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Environment Effects On Forest Richness And Sustainability

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ABSTRACT

Forest sustainability promotes the forest resource to be adequate in benefitting mankind. It depends on effective silvicultural operations to check the sustainable anthropogenic activities that lead to forest loss. As effective as silvicultural operations is in sustaining forest, it will amount to nothing if it is not coupled with appropriate breeding techniques, which in turn environment dependent. No matter viable or plus a tree is, without favourable environment, the qualities will be mutated. Breeding, the tree improvement is an intentional manipulation of genetic make-up of tree species to produce desired traits for man's benefits. Breeding brings about early fruiting and maturity, species stoutness, pest and disease resistance, bole straightness, high wood quality among others. Common breeding methods for tree improvement are; Plus tree selection, Progeny testing, Controlled crossing and Clonal testing. If both the silviculture and breeding can form a synergy in a favourable environment (biotic and abiotic) in tree improvement programme, the forest sustainability will be rapidly enhanced for the trees will rich maturity quickly with no infestation of pest and disease to reduce their quality both morphologically and anatomically. It is observed that the genetic make-up of any plant species is governed by the environment in which it is established, thus, Genotype = Phenotype x Environment. Environment modifies plant species either negatively or positive in relation to its

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original traits making environment an important pivot on which plant species richness and sustainability rest.

Keywords: silviculture; breeding; sustainability; improvement; synergy; environment

INTRODUCTION

MEANING OF FOREST

Forest is a natural community where flora and fauna are ecologically available with other biotic and abiotic of their immediate environment. Forest is a renewable natural resource due to its ability to naturally reproduce.

Edugreen, (2007) defined forest as a complex ecosystem consisting mainly of trees that buffer the earth and support a myriad of life forms.

The World Bank, (2013) remarked 'forests cover about a third of the earth's land area and are essential to the health of our environment. For example, trees and forests absorb and store much of the carbon dioxide that otherwise would be contributing to climate change. Forests are home to about 80 percent of remaining terrestrial biodiversity. Forests also regulate water cycles, maintain soil quality, and reduce the risks of natural disasters such as floods'.

While forests are resilient ecosystems, there are limits to their ability to withstand environmental change, and they degrade when these limits are exceeded. Understanding these limits also allows us to enhance various forest outputs through silviculture (Maini, 1992)

Forests are a rich repository of planet Earth's genetic heritage. Tropical forests contain more than 50 percent of all plant and animal species in about six percent of the world's surface area (Poore and Sayer, 1991). The species diversity apparently decreases toward the higher latitudes. As compared to the tropical forests, composed of hundreds of tree species, large tracts of forest land in the boreal regions may be dominated by a single species. Species diversity and ecological diversity are closely related and their preservation is an integral component of efforts to maintain future options.

WHAT AN ENVIRONMENT IS!

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There is no how a forest is to be identified without making mention of the geographical area such forest belongs. The area in question is referred to an environment in term of place. In real sense, environment determines plant growth and development. It even determines the seasonal variations of an area. Merriam-Webster dictionary defines environment as the complex of physical, chemical, and biotic factors (such as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival. Abdul, (2003) explained that forest environment or site consists of the physical environment surrounding the aerial portions of the tree (climatic factors) and that surrounding the subterranean portion (edaphic factor) and the third one is biotic factor.

MAJOR TYPES OF FORESTS

In further declaration on forest, Forest Facts.org, (2007) described types of forests as following; **Tropical forests** (rainforests but also others) occur near the equator and are the most ecologically rich of all forest types. They regenerate very rapidly but they are the most threatened forests, primarily by logging (reforestation is rare but it has been successfully achieved in some places) and clearance for agriculture (which is often permanent and leads to soil erosion).

They are characterized by 25-35 m tall trees with a multi-layered and continuous canopy, a highly diverse flora, and a fauna including numerous birds, bats, small mammals, and insects.

There are four tropical forest types: evergreen rainforest, seasonal rainforest, semi-evergreen forest and moist/dry deciduous forest.

Temperate forests occur in eastern North America, northeastern Asia, and western and central Europe. Regeneration is slower because the growing season is short. Their total area has not changed much in recent years but plantations have steadily replaced old-growth forests.

