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"GREEN TECHNOLOGIES AND POLICIES FOR FOREST CONSERVATION IN SOUTH AND SOUTHEAST ASIA"

"TECNOLOGÍAS Y POLÍTICAS ECOLÓGICAS PARA LA CONSERVACIÓN DE LOS BOSQUES EN ASIA MERIDIONAL Y SUDORIENTAL"

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Abstract:

Green technologies are very relevant when it comes to implementing good practices in sustainable forest management as well as in the conservation of the forests in the world today. Technologies like satellite, AI, IoT, and blockchain, mean that there are tools to support real-time forest trackers, preventing illicit acts of logging, and better utilising the forest resources at hand. These made the technologies possible for decision making based on values and new environment that allows for fast response to forest fires and pests. In addition, green technologies can also improve the prospects of reforestation with accuracy planting and data mining. Other financial strategies include green finance, carbon finance, and sustainable supply chain for supporting the forest protection, and promoting private capital for conservation. The efficient deployment of green technologies needs sound policy environment, financial backing, and multiple stakeholder engagements. In order to achieve this there is a need for governments, businesses, and local communities to cooperate in developing proper legal frameworks that will force people to adopt the green technologies, while at the same time making sure that the benefits have to reach out to the areas most affected by deforestation. As such, future of forest conservation remains based on further evolution of these technologies and their implementation into overall environmental and economic policies. With the proper connection of technological change to the future governance of our planet, the forestry, climate change, and biodiversity assets may be protected and preserved for the use of future generations.

Resumen:

Las tecnologías verdes son muy importantes a la hora de aplicar buenas prácticas en la gestión forestal sostenible y la conservación de los bosques en el mundo actual. Tecnologías como el satélite, la IA, IoT, y blockchain, significan que hay herramientas para apoyar a los rastreadores forestales en tiempo real, la prevención de actos ilícitos de la tala, y una mejor utilización de los recursos forestales a la mano.Estas tecnologías hacen posible una toma de decisiones basada en valores y un nuevo entorno que permite responder con rapidez a los incendios forestales y las plagas. Además, las tecnologías verdes también pueden mejorar las perspectivas de reforestación con la plantación de precisión y la extracción de datos.Otras estrategias financieras incluyen la financiación verde, la financiación del carbono y la cadena de suministro sostenible para apoyar la protección de los bosques y promover el capital privado para la conservación. El despliegue eficaz de las tecnologías verdes requiere un entorno político sólido, respaldo financiero y la participación de múltiples partes

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interesadas. Para lograrlo, es necesario que los gobiernos, las empresas y las comunidades locales cooperen en el desarrollo de marcos jurídicos adecuados que obliguen a la gente a adoptar las tecnologías verdes, asegurándose al mismo tiempo de que los beneficios tienen que llegar a las zonas más afectadas por la deforestación.Así pues, el futuro de la conservación de los bosques sigue dependiendo de la evolución de estas tecnologías y de su aplicación en las políticas medioambientales y económicas generales.Con una conexión adecuada del cambio tecnológico con la futura gobernanza de nuestro planeta, los activos forestales, el cambio climático y la biodiversidad podrán protegerse y conservarse para uso de las generaciones venideras.

Keywords: Green technologies. Forests. Financial banking. Climate change. Forest conservation. Legal frameworks.

Palabras clave: Tecnologías verdes. Bosques. Banca financiera. Cambio climático. Conservación de los bosques. Marcos jurídicos.

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1. INTRODUCTION

Sustainable forest management and the prevention and mitigation of the problem of deforestation are impossible without the use of green technology. It covers a broad concept of technology and approach that aim at minimizing on the risks that are affecting the natural environment, the sustainability of resources as well as the stability of ecosystems.

In forest industry, applications in green technology including satellite, aerial photography and GIS assist in the measurements of forest cover loss, acts of illegality in logging and state of the forests. This is helpful to the authorities because it allows them to have accurate data of enforcement of environmental policies at real time. Besides, green technologies enable environmental-preservation practices such as agroforestry together with ecological logging. Agroforestry practices will involve growing of trees with other crops so that people will not have to cut down trees from the forests due to other sources of income.

Similarly, sustainable logging practices, like selective cutting also helps in the aspect that only trees that are old enough to be processed are cut down to allow for the growth of trees in the same region. Biotechnology also is also very useful in this process through advanced encouragement of reforestation and afforestation schemes. Intensive research is under way to try to develop

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genetically modified tree species that would grow more rapidly, thereby assisting in preparing ecosystems in need of rehabilitation.

Further, carbon capture solutions such as biochar and carbon storage across forest, play significant role in mitigating Green House Gases (GHG) which cause global warming. Green technology educates consumers and makes them independent of ill-advised traditional companies that continue to harm the environment. It promotes the conservation of forests comprehensively including the environment, economy of local communities and the climate.

India and areas of Southeast Asia are among some of the richest when it comes to biodiverse and carbon rich forests. Altogether, these regions contain a large share of global inventory of forest area that provides a crucial service in carbon storage. Forest cover in India is around 21.7 percent of the geographical area, comprising tropical, temperate and sub tropical forests that provide carbon reserves. Such forests help fight climate change as they sequester millions of tons of carbon dioxide produced in the atmosphere every year. (Prins et al.2023)

Malaysia, together with other countries in Southeast Asia, is also a major player in the carbon sink as possessing large areas of tropical rainforests. Indonesia, Malaysia and the Philippines have large forests acting as reservoirs of carbon that help control climate. These areas of forests are biologically diverse, which support diverse numbers of species, especially the most vulnerable ones like the orangutans, tigers, and elephants. The forests' species are not only important for sustaining species diversity around the globe but also for the adaptation of such areas to climatic change. (Murphy, 2024)
Deforestation, logging, and land transformation for consistent agriculture in both India and the Southeast Asia region have caused high levels of carbon emissions and reduced biodiversity. But these regions are also a focus of global conservation initiatives. REDD+ (Reducing emissions from deforestation and forest degradation in developing countries) is a strategy to protect these carbon sinks and encourage sustainable use of the land while providing financial reward for preservation of the forests.

