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ROLES OF FOREST SCIENCE AND TECHNOLOGY IN SUSTAINABLE MANAGEMENT OF FOREST RESOURCES

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ABSTRACT

***Forest Science and Technology can be defined as the application of scientific knowledge to promote environmental conditions that support some plants and animals. Forest management is the process of organizing and putting into action some lay down practices for the stewardship and use of forests and other land uses in order to achieve the exact environmental, cost-effective, communal and cultural objectives. Common forest management techniques are: prescribed fire, thinning, harvesting (selective, shelterwood, seed-tree, and clear-cutting), site preparation, tree planting, and application of pesticides, herbicides, and fertilizers. Basic technology in Forest management includes; the use of Global Positioning System (GPS), Geographical Information System (GIS), remote sensing, forest modeling technologies, molecular markers, Gas chromatography–mass spectrometry (GC-MS) and* Atomic absorption spectroscopy *(AAS). The two most influential technologies in saw and veneer mills are; scanning technology and engineered wood products. Sustainable forest management aims to reliably manage natural and planted forests by merging both forest output and forest conservation to sustainably enhance benefits obtained from forests and forest ecosystems. The importance of sustainable forest management is that it reduces the impact on people, crops and the immediate environment of frost, strong winds, drought, flooding, intense rainfall, landslides, extreme heat and fire and changing rainfall patterns through various ecosystem services provided by conserved forests. Climate and water regulation, soil generation, erosion prevention, and nutrient recycling are considered to be some of the services provided. The trees help create a different environment which, in turn, affects the kinds of animals and plants that can continue in the forest*.

Keywords: Forest Science and Technology, Forest Resources, Climate Change, Biodiversity and Sustainable Management

INTRODUCTION

Forest Science can be defined as the study of a complex ecological unit consisting mostly of trees that preserve the earth and support countless life forms. In recent time, Forest Science has become a function of a description of forests and forest processes and how those processes are efficiently manipulated to meet human wants and needs. Forest managers are gradually using a range of strategies and techniques to achieve their goals, in which goal of sustainable forest management is inclusive. Technology has a key influence on the advancement of research and management techniques. According to Teischinger and Müller (2010), technology comprises of both material and immaterial, produced by the function of intellectual and physical efforts in order to meet demands and

create values. Therefore, Forest Science and Technology can be defined as the application of scientific knowledge to promote environmental conditions that support some plants and animals.

Forest management can be defined as the process of organizing and putting into action some lay down practices for the stewardship and use of forests and other land uses in order to achieve the exact environmental, cost-effective, communal and cultural objectives (FAO, 2018). It deals with largely the administrative, economic, legal, social, technical and scientific aspects related to natural and planted forests. It may involve calculated human intervention of varying degree, with the main aim of safeguarding plants and animals. This is usually backed up with action to maintain forest ecosystems and their functions. The success of any forest management techniques used in promoting environmental conditions that support some species of plants and animals depends on the management objectives.

Forest management can be used to build an environment that sustains some plant and animal species and it can be used also to create conditions that do not support some plant and animal species. In a null shell, forest managers can encourage or discourage the growth of plants and animals. This can only be achieved by understanding the characteristics and needs of the biotic component (plant and animal species) of the ecosystem.

Common Forest Management Techniques

The common management techniques used in forest management includes;

i. prescribed fire,
ii. thinning,
iii. harvesting (selective, shelterwood, seed-tree, and clear-cutting),
iv. site preparation,
v. tree planting,
vi. Application of pesticides, herbicides, and fertilizers.

Prescribed fire

Prescribed burning can be defined as the fire applied to a fixed area of forest within an approved set of conditions with dates coupled with suitable safety measures to achieve some already lay down objectives. It is the controlled use of fire to achieve resource management target of a premeditated land. However, prescribed burning may be useful to grassland, hayland, pasture land, forest land, and wildlife land. The major roles of prescribed burning in forest management according to ESC (2005) and USDA (2009) are:

i. It reduces the accumulation of fuel to support the control of accidental fires.
ii. It enhances ecological burning for species conservation.
iii. It stimulates forest regeneration after harvesting operations.
iv. Controlling the growth of undesirable vegetation is possible.
v. It is used in site preparation for harvesting, planting or seeding.
vi. It reduces the spread of plant disease and wildfire hazards.
vii. It promotes habitat improvement for wildlife.
viii. It stimulates improved plant and seed production in terms of quantity and quality.
ix. It brings about the removal of debris.
x. It facilitates the distribution of grazing and browsing.
xi. It brings about animal's restoration and maintenance of ecological sites.
xii. It promotes the management of native plant diversity and composition.