Temperatures vary from –30°C to 30°C and precipitation (75-150cm) is evenly distributed throughout the year. The soil is fertile and the canopy moderately dense. There are some 3-4 species of flora per square kilometer and fauna is represented by squirrels, rabbits, birds and deer among others.

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There are five temperate forest types: moist conifer forest, dry conifer forest, Mediterranean forest, temperate coniferous and temperate broad-leaved rainforest.

Boreal forests, or **taiga**, represent the largest terrestrial biome. They are found in areas with shorter, warm summers and long winters. Hence the growing season is very short, and regeneration occurs slowly. There are boreal forests in Europe, Asia, Siberia, and North America. Because of the cold climates, plant life in the boreal forest is sturdy, consisting mainly of evergreens and other resilient vegetation. The forest canopy is so dense that little light reaches the forest floor.

Temperatures are very low and annual precipitations (mostly snow) range from 40 to 100 cm. The soil is nutrient-poor and acidic. Flora is mostly cold-tolerant evergreen conifer and fauna includes woodpeckers, bear, lynx, fox and wolf among others.

Renewal of a forest ecosystem, following harvesting or other forms of disturbances, is dependent on the nature and intensity of disturbance and the mode of reproduction of species located on the site. Under many tropical conditions, forest revegetation by seed or vegetative means is rapid and is completed within a few months with high species diversity (Lamb, 1990).

BENEFITS OF FOREST TO MAN AND HIS ENVIRONMENT

Forest is so important in many ways to the survival of man, animals, and all abiotic factors. Among the benefits of forest are; Ecological benefit, Socio-cultural benefit and Economic benefit. Edugreen, (2007) itemized the importance of forest as follow; the trees help create a special environment which, in turn, affects the kinds of animals and plants that can exist in the forest. Trees are an important component of the environment. They clean the air, cool it on hot days, conserve heat at night, and act as excellent sound absorbers. Plants provide a protective canopy that lessens the impact of raindrops on the soil, thereby reducing soil erosion. The layer of leaves that fall around the tree prevents runoff and allows the water to percolate into the soil. Roots help to hold the soil in place. Dead plants decompose to form humus, organic matter that holds the water and provides nutrients to the soil. Plants provide habitat to different types of organisms. Birds build their nests on the branches of trees, animals and birds live in the hollows, insects and other organisms live in various parts of the plant. They produce large quantities of

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oxygen and take in carbon dioxide. Transpiration from the forests affects the relative humidity and precipitation in a place.

NEED FOR SUSTAINABLE FOREST

Despite the importance of forest benefits to man and his environment, it is experiencing suffering from man through his activities termed anthropogenic activities among which are clearing land for agriculture, construction of roads and bridges, buildings of industries, hospitals and residential houses to mention but a few, and natural disasters. All these coupled with natural disaster like climate change which affects all life result to forest loss which can be summed up as deforestation. But for forest to retain its obligation to mankind this natural resource needs to be sustained in all ramifications, hence there should be forest sustainability.

Technology Student, (2019) reported that a sustainable forest is a forest that is carefully managed so that as trees are felled they are replaced with seedlings that eventually grow into mature trees. This is a carefully and skillfully managed system. The forest is a working environment, producing wood products such as wood pulp for the paper / card industry and wood based materials for furniture manufacture and the construction industry. Great care is taken to ensure the safety of wildlife and to preserve the environment. Sustainable forests are the result of a commonsense policy to replace trees that are felled so that forests continue to exist providing natural materials for us all. A typical sustainable forest will contain trees of all ages and often different species of trees. As the trees mature they are felled and the natural wood is processed at saw mills. Felled trees are replaced with seedlings. In this way the forest is constantly renewed.

In its own contribution, Rainforest Alliance, (2016) explained convincingly, “For many, the term “sustainable forestry” may seem like an oxymoron. How can logging ever be sustainable when, by definition, it requires that trees be cut down? The complete answer is complex, but if we had to reduce it to one word, it would be “balance.” The hallmark of sustainable forestry, from a purely ecological perspective, is the extent to which forestry practices mimics natural patterns of disturbance and regeneration. Sustainable forestry balances the needs of the environment, wildlife, and forest communities—supporting decent incomes while conserving our forests for future generations. There are many practical steps that a community or business can take to

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protect the health and longevity of a forest while still profiting from the production and sale of timber and other forest products, such as nuts, fruits, oils, and plants".