Apart from playing an important role of carbon stock, the forests offer other services including water supply, soil and nutrient conservation, air quality, and are the source of livelihood for millions of people in the region. Global

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challenges on environment are present many of them are symbiotic; there is for instance deforestation, loss of species, and global warming. The converse is the deforestation due to agricultural production, non-legal logging and the expansion of urban infrastructure.

Similarly, the emission of carbon and the destruction of the forests lead to the loss of habitats, organisms, and the disruption of ecological systems. In areas such as Southeast Asia, and in India in particular, deforestation continues to be a major problem at a very fast rate, and this means that important sources of plant and animals many of which can be useful in the development of medicine, or in the improvement of agriculture and hence food security are being lost. Another important issue that exists globally is that of loss of biodiversity. The world's bio-geo clusters-such as the forests, wetlands, and marine habitats-are endowed with millions of species most of which remain unrecognized to date. The extinction of these species is evident after ecosystem destruction leads to inability of the ecosystems to counter climate change impacts.

About 27% of our diet depends on biological resources for pollination, pest control and natural diseases that are critical to food security. They are also worsened by climate change impacts that are associated with natural environmental crises. Global warming, climatic volatility and calamities such as floods, droughts and heat bursts are some of the factors that negatively affect both ecosystem and human institutions.

While forests particularly tropical forests play a central role in reducing emissions through sequestration of carbon, they are a source of emissions when carbon stored in them is relinquished through deforestation and degradation. There is an evident need for sustainable intervention. Failure to act now on forest conservation, protection and restoration, halting the loss of biodiversity, and tackling climate change means the future is set for further global ecosystem destruction and for future generations.

Incomes such as the green technologies, sustainable land use practices, and better polices of conservation are likely to help get over these trends and for the development of a better future. (Agarwal et al. 2014)

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2. CURRENT REGULATORY FRAMEWORKS FOR FOREST CONSERVATION

National Forest Policy (1988): The National Forest Policy formulated in 1988 also envisages the policy of sustainable forest management of forests, restoration of degraded forests, afforestation and wise utilization of forest resources. Its purpose involves enhancing sustainability, rational use and protection of the forest resources; and increasing the contribution of forests to livelihoods and the involvement of people in forests.

Another key focus of the policy is the emphasis on carbon capture and storage as a measure to fight climate change. This highlights the growing importance of forests in mitigating environmental impacts and promoting long-term sustainability.

Forest Conservation Act (1980): The FC Act 1980 was passed to see that no alteration of forest for other uses the purpose is allowed without the consent of the central government. This law provides that no part of the forest land shall be used for any other purpose other than forestry purposes except where there is a demonstration of a national interest. The Act is particularly important for protecting forests because the government has to assess the impact of the use of forest land before allowing its use. (PIB 2010)

Biological Diversity Act (2002): Significant effort put to the regulation of biological diversity in India is the Biological Diversity Act, which deals with the conservation of biological Diversity, sustainable use of biological resources and sharing of benefits arising out of use of biological resources in a fair and equitable manner. The Act proclaims institutions and procedures regarding ecosystems conservation, genetic resources, and species, with special emphasis on the importance of the involvement of the local communities. This Act supports forest conservation by encouraging the conservation of biological diversity within forested habitats.

Minister of Environment, Forest and Climate Change (MoEFCC) has an important role in Formulating and Implementing the Forest Policy and further Promotion of Green Technology in India. The MoEFCC has been accorded a prime responsibility in the country's forest policy as well as incorporation of measures that seek to adopt green technologies in the protection and preservation of forests in the country. The MoEFCC is department which was

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formulated to execute the environmental policy regime of the country to rightly manage the environmental affairs of forest estate management for sustainable production, and wildlife biodiversity and climate change. (PIB, 2022)

Policy and Regulatory Role: It outlines the MoEFCC's complementary role in deciding the National Forest Policy and in implementing other significant acts including the Forest Conservation Act and the Biological Diversity Act in the country. It makes sure appropriate local forest policies match with India's sustainable development objectives and its signed global environmental conventions. (PIB, 2010)

Forest Management and Green Technology: Recently the MoEFCC have implemented many steps to incorporate the green technologies into Forest Conservation. To implement measures set in the Green India Mission under the National Action Plan on Climate Change, the ministry has promoted the use of remote sensing, GIS and drone surveillance in assessing extent of forest and identify cases of illicit felling of trees or clearing of forests. All these technologies assist in real-time observation, monitoring, and evaluation of resources in a given forest as well as data collection for improved forest conservation. (MoEFCC, 2016)

Promoting Sustainable Forest Management: The MoEFCC promotes responsible forest management including Agroforestry and Community Forest Rights for practice of forest management by the community. The Ministry also supports the bioenergy and agroforestry technologies that present the different approaches of using the forest resources in a sustainable manner other than destructive logging. (Rawat et. al., 2008)

Climate Change Adaptation and Mitigation: Another ministry under MoEFCC is also engrossed in India's signatory to the principles of Paris Agreement where a special emphasis has been given to the role of forests in carbon storage. The ministry of environment supports afforestation, reforestation, and the regeneration of degraded ecosystem in order to improve the carbon stocks of India. Also, the ministry operates on policy for the elimination of carbon emission from deforestation and land degradation through REDD+ that encourages the maintenance of forest resources. (MoEFCC, 2021)

Therefore, through an effective cooperation between forest policy and green technologies, the MoEFCC will enhance its efforts to protect forests, promote

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the conservation of biological diversity and support the national and international climate change policies.

Figure 1, summarizes the current regulatory framework for Forest Conservation.

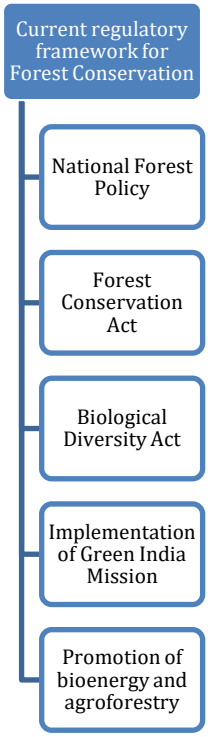

Fig. 1: Current regulatory framework for Forest Conservation

2.1. Asean's political environment and legal regulations

The conservation of forests in Southeast Asia is rationalized by both the regional and national laws. The ASEAN (Association of Southeast Asian Nations) organisation stands notably for environmental protection and cooperation within the region concerning the forests management.