Thinning

This is the practice of removing some young stand of trees in order to increase the growth of the trees that are left behind and to stimulate the total yield of exploitable wood. Thinning is basically a silvicultural operation used to reduce the density per stands in which the trees are roughly the same age to improve the quality and growth of the remaining trees in order to stimulate

the production of the saleable product (Kerr and Haufe 2011). Apart from that, thinning can also be used to alter the species composition of a stand, improving the health of the remaining trees or upsetting an established ground flora to increase opportunities for natural regeneration,

The benefits of thinning in forest management are:

i. It reduces competition between plants for limited water and soil nutrients by making more water and nutrients available for the remaining trees after thinning.
ii. It also opens the stand's crown canopy, making more light available for the remaining trees.
iii. It is equally used to control stand density and provide sufficient growing space for tree crops of choice.

Harvesting (selective, shelterwood, seed-tree, and clear-cutting)

The common methods used in forest harvesting are: clearcutting, shelterwood (including seed tree) cutting, selection cutting, and high-grade cutting (Nix, 2017). Clear-cutting and shelter-woods are recommended in the production of even-aged forest stands with approximately the same age. In forest management, harvesting may influence various activities in the forest. For example, recreation potential, wildlife, water quality and other environmental issues. Clear-cutting removes wildlife habitat especially species that require mature forests, clearcutting also improves habitat for some wildlife species (Gagnon, 2016) with emphasis on species that satisfy all or partial life necessities in low vegetation and encounter with little overhead shade; for example, small rodent species and ground-nesting birds. These animals are normally abundant immediately after a clearcut. Birds of prey and other predators are not left out due to the abundant supply of small mice and rodents which serves an as good source of feed. However, forest managers can reduce the effects of cutting using the following measures;

i. Clearcutting should be done with a backup plan on how a site will grow back with new tree seedlings.
ii. Money should be set aside for procurement of new seedlings and planting cost, this can be achieved by setting some money aside from wood sales to help cover these costs.

Site preparation

Forest managers over the years have been able to identify the similarity between agronomy and intensive plantation silviculture because, for maximum productivity, both the plant and the soil need to be vigorously managed (Fox *et al*., 2004). In order to increase leaf area and corresponding growth to achieve the best value from plantation management, site-specific silvicultural prescriptions must be developed and implemented, with more emphasis on specific soil and site properties coupled with local market conditions.

In site preparation treatments, the basic target of a forest manager is to guarantee satisfactory survival and early growth of planted seedlings. In order to improve soil fertility, fertilizer application is needed a lot of times during the rotation. Removal of vegetation with the potential to compete with planted seedlings should be carried out during the rotation to maintain best resource availability. Fertilizer application improves soil fertility (Thomas *et al*., 2007) and it is a recommended silvicultural option since most forest soils are deficient in mineral elements that are capable of promoting plant growth. However, sporadic application of fertilizers, pesticides, and herbicides to reduce mortality of desirable tree species enhances environmental pollution. Chemicals such as fertilizers, pesticides, and herbicides can enter surface waters and therefore, precautions should be taken to prevent water

contamination which can easily pose a threat to wildlife.

Tree Planting

Some of the objectives of tree planting in forest management are;

i. To improve the availability of food for birds and other wildlife (Paul, 2011). Examples of forest trees that produce fruits for birds are bush mango, red osier dogwood and high bush cranberry.
ii. To provide cover (Gagnon, 2016) for wildlife. Examples of forest trees that give cover to wildlife are plantation of, Gmelina, Teak, Eucalyptus spp., oil palm, cedar, spruce and pine species just to mention a few. They offer excellent cover for small animals such as rats and rabbits within a short period of time. In plant forest trees, silvicultural prescriptions should be put into consideration by planting high-quality seedlings from the best families of desirable tree species (Jackson**,** 2014; Schnepf and Sullivan, 2019). Good site groundwork before and during planting in addition to excellent follow-up care reduces the duration the plant experiences transplant shock and also stimulates the quick establishment of the plant in the new location due to rapid recovery. The simple steps that can be used to reduce the stress placed on the plant during planting are; dig a shallow, broad planting hole, identify the trunk flare, place the tree at the proper height, straighten the tree in the hole, fill the hole gently but firmly, stake the tree, if necessary**,** mulch the base of the tree and provide follow-up care (Jackson**,** 2014).