SILVICULTURE AND ITS IMPORTANCE TO FOREST

Silviculture can be referred to as all operations put up in establishing a forest from clearing of land, measuring for spacing, pegging, lining, planting of stocks, weeding, manuring, protecting, pruning, and other nurturing activities to harvesting and loading of timber.

Neil, (2018) defined the scope of silviculture as the regeneration of forests through preparation of sites for, and the establishment of trees in a forest with the follow-up tending (weeding, herbicide release, thinning) and some aspects of harvesting.

In its own contribution, Forestry Focus, (2019) described silvilculture as "the art and science of controlling the establishment, growth, composition, and quality of forest vegetation for the full range of forest resource objectives. Successful silviculture depends on clearly defined management objectives. However, silviculture is often confused with managing stands and forests purely for timber. The term silviculture is also used to manage forests for wildlife, water, recreation, aesthetics, or any combination of these or other forest uses".

For forest to attain high and successful level of sustainability, silviculture must be handled by expert with high level grade of commitment. The New Zealand Digital Library Project, (1998) reported "Silviculture is a set of techniques that can be applied to help attain specified forest management objectives. It aims to achieve the implementation of objectives through manipulation of the composition and structure of a forest. In most instances in a wood production forest, the aim of silviculture is to enhance the growth and quality of potential crop trees".

Smith *et al*, (1996) cogently contributed that the main purpose of silviculture is one where "natural processes are deliberately guided to produce forests that are more useful than those of nature and to do so in less time".

In conclusion, silvilculture is environment dependent for the success of silviculture also depend on favourable and fertile environment.

PLANT BREEDING AND ITS IMPORTANCE

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Plant breeding is an intentional manipulation of plant genetic make-up to produce desired traits. Breeding is an act of producing offspring with pronounced genetic transmission from each of the parents dominantly or recessively. Breeding can be natural which has no man intervention or any form of manipulation from man. The one in which man determines the traits to be produced by the plants which has to do with the manipulation of such plant natural genetic set-up is referred to as artificial plant breeding.

In another view, plant breeding can be said to be achieved on growing on the field or performing of DNA with primers, and or isolation and transfer of genes in laboratory set-up.

European Seed Association, (2018) contributed to plant breeding development by reporting that further discoveries and advanced understanding of the biology, physiology, genetics and chemistry of plants and their interaction with their environment continues to fuel the flow of plant breeding innovations. The latest ones can be summarized under the term “Genome Editing” and consist of different tools like the famous CRISPR-Cas tool that can very specifically address certain locations in the plants DNA and introduce small changes (mutations) that lead to improved plant characteristics, like a resistance against pests and pathogens. With the knowledge of breeding in forestry, growth of trees will be enhanced. It also leads to species improvement in term of pest and diseases resistance like *Triplochiton scleroxylon*, *Detarium microcarpum*, *Adasonia digitata* and other similar species which are highly susceptible to pest infestation during heir seedling stage. Breeding removes undesired trait and give the breeder the desired trait thereby improving the forest species. Among those traits are straightness of bole, early maturity of species, fruit improvement and others.

PLANT GENETIC RESOURCES

The term "genetic resources" refers to the economic, scientific or social value of the genetic variation found among and between species. If properly managed, these resources are renewable; they can be used, without ever being used up (Ledig, 1986).

Plant genetic resource conservation has become increasingly important as more plants have become threatened or rare. At the same time, an exploding world population and rapid climate change have led humans to seek new resilient and nutritious crops. Plant conservation strategies generally combine elements of conservation on farm (as part of the crop production cycle, where

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it continues to evolve and support farmer needs), *ex situ* (for example in gene banks or field collections as seed or tissue samples) or *in situ* (where they grow in the wild or protected areas). Most *in situ* conservation concerns crop wild relatives, an important source of genetic variation to crop breeding programs (Thayer, 2005)

Plant genetic resources that are conserved by any of these methods are often referred to as germplasm, which is a shorthand term meaning "any genetic materials". The term originates from germ plasm, August Weismann's theory that heritable information is transmitted only by germ cells, and which has been superseded by modern insights on inheritance, including epigenetics and non-nuclear DNA.