ASEAN Environmental Frameworks: ASEAN has implemented several environmental frameworks for the proper utilization of forest and conservation of biodiversity. One of the most important regional treaties is the ASEAN Agreement on Transboundary Haze Pollution adopted in 2002. This agreement specifically addresses the issue of forest fires, particularly those caused by the slash-and-burn method used for field clearing.

The Prohibition of Smoke Haze Pollution and Control of Transboundary Haze from Burning Fires in Asia centres on the management of the smoke haze pollution. It ensures that members of Association of Southeast Asian Nations

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exercise regional cooperation in preventing and combating cases of environmental degradation caused by burning of forest lands which is experienced frequently in the participating countries such as Indonesia and Malaysia. (UNEP, 2024)

ASEAN Cooperation on Forests: ASEAN also launched the ASEAN Forest Cooperation (AFoCo), aim of which is the promotion of effective forest management for sustainable use, prevention of deforestation as well as to strengthen regional cooperation in ASEAN's forest related initiatives. The AFoCo framework promotes the utilisation of green technologies and sustainable systems such as reforestation technologies, forest certification and community-based forest management. (AFoCO, n. d.)

ASEAN Agreement on Transboundary Haze Pollution: Due to this agreement, the annual haze crisis due to acts of illegal land and forest fires especially in Indonesia zone has been solved. It calls upon countries to avoid burning forests and encourages the formation of policies that offer sustainable strategies for land use; seeks to minimize the environmental effects of such fires, seven of which are identified as being destructive to the biosphere thus contributing to environmental pollution and global warming. (ASEAN, n. d.)

Countries in Southeast Asia such as Indonesia, Malaysia and Thailand have set national policies in conserving forests and the promotion of green technologies.

Indonesia: The Republic of Indonesia that has more than 2 million hectares of rainforest reserves is experiencing a severe threat to deforestation caused by palm oil plantations and a high prevalence of illegal logging. Nor has the Indonesian government failed to act to address the problem; it has put measures such as the Moratorium on New Forest Clearing and the Indonesian Forest Carbon Partnership in place to combat the problem. Modern green technologies of satellite monitoring and aerial filming are widely employed to monitor forest clearing for violation of copyrights for logging. Also, Indonesia is focusing on the expansion of other palm oil farming and other crop growing practices which are not hazardous to the forests. (Gunawan et al. 2024)

Malaysia: Through the National Forestry Policy, Malaysia has laid down its basic framework of protection of forests and sustainable forest management. It is applying technologies like certified sustainable timber and forest certification system in the hope that it would reduce on the chances of the country being exposed to deforestation through the sale of timber. It is also promoting green technology in its palm oil production like the sustainable palm oil that does not affect the expansion of plantation on the forests of Malaysia. REDD+ is the

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tangible effort focused on reducing emissions from deforestation and forest degradation in the country. (Chen Ng et al., 2022)

Thailand: Generally, the current policies of the government of Thailand is directed on enhancing of forest cover and fight against the processes of deforestation. The yardsticks adopted by the country, include reforestation, whereby trees are planted to replace those that have been cut, and community-based forest management, where villages are involved in the management of the forests. Thailand requires green technology in the implementation of geo-spatial technologies for monitoring, mapping, and detection of forest fires. These nations are trying to attain the sustainable development whereby economic growth is attained side by side with conservation of the forest, an effort that has put emphasis on green technology to lessen the impacts that are implicated by extraction of the forest resources. (World Bank, 2016)

Figure 2, below, illustrates the key components of the environmental governance and cooperation framework within ASEAN regarding forest management and green technology.

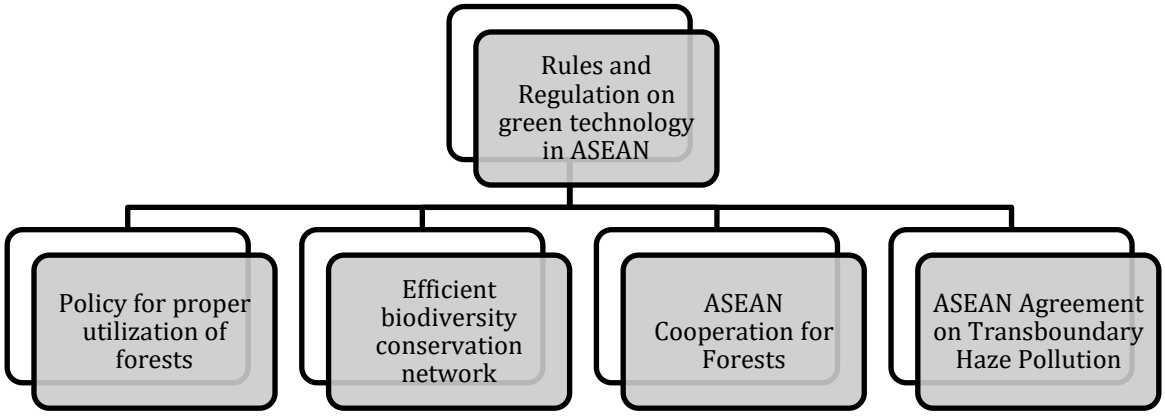

Fig. 2: Rules and Regulation on green technology in ASEAN

2.2. International treaties and frameworks

The foundation of global action is the Paris Agreement (2015) – an international treaty on climate change that seeks to limit the global temperature increase to below 2° C, with a preference for 1.5° C, due to obligatory reduction of emission of greenhouse gases. The forests are central to this deal because they are used as carbon offsets, which reduces the effects of climate change.

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India's Nationally Determined Contributions (NDCs) and most of the other countries aim to address climate change through permanent forest preservation. India, for instance, has committed to growing its forested area and raising the level of carbon stock through the planting of more trees under re-afforestation campaigns.

