomonas syringae*, amount of ice nuclei, and incidence of blast dormant flower in commercial pear orchards in Catalunya, Spain. Phytopathology 81: 113-119. DOI: 10.1094/Phyto-81-113.

Morris CE, Sands DC, Vinatzer BA, Glaux C, Guilbaud C, Buffiere A, Yan S, Dominguez H, Thompson BM. 2008. The life history of the plant pathogen *Pseudomonas syringae* is linked to the water cycle. Intl Soc Microbial Ecol (ISME) J 2: 321-334. DOI: 10.1038/ismej.2007.113.

Olive JW, McCarter SM. 1988. Occurrence and nature of ice nucleation-active strains of *Pseudomonas syringae* on apple and peach trees in Georgia. Plant Dis 72: 837-843. DOI: 10.1094/PD-72-0837.

Ruggles JA, Marshall MN, Fall R. 1993. Kinetics of appearance and disappearance of classes of bacterial Ice Nucleation support and agregation model for ice nucleus assembly. J Bacteriol 175: 7216-7221. DOI: 10.1128/jb.175.22.7216-7221.1993.

Samsali O. 2008. Tumbuhan Epifit Berkhasiat Obat di Sepanjang Jalur Pendakian Cemoro Sewu Gunung Lawu. [Skripsi]. Universitas Sebelas Maret, Surakarta. [Indonesian]

Setyawan AD. 2000. Tumbuhan epifit pada tegakan pohon *Schima wallichii* (DC) Korth di Gunung Lawu. Biodiversitas 1 (1): 14-20. DOI: 10.13057/biodiv/d010103. [Indonesian]

Stephanie, Waturangi DE. 2011. Distribution of Ice Nucleation-Active (INA) bacteria from rain-water and air. Hayati 18 (3): 108-112. DOI: 10.4308/hjb.18.3.108.

Van Steenis CGGJ. 1978. Flora. Pradnya Paramita, Jakarta. [Indonesian]

Wahyudi AT. 1995. Pembentukan inti es oleh bakteri. Hayati 2: 55-59. [Indonesian]

Waturangi, DE, Tjhen A. 2009. Isolation, characterization, and genetic diversity of Ice Nucleation Active bacteria on various plants. Hayati 16 (2): 54-58. DOI: 10.4308/hjb.16.2.54.