Genetic variation has a number of fundamentally important functions; it constitutes a buffer against changes in the environment (including those brought about by pests, diseases and climate change) and it provides humans with the building blocks for selection and breeding to adapt plants and animals to a range of environments and end uses (Palmberg, 1987). Intensive selection and breeding for increased yields and uniformity has long been practiced for agricultural crop species. While such selection can improve certain traits in the short term, it may also reduce genetic variation when done over many plant generations, and the more genetically uniform populations have a decreased ability to respond to changing environmental pressures (including attack by pests and diseases) or shifting human needs. Therefore the use of narrowly based genetic materials grown for short term productive purposes must always be paralleled by conservation of the maximum amount of available variation through the establishment of reserves and managed resource areas and through the inclusion of genetic conservation concerns in improvement and breeding strategies.

PROSPECTS OF SILVI-BREEDING

Silviculture, and selection and breeding each have the potential to improve the quality and quantity of the final crop; when combined correctly there is the potential for large improvements in financial returns. Similarly, silviculture and breeding cannot be seen as independent of each

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other. Taken in isolation, there is the potential for the crop to fail to provide productive or economic returns. The best genetic material will not perform well on a testing site with little management (Jason and Steve, 2005).

Silviculture will not yield any result if breeding is not planned along. There are many indigenous tree species in Nigeria such as *Milicia excelsa, Triplochiton sclerocylon* and *Garcinia kola* among others that take many years before maturity. Considering their valuable contributions to the economy of the nation, their genetic make-up need to be manipulated to produce early maturity and pest and diseases resistant species. Jason and Steve (2005) reported that a major difference is that improvements due to breeding are retained in perpetuity and can be added to; improvements due to silviculture last just one rotation. When tree breeding and silviculture are combined the gains will be greater than either one in isolation. silvicultural operations are effective within a given rotation whilst the gains from breeding are delayed until improved material is available. And Yanchuck, (n.d) contributed that As far back as the early and mid-1900s emphasis was placed on wide-range genetic surveys (i.e., provenance testing) using "common garden" experimental principles. The early common garden experiments by ecologists in the 1940s (and earlier) served as the initial models for these investigations in forestry and ecology research. The process was relatively simple in concept. Samples are collected from natural populations of interest (i.e., provenances) then planted in several test environments (usually within the range of the provenance collections) to test performance of the local provenance versus others. These early studies showed that most tree species had large amounts of genetic variation both within and among populations, but local populations were not always the best.

Haapanen, (2016) concluded that bioeconomy demands increasing but sustainable utilisation of forest resources. One efficient way to respond to this challenge takes place in the course of forest regeneration.

But leaving forest regeneration to natural means only slow down the process and at times reduce trait quality, hence there is need for tree improvement. Tree improvement, or as it is often referred to as genetic improvement, is the process of improving the genetic quality of a tree species. Our forest trees are still genetically close to their wild state in their natural range. However, considerable variation exits in economic traits such as growth rate, stem form and

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wood quality between different populations within a species, and also between individual trees within populations. Opportunities, therefore, exist to improve the silvicultural value of a species by identifying the best wild seed sources; and also to select individuals within these to develop varieties that are considerably better than the wild material. Hallander, (2009) reported “A cornerstone of forest tree breeding theory is the selection procedure. For example, the breeder has to choose which trees to select from all the available candidate trees; those chosen will contribute to future generations and effective size of the breeding population. In addition, the mating proportion of each selected tree needs to be decided. A breeder generally wants to select the best-ranked trees according to their estimated breeding values (EBV), because the offspring of these trees are expected to perform in a similar way to their parents. Hence, by selecting the best parents, the selection differential is likely to be increased in comparison to randomly selected trees in the breeding population. There is, however, a problem with this strategy, since the top-ranked trees are likely to be related, particularly if the heritability of the target trait is low. The reason for this problem is that more family information is taken into account in genetic evaluations, which results in a higher correlation of EBV between relatives. If too many related trees are selected, the genetic variability of the population becomes severely reduced, which could reduce the long term response to selection. On the other hand, due to the long generation times in forest tree breeding in general, the short term response is very important. Therefore, a healthy compromise between short and long-term responses to selection is needed”.