The intention of the Paris Agreement is to prevent deforestation, and land degradation, as well as to support the restoring of degraded land and improving the sustainable land management to improve the storage of carbon in the forests. Furthermore, the agreement encourages countries to formulate and include forestry management strategies in their national Climate Change mitigation and adaptation strategies as part of overriding global Climate Change targets. (Denchak, 2021)

2.3. United Nations REDD+ Program and Its Implication to the Forests

UN REDD+ strategy is an important international instrument of the United Nations for motivating the countries of the third world to conserve their forests. REDD+ embraces concept, which involves paying countries to avoid emitting greenhouse gases from deforestation and forest degradation and to conserve and maintain forests. It does this by providing funding to developing nations that integrate policy and measures to minimise deforestation in addition to boosting the levels of carbon density of their forests. (UNEP, n. d.)

For tropically forested nations, REDD+ can therefore be regarded as mechanism for earning revenues from the provision of ecosystem goods and services without having to undertake destructive forest exploitation or conversion. The kind of policy borrowing pointed to should be seen as the long-standing adaptation of policy and regulatory ideas filling out national policies where, for example, Indonesia, Brazil, and India can improve forest conservation and global climate change mitigation. (Butler, n. d.)

REDD+ also aims at promoting community involvement because stakeholders of local communities are involved in the use of sustainable forests. It makes forest-dependent benefit from practicing sustainable practices and contribute to fight against climate change at the international level. Some of the meanings that REDD+ has for forest regions are better governance of the forest and

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better monitoring and use of green technology to get accurate measurement and verification of carbon stocks. (Pandey et al., 2024)

2.4. Challenges in current regulatory and policy frameworks

Policy implementation inconsistency means that policies can be instituted but their implementation is not coherent, thus goes against forest conservation policies. The laws are hardly implemented in countries such as India and most of the South-East Asian countries and different actors from public to private sectors to local community groups may have contradictory motives.

Most of the policies developed to address issues of forest conservation may be noble but they may fail due to poor coordination between the central and other levels of government, insufficient funding or interference by politicians. For instance, the MoEFCC in India might provide a set of directives for forest conservation, but either the state-level authorities and subordinate regional bodies cannot or will not apply these laws.

Moreover, the process of forest policy disregards the rights of indigenous people who are the direct stakeholders in policies related to land usage but whose voice is rarely heard and considered. This has a dysfunctional model, in which local communities are sometimes locked out of the policies on tenure and governance of forests in which they are the main stakeholders.

Likewise, in Southeast Asia whereas instruments like the ASEAN Agreement on Transboundary Haze Pollution exist, implementation remains a major issue especially in countries, which are notorious for forest fires and Illegal logging. Multiple government departments, as well as a lack of synchronisation between national governments and local politics, are the factors that lead to policy fragmentation. This makes it difficult to respond to several interrelated problems such as deforestation, land degradation, and loss of biological diversity. (Marquardt et al., 2023)

Coordinated action by central, state and local governments, communities, and the private sector is necessary for implementation of public policies. It also requires adequate financial and human resources, clear reporting procedures, and a systematic approach regarding monitoring the actual implementation of conservation laws and possessing sufficiently stringent guidelines to safely

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reduce policy rigidity and instability on the environment. (Zabel & Hausler, 2024)

One of the major problems facing forest conservation is deforestation, and reforestation-conflicting uses of the land remain a critical issue in the conservation of forest habitat for most portions of the world, especially developing landscapes like Southeast Asia and India. These conflicts occur when for instance, agricultural expansion, urban development, industrialization and conservation leads to over utilisation of forest resources or loss of ecological systems.

In India, agricultural expansion is often cited as the primary reason for deforestation, as it is the fastest-growing sector in the country. Farmers often engage in deforestation to prepare land for farming or to create grazing areas for livestock due to the rarity of fertile land. The conflict is facilitated by land-use policies where there is licence for the expansion of agricultural production without ideological impacts.

Urban development is another growing pressure on forested areas, as cities expand, and infrastructure projects encroach on natural habitats. This further fragment the living spaces of wildlife, making it difficult for species to thrive. Similarly, large-scale commercial farming across Southeast Asia including palm oil, rubber and timber farming have been attributed to deforestation. It is produced from oils extracted from crops and mainly cultivated in Indonesia and Malaysia where forests are cut down to pave way for these crops, thus causing extensive loss of species and hazy weather of the region.

Sustainable economic development, based on industrialized agricultural practices results in the overall neglect and destruction of forests. This creates a dilemma: while forest conservation is promoted as a key to a long-term well-being, if often feels like a catch-22 situation. The push for conservation becomes increasingly difficult when it conflicts with the demands of economic growth and industrialized agriculture, making it less of a "win-win" solution as initially hoped. (Scheidel & Gingrich, 2020)

Increased resource competition does lead to land-use conflicts over resources such as water, pastures or grazing lands, timber or minerals, due to unsubstantial tenure systems that local people, especially indigenous ones, have

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over their land. As a result, there is no legal protection on such rights; individuals can be forcibly evicted and traditional means of living eliminated.

Local people, mostly Indigenous people believe in sustainable land management but many a time their voices go unnoticed due to many corporate industries and unsustainable policies and legislation that advance short term economic benefits.

Solving these issues can only be achieved through the multi-actor approach that will have to address the interests of business and development, indigenous people, and conservation. Long term solutions on mitigating these conflicts include formulation and implementation of sustainable agriculture policies, reforestation policies, and recognized territorial rights for the indigenous people. (Bergius et al., 2020).