Application of Technology in Forest Management

Forest management has really improved over the year as a result of development and use of the following technological advancement in research

i. Global Positioning Systems (GPS),
ii. Geographic Information Systems (GIS),
iii. Remote sensing,
iv. Forest modeling technologies,
v. Gas chromatography and mass spectroscopy (GC-MS),
vi. Molecular markers,
vii. Atomic Absorption Spectrometry (AAS).

Global Positioning Systems (GPS)

GPS enables researchers to precisely map topography, locate sample plots in forest stands (Cojoacă *et al*., 2014), navigating for aerial surveys, updating forest map, reference research areas, monitor landscape changes, and track wildlife (Tomkiewicz *et al*., 2010). Apart from that, it allows researchers to measure distances in the forest (Hejazian *et al*., 2013). It can also be applied in forest signal absorption coefficient index research (Wright *et al*., 2018).

Geographic Information Systems (GIS)

GIS gives researchers and forest managers the capability to acquire, plan view, interpret, and correlate a variety of geographic information including soil type, vegetation, wildlife population, human demographics, climate, topography, bedrock geology, and hydrology. Apart from that, high carbon survey can also be carried out using GIS (Baral, 2004).

Remote sensing

According to Jin *et al*. (2011) and Kai *et al*. (2012) remote sensing allows for the continuous monitoring of forest ecosystem ecology for example, moisture, temperature, pH, ozone, light intensity), measuring and monitoring forest resources, measuring forest tree diseases and insect interactions forest fires, urban forest, forest-wildlife management and forest ecophysiology using instrumentation that remains on-site and records data at specified intervals or records information from satellites (Kai *et al*., 2012).

Forest modeling

Forest modeling is very essential in guiding the management activities by using data on

the tree or animal characteristics, environmental conditions or variables, and management techniques to predict how forests will react to different management strategies or regime over time (Stephen *et al*., 2017).

Gas chromatography and mass spectroscopy (GC-MS)

The GC-MS instrument is made up of two parts. The gas chromatography (GC) portion separates the chemical mixture into pulses of pure chemicals and the mass spectrometer (MS) identifies and quantifies the chemicals. Analysis of several pesticides and herbicides used to control pests and weeds in forestry (simazine, hexazinone, pendimethalin, and thiazopyr) has been performed by GC−NPD (Thermionic Specific Detector) and GC-MS. A method based on the extraction of soil samples in small columns has been used for the determination of these compounds in the soil to know their level of accumulation (Pérez, *et al*., 1998). It is important to consider herbicide activity in the choice of selecting a product. This has to do with how the product will enter the plant, for instance through the foliage, stem, or roots. Some herbicides have more than one type of activity. When treating vegetation in the forest understory, always ensure that the product will not affect the over-story trees through soil activity (Jackson and Finley, 2007). However, the concentration of the pesticides in the forest soil can be determined using GC-MS to know whether the permissible limit for forest soil has been exceeded to reduce excessive accumulation of herbicides in forest products. Apart from that, biopesticides in plants can also be assessed using GC-MS.

Molecular markers

In advanced breeding programs, molecular markers are very essential in studying forest species with respect to quality control, for example, checking of clonal identification, orchard contamination and within orchard mating patterns. Molecular markers proved to be useful for supporting research for tropical hardwoods and non-industrial species, in particular for indispensable studies of mating systems. They can be useful for the quantification of genetic variation, although they must be used wisely. The major application of markers lies in strategic research in the great contributions which marker studies are making to rapid advances in the understanding of basic genetic mechanisms and genome organization at the molecular level (Kloch *et al*., 2015).