Yanchuk, (n.d) stated elaborately that in the early 1970s genetic surveys of forest trees, with the use of molecular genetic markers, further confirmed large amounts of genetic variation were present, as they had shown in fruit flies, and other organisms. However, these molecular marker studies largely sample neutral genes i.e., genes that vary in the population, but do not have noticeable "phenotypic" effects on individuals. (The term "phenotype" refers to the entire "observed" organism, which is a combination of both the genotype of the organism, environmental effects it has encountered, and the interaction of the two. For instance, genetic variation measured by molecular markers, called isoenzymes (protein variants called allozymes), have been useful for investigating gene flow, mating dynamics within and among stands, heterozygosity (genetic diversity), and various other measures of genetic variation (e.g., effective population size, number of alleles per locus, variation levels among populations and species, and the frequency of rare alleles).

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It is now clear that both neutral ("random" molecular genetic markers) and non-neutral (adaptive, quantitative genetic variation from common garden studies) were important to study.

The continued development of more complex DNA markers (e.g., Random Amplified

Polymorphic DNA (RAPD)), or Simple Sequence Repeat (SSR's or microsatellite markers) are now providing better information on variation at neutral or quasi-neutral gene loci.

Forestry Focus, (2019) expounded different techniques used by tree breeders as:

Plus tree selection

Superior trees (Plus trees) are selected in the best forest stands as breeding stock for the improved varieties. These trees display superior characteristics to the surrounding trees in the stand e.g. straighter stem, larger volume etc. Shoots from these trees are taken and grafted onto seedling rootstock in the nursery. These grafts are clones and are therefore genetically identical to the original plus tree. They are planted out in a clonal archive or clone bank to preserve the genes of the original tree and to be used as breeding material. Plus trees are generally selected on the basis of their appearance (phenotype) in the forest but their breeding value cannot reliably be assessed by the trees outward appearance alone. Their breeding value must therefore be determined by testing their offspring or progeny.

Controlled crossings

Controlled crossings are carried out on flowers produced by the grafts of the original plus trees in the clone banks. Their purpose is to produce seed from selected parents to test their breeding value and/or to combine the best traits of the selected trees for the next generation.

Controlled crossings are carried out in spring when the flowers first emerge. In conifers the male and female flowers are separate and the female flowers are isolated using plastic tubes or pollen proof bags. Pollen is then gathered from the donor tree and injected onto the isolated female flowers when they become receptive. This process requires great attention to detail both in record keeping and observing when the females reach their optimum receptivity and also in collecting and maintaining hundreds of separate seed lots.

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The seed from controlled crossings is collected, kept separate by mother tree and sown to produce offspring which are then planted out in progeny tests on typical forest sites.

Progeny testing

In developing improved varieties it is important to test the offspring or progeny of plus trees to determine their breeding value. Only those plus trees that produce superior progeny are used as breeding stock for the next generation. The progeny from a particular plus tree or controlled crossing is known as a family.

The performance of families is determined in progeny tests established on forest sites typical for the species. The families are planted in replicated plots and their growth and development assessed at periodic intervals. It can take many years before reliable information on the performance of the progeny is known – approx 10 for Sitka spruce and many more years for slow growing species such as oak.

The results of progeny tests are used to select the plus trees with the best breeding value. These can be either the original plus trees or superior individuals selected within the progeny test itself. Material (grafts or seed) from these trees is then used create a seed orchards for the production of improved planting stock.

Clonal testing

Within populations (unimproved stands, seed stands or families) individuals are often found with outstanding characteristics which are far superior to the rest. Tree breeders select and vegetatively propagate these individuals to produce superior clonal varieties with the same traits as the parent trees. In developing these varieties it is necessary to test the performance of the clones to ensure that they are indeed superior and will perform consistently over a range of site types. Clonal testing is similar to progeny testing in having the objective of screening the best material for the production of improved planting stock.

Since forest tree genetic resources includes various species which are long-lived and big in size, both in-situ and ex-situ conservation of targeted genetic resources are mainly applied. To meet various demands, conservation by the form of seed or pollen is also conducted Forestry and Forest Products Research Institute, (2018).