The European Union (EU) 2023/1115 on deforestation-free products is poised to significantly impact Asian countries that export raw materials, particularly those involved in the production of palm oil, soy, coffee, cocoa, rubber, and wood products. This regulation aims to curb deforestation and promote sustainable practices in global supply chains. To comply, products must not contribute to deforestation or forest degradation after December 31, 2020, and commodities must be produced in accordance with the relevant laws of the country of origin. Asian countries that export raw materials will need to adapt to these new regulations to maintain access to the EU market. This may involve implementing sustainable practices, ensuring compliance with local laws, and providing detailed information about their supply chains. Companies will also be required to conduct due diligence to ensure that their supply chains are deforestation-free and compliant with local laws. This will involve collecting detailed information about suppliers, assessing and mitigating risks, and maintaining documentation for at least five years. While the regulation presents challenges for Asian countries and companies, it also offers opportunities for sustainable growth and development. By adopting deforestation-free practices, companies can reduce their environmental impact, improve their reputation, and maintain access to the EU market. Ultimately, the regulation has the potential to promote sustainable and responsible trade practices, benefiting both the environment and the economies of Asian countries. (van Noordwijk et. al., 2025)

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Figure 3 represents the main challenges faced in the current regulatory and policy framework for forest conservation. These interrelated issues create barriers to the successful implementation of forest conservation policies, making it difficult to balance environmental protection with economic development needs.

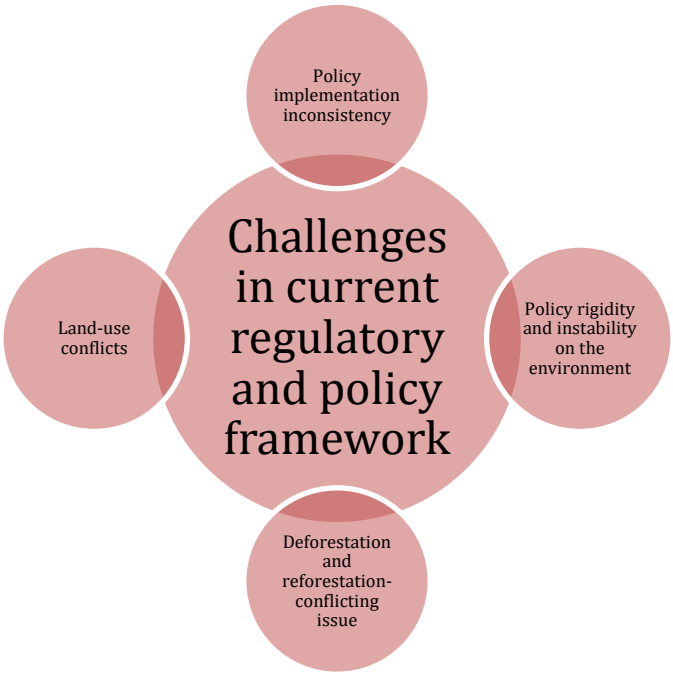

Fig. 3: Challenges in current regulatory and policy framework

3. USE OF TECHNOLOGY

Lack of technological use is one of the biggest issues in preventing forest protection especially in the developing part of the world such as India and Asia. Although green technologies are opportunities to redesign forest management, their adoption and incorporation into the existing forest conservation paradigms remains a challenge.

As a result, it is fairly apparent that the technological application is inconsequential and deficient in several ways, for example, in the observing and implementing of the forest protection laws. Technologically enhanced methods such as satellite imagery, GIS, and drone-based methods may help to gather information on the current frontier in deforestation, unlawful logging, and forest health. However, these technologies though exist in several countries they are under exploited due to high costs, inadequate technical requirements and limited human resources.

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For example, although India's MoEFCC has trailed satellite-based monitoring technologies, the adoption of such tools is still tiny because the country's budget does not allow for extensive investments in this sector and many rural forests lack technical support. In countries such as Indonesia and Malaysia have gradually accepted the usage of satellite monitoring to monitor forest loss, but the technologies are disjointed and there is not always a proper coordination of relevant data and information can flow between one agency to another.

Further, there is a notable lack of application of technology on sustainable use of land resource. Sustainable timber production, bioenergy use of forest residues, and precision agriculture can greatly minimize environmental harm, though the application of these advances is limited because individuals and local communities as well as policymakers have limited awareness, funding, and expertise.

Another major challenge is the lack of cooperation from local clans who have been used to following traditional forms of forest governance. As a result, countering this resistance entails proper capacity development, conduct of technical skills and adequate training of end users and stakeholders about affordability, ease and relevance of green technologies at the end user level.

To overcome these barriers characteristic for developing countries, governments and Non-Governmental Organizations should concentrate on applying modern techniques in the sphere of forest management, invest into improving capacities of employees, and encourage collaboration with private sector to promote application of sustainable practices. Policy initiatives and international cooperation may also be used as vehicles in the improvement of the technological advancement in the management of forests. (Raihan, 2023)

Figure 4 highlights the key areas where technology is applied in modern forest management practices.

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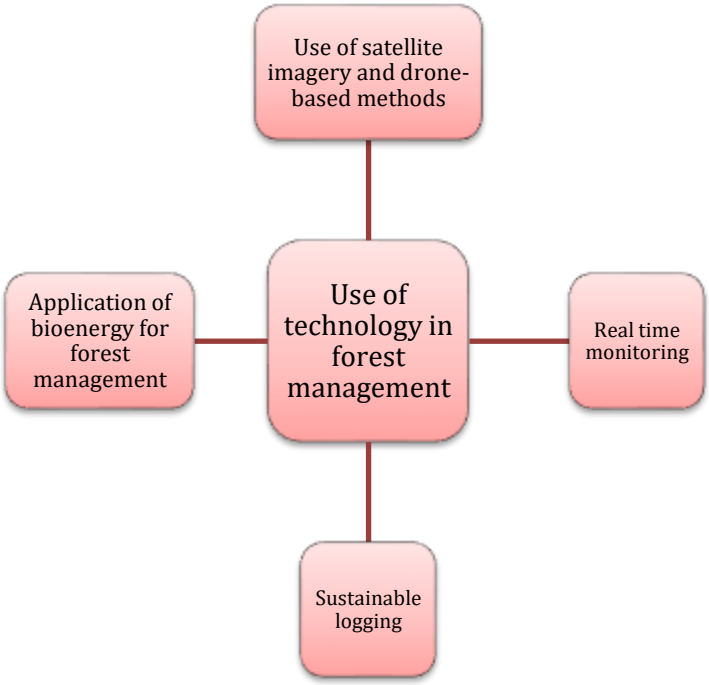

Fig. 4: Application of technology in sustainable forest management

3.1. Potential of Green Technology in Forest Management and Conservation

Green technology has become a forceful weapon that can be adopted in the search for sustainable utilization and protection of forests. With increased environmental concerns such as deforestation, loss of biodiversity and climate change, green technology provides a chance to introducing new products that fit the global challenges and achieve both the environmental and economical goals for society.