Atomic Absorption Spectrometry (AAS)

AAS is used to determine the concentration of heavy metals and trace element in plants and animals tissue including their environment. The pollution of the environment by heavy metals due to anthropogenic processes is a serious global problem. Environmental contamination by heavy metals is not like organic pollutants that may lose toxicity with biodegradation because metals cannot be degraded further and their toxicity can be long-lasting (Ukoha *et al.,* 2014). Hence, metals and other fluvial contaminants, in suspension or solution do not simply flow downstream in the most forest, they form complexes with other compounds, settled to the bottom and ingested by plants and animals or adsorbed to sediments which can easily be ingested through water and feed intake by wildlife thereby accumulating in vital organs. Trace metals, such as arsenic, zinc, copper, and selenium, are naturally found in many different ponds of waters. Some human activities in the forest such as mining and agriculture can lead to an increase in the mobilization of these trace metals out of soils or waste products into fresh waters. Even at extremely low concentrations, such additional materials can be toxic to wildlife or can impair reproductive and other functions. In the early 1980s, high concentrations of selenium in agricultural drainage water discharged to the Kesterson

National Wildlife Refuge in California extirpated all but one species of fish and caused widespread bird die-offs, as well as severe deformities in several bird species (Ohlendorf *et al*., 1986).

Wood Technology

There are two most influential technologies in saw and veneer mills namely;

i. Scanning technology
ii. Engineered wood products.

Scanning technology

In scanning technology lasers, optical scanners and X-ray scanners are used to measure logs and detect flaws which may be superficial and interior Scanners allow for increased energy efficiency and optimal utilization of logs (Alfred, 2010).

Engineered wood products

In order to further increased wood utilization, a great deal of the waste left from the sawing process are incorporated into products that can be substituted for solid wood products or products made from other materials (Alfred, 2010). Lumber, veneer, sawdust, irregular wood, and wood chips are formed and glued into panels, boards, and trusses. These include plywood, oriented strand board (OSB), glued laminated timber, laminated veneer lumber, and structural I-joists. These technologies, as well as automated handling systems and pollution filtering technologies, have helped the forest products industry to reduce its energy inputs and pollution outputs per volume of product, with emphasis on environmental related focus.

The Role of Technology in Sustainable Forest Management

Sustainable forest management aims to reliably manage natural and planted forests by merging both forest output and forest conservation to sustainably enhance benefits obtained from forests and forest ecosystems. Sustainable forest management provides socio-economic goods and services to communities who depend on the forest as their means of livelihood through the generation of income and employment opportunities, food, timber, and non-timber products (Rephann, 2013). It reduces forest susceptibility and maintains forest yield. With specific management practices promotion of carbon seizure, biodiversity, and soil and water conservation are possible. Technology is a valuable approach to reduce land degradation and concurrently support climate change mitigation.

Technology can help us to manage forests sustainably:

i. Technology helps us manage forests across the landscape. GPS, GIS, and remote sensing allow us to more efficiently map, analyze, monitor, understand, and manage natural resources.
ii. Technology helps us manage our forests through time. Forest modeling, tree improvement, and tree protection allow us to better plan, protect, and ensure the availability of forest values in the future.
iii. Technology helps us reduce the environmental impact of transportation, heat, and electricity needs. Renewable energy technologies (e.g., photovoltaic panels, biofuels, and wind turbines) can reduce our dependence on fossil fuel sources of energy.
iv. Technology promotes the modification of production from native forest to plantations with emphasis on relative advantage.
v. More information is made available to forest manager which stimulate decision making, more alternatives for biodiversity conservation.
vi. Annual planning cycle is possible coupled with formulation of objectives, preparation of a strategy, planning, implementing, monitoring and reappraisal.

The role of Community in Sustainable Forest Management

Sustainable forest management stimulates local community development at the same time as conserving biodiversity and sequestering carbon; it has the potential to eradicate deforestation and restore forest cover. The aid of reduced-impact logging practices, have a high degree of regards to conservation areas, protecting seed trees, censusing and mapping commercial trees, protecting against fires and promoting natural forest regeneration (CCMSS, 2010). Sustainable forest management stands on the identification of land tenure, good resource use, and management as well as community involvement and commitment.