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CONCLUSION

Forest sustainability depends on effective silvilculture which in order way round depends on environment and other inputs such as good seeds that promote good seedlings and ultimately quality forest.

The good physique of tree species is a product of its genetic component upon the environment that aid its growth.

With breeding coupled with environment, other traits of tree species will be improved upon such as pest and disease resistance, drought resistance, straightness of bole, largeness of bole, flower abortion resistance, pollination failure resistance among others. Above all, all desired traits will be selectively improved morphologically and anatomically as long as the environment for the species is proper and productive.

REFERENCES

Abdul, S.A (2003). Influence of Forests on Environment. Accessed at www.fao.org>XII

Edugreen, (2007). Forestry. Accessed at http://edugreen.teri.res.in/explore/forestry/what.htm on 11/06/2019

European Seed Association, (2018). The Latest Plant Breeding Methods. Accessed at https://www.euroseeds.eu on 11/06/2019)

Forestry and Forest Products Research Institute, (2018). Forest Brochure Accessed at https://www.ffpri.affrc.go.jp on 9/6/2019

ForestFact.org, (2007). Facts on Forests and Forestry. Accessed at https://www.forestfacts.org/l_2/forests on 11/06/2007

Forestry Focus, (2019). Silvicultural Systems. Accessed at https://www.forestryfocus on 11/06/2019)

Forestry Focus, (2019). Tree Improvement. Accessed at https://www.forestryfocus on 9/6/2019

Jason, H. and Steve, L., (2005). A review of the relative roles of silviculture and tree breeding in tree improvement: the example of Sitka spruce in Britain and possible lessons for hardwood breeding. Accessed at https://academic.oup.com/forestry/article-ab on 10/6/2019

ISSN:0971-1260
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Jon Hallander, (2009) Novel Methods for Improved Tree Breeding Doctoral Thesis Swedish University of Agricultural Sciences

Lamb, D. (Unesco). 1990. Exploiting the tropical rain forest. *Man and the Biosphere Series*, vol. 3. Cornforth, UK, The Parthenon Publishing Group.

Ledig, F.T. 1986. Conservation strategies for forest gene resources. Forest Ecology and Management, 14: 77-90.

Maini, J.S (1992). Sustainable development of forests. A Chapter in Unasylva - No. 169 – Sustainability. An international journal of forestry and forest industries - Vol. 43 - 1992/2

Matti Haapanen, (2016) Tree Breeding. Accessed at https://www.luke.fi/en/natural-resources/forest/tree-breeding on 11/6/2019

Neil Stocker, (2018). What is the Scope of Silvilculture?. Accessed at https://www.quora.com on 11/06/2019).

Palmberg, C**.** 1987. Conservatión de recursos genéticos de especies lenosas. Actas, Simposio sobre Silvicultura y Mejoramiento Genético de Especies Forestales, 11: 58-80. Buenos Aires, Centro de Investigaciones y Experiencias Forestales.

Rainforest Alliance, (2016). What is Sustainable Forestry?. Accessed at https://www.rainforest-alliance.org/articles/what-is-sustainable-forestry

Smith, D. M., Larson, B. C., Kelty, M. J., & Ashton, P. M. S. (1996). The Practice of Silviculture (9th ed.). Wiley.) in Global Forest Atlas, (2019). Silviculture. Accessed at https://globalforestatlas.yale.edu/forest-use-logging/silviculture on 11/06/2019).

Technology Student, (2019). What is a Sustainable Forest?. Accessed at http://www.technologystudent.com on 11/06/2019

Thayer, Alan (2005). "A new look at conservation as a means of maintaining wild type genetic variation among economically important crop species". International Journal of Agricultural Research. **20** (16): 117–132.

The New Zealand Digital Library Project, (1998). Agricultural Information Modules. Guidelines for the management of tropical forests 1. The production of wood. (FAO Forestry Paper 135). Accessed at www.nzdl.org on 10/06/2019.

The World Bank (2013). Forests and Environment. Accessed @ https://www.worldbank.org

Yanchuk, A.D. (n.d). Techniques in Forest Tree Breeding. Accessed at https://www.eolss.net