If well harnessed, green technology in the management of forests has the potential of increasing the effectiveness of the conservation processes, mitigating on the negative impacts of the environment to the forests and generally improving on the sustainability of the forest resources. The area where green technology has provided a great benefit to the management of the forests is in the area of detection and information gathering. Real-time follow up on health and deforestation using technologies like remote sensing, GIS, satellite images.

These technologies make it possible for the forest managers and policy makers to monitor the level of illegal loggers, to identify areas that are prone to fire and to assess the overall change in the forest cover in an incredibly short time span. For instance, the development of satellite-based systems such as the Global Forest Watch platform the enables a follow up of current data on deforestation

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based on which it is possible to notice illicit acts of logging in a certain forested area which was previously inaccessible.

By utilizing these technologies, forest management agencies are better equipped to respond to threats as they arise, prevent further damage, and enforce policies effectively. (Feigin et al., 2023)
Besides the monitoring function, green technologies facilitate the restoration and protection of degraded forest ecosystems. Sustainable forestation and afforestation-have key actions towards the replenishment of the world's canopies-automation like; drone seeding and planting. Large quantities of tree seeds can be planted in a relatively short period by drones especially in large scaled afforestation in the hard to reach region.

These technologies do not only hasten the restoration process but also raise the possibilities of establishing plants through right environmental conditions which improves forest regeneration. Yet another field where green technology holds potential for refined work is the cleanest forestry for foresting forests. These include timber, fuelwood, and non-timber forest products whose use is a challenge due to overexploitation of the forest resources.

Efficiency can therefore be used to balance resource extraction, using green technologies like precision forestry tools. For instance, laser scanning and drones with LiDAR can map density and structure of the forest that will allow to manage the forest resources and decide what trees, and when, should be cut. These results reduce wastage and guarantee that the practice of the following harvest is proper in maintaining the forest for the next generations. (TraceX, 2023)

Green technologies can enhance the change of more sustainable land-use practices in agriculture and other related sectors. In nations where deforestation is because of agriculture, innovational methods such as agroforestry and precision farming can offer similar revenues sources for farmers without the need to cut down trees.

Agroforestry offers several benefits, including the integration of trees within crop production systems, which enhances biological culture, soil health, and boosts carbon levels in the ecosystem. Unlike traditional agriculture – which often has a destructive effect on soil, water, and living organisms while damaging the surrounding forests – agroforestry promotes sustainability.

Precision agriculture serves as another example of how green technologies can transform farming. By leveraging data technologies, farmer can minimize the use of water, fertilizers, and pesticides, which not only optimizes harvests but

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also reduces environmental harm. This innovative approach mitigates the negative impacts of traditional farming on forests and ecosystems.

Green technology also plays a crucial role in combating forest fires, which pose a serious threat to forest ecosystems worldwide. Early detection of fires is now possible through satellite-based fire monitoring, and ground-based sensors. These fire detection technologies help in early detection hence faster response as flames do not spread.

Further, the fire prevention systems incorporating data on weather conditions moisture contents in the foliage vegetation can determine potential fire risks and undertake measures like fire generators or the removal of flammable vegetation. These technologies are very useful in controlling risks on forest fires especially in areas that may be affected by climate change that causes instance wildfires. (Konfo et al., 2024)

Innovative advances such as the green technology is significant in ensuring that forest conservation agenda do not break the financial back. One of the key challenges hindering the protection of tropical forest is the lack of adequate financial support for conservation initiatives. New mechanisms such as carbon trading and Payment for Ecosystem Services (PES), offer sustainable solutions to this challenge. These systems pay for the protection of forests, allowing forest owners and nations to sell credits for preserving forests that absorb carbon, thereby contributing the fight against climate change.

The carbon credits may then be sold to other firms or government whose aim is to reduce their emission of greenhouse gases. Likewise, PES schemes provide incentives such as financial incentives to landowners or communities practicing appropriate sustainable forest management practices to promote and practically make forest conservation financially sustainable. (Edwards et al., 2019)

Therefore, utilization of green technology in the management of forests accelerates when there is incorporation of the local community. Technology assisted community-based forest management results when the forest target groups are encouraged to play an active role in the management of the forests. It is possible to use technologies to control the forest condition, identify species and distribution, and effectively manage the resources.

With green technology, various communities can receive tools such as mobile applications, drones, GPS devices, so that they can also participate actively in sustainable forest use and hope that the conservation programs will be in concordance with their knowledge. It is, however, crucial to clarify that green technology as applied to the forest management and conservation can open also

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a vast number of opportunities which needs, however, stable and favourable policies, good governance, appropriate public- private partnerships. Superpowers and international organizations need to put more efforts in Research and Development to ensure that environmentally friendly technologies cost low to ensure countries especially the developing ones embrace them. Finally, capacity-building is vital to support education learning to enable local people to use these technologies meaningfully by those involved in forest management. (Ota et al., 2020).

Figure 5, below, illustrates the various opportunities offered by green technology in the sustainable management and conservation of forest ecosystems.