Technology alone cannot ensure the sustainable management of forests. Human populations must make decisions and take actions that reduce the environmental impact of resource use. Sustainable management requires action by public institutions (Gagnon, 2016), private businesses, and individuals. Collective decisions must be made about how public and private institutions manage resources, use energy, and emit pollution. Individuals must (VDOF, 2014) make decisions about consumer habits and consider how they influence the current and future availability of forest resources to conserve heat at night, and act as attractive sound absorbers.

Factors Militating against Sustainable Forest Management

For sustainable forest management to be successful there must be assurance with respect to land tenure and organizational competence within the community coupled with the support of forestry engineers to create management plans and give training to instituted community production enterprises (CTCN, 2019). The factors limiting sustainable forest management are; land tenure system, organizational competence within the community coupled with inadequate support of forestry engineers to create management plans and give training to instituted community production enterprises.

Land tenure system can be defined as a system of land ownership which implies that the land either belongs to an individual, family, community, cooperate organization or government, who is said to "hold" the land. It gives details of individual that are qualified to use the land, for what duration coupled with the prescribed conditions. In addition, it is based on official laws and policies, and on informal customs (Raimi *et al*., 2013). It varies from countries to countries, for example in Nigeria the following land tenure systems are obtainable; the communal land tenure system, open access land tenure system, inheritance tenure system, leasehold tenure system, gift tenure system, rent tenure system, freehold tenure system and tenants at the government will. Land ownership is militating against sustainable management of forest resources due to demand for land basically for other forms of land use, for example there is a conflicting interest between land use for forestry and wildlife conservation and other forms of land use such as land use for food crop cultivation, livestock grazing and oil palm plantation establishment.

The process of giving a comprehensive and suitable services that meet different requirements in an organizational in the community can best be described as organizational competence within the community. Organizational competence is a step by step method utilized to stimulate enhancement in terms of service render and its relative delivery. It starts with a focus on the interactive purview of the Government-practitioner/host community collaborations, though its possibility has been long-drawn-out to comprise administrative and systemic strategies (Trenerry and Paradies, 2012). Poor frame work of organizational competence within the community is

seriously militating against sustainable management of forest resources.

In forest management, planning process is very essential because it will definitely results to good implementation if and only if the planning process is acceptable coupled with the approval of plans. Operational execution is based on how well the plan is well understood in addition to its acceptability by government executives, managers of the forest resources, rangers or forest workers, machinists and host communities just to mention but a few that might be connected to forest task execution (FAO, 2021). However, once any of the aforementioned stakeholders is skip it might affect sustainable management of forest resources due to a breakage in the chains of responsibility, because responsibilities differ from one stakeholder to another.

Similarly, every agencies involves in instituted community production enterprises should be considered for active training of crew members involves in forest management such as planting, logging, processing sales of timber and forest road constructions basically to stimulate professionalism at work place, improve work quality and performance, and acquire enhance awareness skill coupled with social and environmental issues (FAO, 2021). Inadequate training of instituted community production enterprises will also affect sustainable management of forest resources.

Why Sustainable Forest Management is inevitable in 21st Century

Sustainable forest management reduces the impact on people, crops and the immediate environment of frost, strong winds, drought, flooding, intense rainfall, landslides, extreme heat and fire and changing rainfall patterns through various ecosystem services provided by conserved forests (CTCN, 2019). Climate and water regulation, soil generation, erosion prevention, and nutrient recycling are considered to be some of the services provided by forest coupled with capturing and storing CO_2 which helps to mitigate climate change.

CONCLUSION

Sustainable forest management reduces the impact on people, crops and the immediate environment of frost, strong winds, drought, flooding, intense rainfall, landslides, extreme heat and fire coupled with changing rainfall patterns through various ecosystem services provided by conserved forests. Climate and water regulation, soil generation, erosion prevention, and nutrient recycling are considered to be some of the services provided. Capturing and storing CO_2 by forests assists mitigate climate change. Trees help create a different environment which in turn affects the kinds of animals and plants that can continue to survive in the forest. The factors limiting sustainable forest management are; land tenure system, organizational competence within the community coupled with inadequate support of forestry engineers to create management plans and give training to instituted community production enterprises. The only way to continuous human and animal existence on earth is to conserver the trees. If trees are not conserved the whole human race will be eradicated from the surface of the earth. Forest Conservation is the sure way to life. There is no other alternative.

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