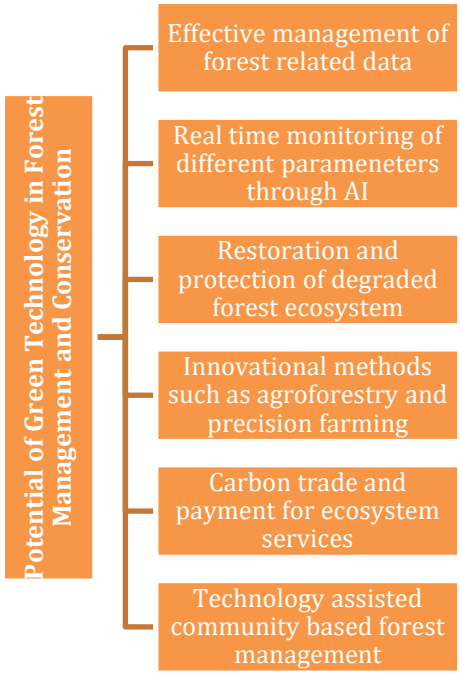

Fig. 5: Potential of Green Technology in Forest Management and Conservation

3.2. Policy Implications for Robust Green Technology Application

There is a lot of potential for green technologies in the domain of forest management and conservation, yet for the latter to work, it is a pre-requisite that these need supportive policies. There is a need for comprehensive policies for the development of green technology solutions for various sectors of an economy as well as for their implementation. These policies require being broadly defined to encompass not only the technology requirements, but also the environmental, social and economic environments in which these technologies are applied. In their absence the effectiveness of such technologies and equipment is unlikely to be achieved. (Prins et al., 2023)

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Perhaps one of the most significant policy barriers to the application of green technology for forest conservation is the bureaucratic framework that often slows progress. Government should thus provide laws that provide a clear policy on forests management and should also be able to be enforced to the letter. This also includes development of protocols for assessing the status of the forest, capacity in storing carbon as well as supervision of the extraction of other resources. The use of satellite imagery, drones and other tools can be encouraged through legal provision that mandates reporting of deforestation, log cutting and forest burning in real-time. A favourable policy environment guarantees that more of these technologies are not just mere 'nice to have' instruments in forest management and conservation, but framework enablers in those contexts.

Beside regulation, the few well established financial incentives contribute to green technologies enhancement regarding their utilization. There is a need for public and private partners to develop financial structures that can ensure better access to green technologies among managers, communities and businesses in the forests. Subsidies, grant funding and concessional credit are examples of the financial incentives that can help reduce the requirement of upfront capital investment in green technologies, especially in less developed regions where lack of capital may be a major factor deterring the promotion of green technologies.

Moreover, governments could introduce carbon credits or payment for ecosystem services (PES), the latter allowing those that extend forests employing green advances to be financially compensated. Some of these included have been known to support sustainable management activities by checking the costs and providing sustainable benefits to the communities and forest managers. (Shah, 2023)

Governments should support changes that promote research and development (R&D) in green technologies so that innovations would make these green technologies affordable. Policy makers in governments, industry and academia need to continue to invest in, at least, precision forestry, sustainable timber production and restoration of forest damaged by calamities. Thus, through investing in innovation, policies increased chances of achieving scale economies in the deployment of green technologies to the users. At the same time, the R&D can provide more specific information of the ways to apply those technologies adapted to the local environment, which also plays an important role of implementing those dependable technologies in various forest ecosystems.

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Capacity development and education are the critical elements to the ability to implement green technologies. These technologies can be improved with a solid governmental and international organizations investment in training programs that can raise the awareness of local communities, forest managers, and policymakers about the uses and values of these technologies. It is crucial to establish top-down conservation while also giving local populations tools to want to save the planet, to use eco-friendly technologies and achieve sustainable development more effectively.

For example, capacity building in the use of satellite tools, drones and GIS for example, would enable local forest managers keep better track of their forest resources, and to identify early onset of any unlawful incidence. In the long term, such training will go a long way towards establishing an innovation culture that promotes adoption of technology among the local players. (Ikram & Sadki, 2024)

A policy approach also needs to include green technology at the intersection of environmental and development policies. Measures should integrate its goals of promoting forest protection with national emission reduction goals under climate change, strategies for country's further economic growth, and programs for species preservation.

Sustainable land management practices and agroforestry are part of green technology that can contribute to the fulfilment of these wider objectives, since they relieve the pressure on forests and at the same time offer income-generation opportunities for the communities involved. Environmental management should not be seen as a sub strategy or an appendage to development blueprints but should form an integral part of development blueprints so that forest preservation and economic growth are complementary. This approach can eliminate areas of conflict and inconsistency between the development and the conservation, thus, supplying a better, sound and sustainable answer to the issues of deforestation and land degradation. (Dwivedi et al., 2022)

Solidarity and information exchange is critical when fostering the use of green technologies on the international level. Most countries responding to the survey are in the similar position as many countries in Southeast Asia and Sub-Saharan Africa grappling with issues of deforestation, and/or illegal logging in degraded forests. At the global level, through United Nation's REDD+ program or the Convention on Biological Diversity, countries learn, adopt and implement the best practices in the management of forests. Global collaboration also proves beneficial in the search of fund sources to finance big projects intended for the environment, particularly to those countries that have little capital.

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Some of the problems of forest management are the transboundary problems which may include the fire and the cutting of trees at cross border areas, habitat diminishing and many others. By these reasons, countries in the region may need to come up with joint solution to manage the forest through employing the technological solutions and measures on the same manners.

Community awareness and support are another prerequisite to policies on green technology. Members of the public together with governments, NGOs, and organizations should begin to spread awareness of green technologies that are useful in protecting forests. Through public campaigns, consumers, businesses, and policymakers can be informed about sustainable forest management promoting greater use of eco-products and services.Unfortunately, the level of educated populaces at a given time denotes that once informed, the public forms capable bottom-up pressure for change that can compel industries and policymakers to be sustainable. (TraceX, 2024).

Figure 6, summarizes the policy implications for robust green technology applications as described in the text.

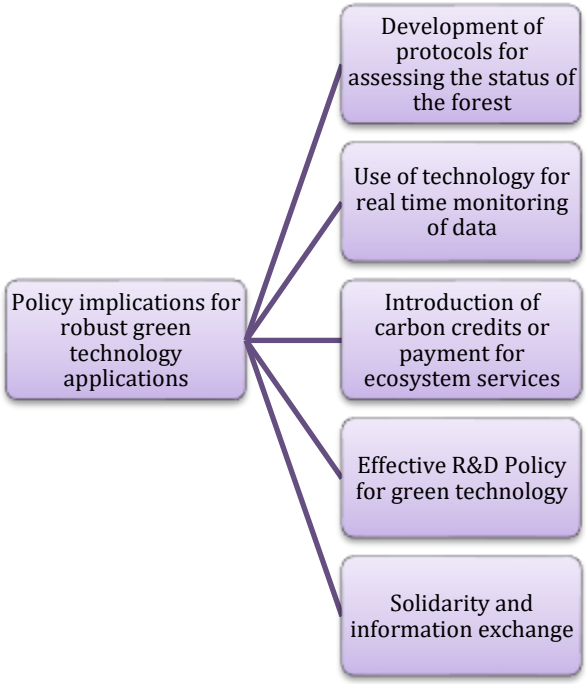

Fig. 6: Policy implications for robust green technology applications

3.3. Green Governance: Integrating Green Technology into Policy Making

Green governance can be explained as the process of implementing environmental sustainability objectives in running governance systems,

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exercising decision making, policymaking and undertaking other functions with the view of promoting ecological balance in the long run. Green governing which is the incorporation of green technology in policy making is an important aspect which is needed so as to ensure that leaders embrace green technology to solve the various environmental problems such as deforestation, pollution and climate change among others.

This integration not only improves the efficiency of a policy but also makes sure that the modern technologies are utilized to fulfil other sustainability objectives. If green technology is to be integrated into the policy sector, governments should come up with policies that cater for sustainability on a global scale.

This involves including green technologies into national frameworks that deal with climate change management, conservation, and globally endowed economic development. For instance, the use of policies; renewable energy, agriculture, and forests should be complemented by applications of green technology; solar power, smart farming equipment, and satellite imagery of forest health respectively. As such, governments may establish linkages between these technologies so that they complement the objectives of the conservation society and meet technological demands. (Li et al.,2018)

Another important attribute when speaking about green governance is the establishment of green enabling environment to foster usage of green technologies. Great efforts have to be made to provide the sufficiently clear and stable framework as far as to provide proper motivation for businesses and industries to use sustainable technologies. This can include tax credits and subsidies for efficient power technologies as well as fair grants to companies managing renewable power technologies or tools.

Moreover, environmental regulations can only be enforced when and where there is technological support available. For example, using satellite imagery it is possible to monitor the violation such as illegal logging or deforestation and guarantee that law enforcement agencies will be able to respond promptly. (Wu & Tham, 2023)

Stake-holders have played a role in the development of this policy. Incorporation of green technologies is the central area of the collaboration of governmental organizations on the one hand and scientific institutions and private sector as well as countries' inhabitants on the other hand. In some cases, carbon control may be more effective not just if it is done as joint public-private partnership, but also when it can be introduced in a flexible and responsive manner to meet the specific needs of individual countries. This means that the

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communities' involvement in decision making especially those depending directly on natural resources can make policies to be more efficient, relevant and more so supportive of the green technology use. (Hamdan et al., 2021)

4. CASE STUDIES

Exploratory studies of green technologies in preservation and management of forests provide insights in usage of technologies in practical settings. These examples showed how innovation may address urgent environmental issues including deforestation, loss of biodiversity and climate changes while supporting economic growth.

This paper presents a well-known example of satellite-based monitoring systems employed by the Global Forest Watch (GFW) initiative. Built for governments, NGOs, companies and other stakeholders, GFW provides real-time satellite imagery to observe forest loss, and helps to evaluate the degree of deforestation with much greater precision. For example, the GFW platform was used effectively to monitor and record violation of the law on deforestation in Indonesia and Brazil. This has therefore resolved a problem of lack of appropriate information on forest protection laws for local governments to enforce as well as given the ability to shame corporations on their supply chain. (Weisse & Petersen, 2015)

This is a pilot project which has shown a lot of success in Kenya using drone technology to support reforestation. The World Wildlife Fund (WWF) hired drone companies to employ the aerial seeding technique that went on to rehabilitate vast areas of land. This means that instead of spending many days physically planting trees, seeds can be sown using drones in inaccessible regions with the aim of undertaking tree planting at a much faster pace due to the reduction of time and cost bearing in mind that human led planting immediately results in exhaustion. It has been most helpful in reforestation of areas that are hard to access and where vital ecosystems to acts as carbon reservoirs have been degraded. (Asher, 2023)

This has been applied in US especially in the Pacific Northwest and another example is precision forestry. The latest tools in the management of people's forests include LiDAR (Light Detection and Ranging) and drones to make maps of the structures of the forests, to identify the species, and, therefore, to organize the operations in logging with greater accuracy. This means that only trees that have met their maturity level and are ready to be sold in the market are cut down leaving the young trees to grow thus enhancing sustainable production of timber and regeneration of forests. (Hudak et al., 2009)

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These case studies demonstrate how green technologies can help to foster progress towards the goal of saving forests and, therefore, there is a need to see more investment and policies to promote the use of these technologies all over the world.

5. FUTURE DIRECTIONS

The future of forest conservation is built on the future development and application of green technologies, which will help monitor, protect, and recover forests. Where the climate change, the increased loss of biological diversity, and the rapid rate of deforestation are emerging challenges globally, green technologies will be becoming the key determinants of viable solutions. Thus, the future directions in this field will include the scaling up of regards technological applications, the improvement of the accessibility of technologies, and the integration of other industries.

AI and Machine learning are promising future directions for green technology for conservation of forests are in great potential. AI can give more value by integrating large amount of environmental data acquired by satellites, drones and sensor networks. It has been claimed that with the help of machine learning it is possible to predict the state of forests and detect preliminary signs of deforestation and declining level of biodiversity with a high degree of accuracy.

For instance, algorithms can use satellite images to filter out or instantly recognize instances of piracy in logging or areas prone for fire disasters in the forest. Many of these technologies can deliver information that forest managers can use to make better decisions and prompt interventions.
Moreover, with its help, it would be possible to make the processes of restoration of forests more effective. Even though reforestation or afforestation exists, the models will enable the AI systems to identify the best locale and climate for undertaking such projects. This can augment the efficacy of restoration strategy's goal for approaching new forests and they would be fit to grow in new climates.

The Internet of Things (IoT) is another technology that can enhance forest conservation performances greatly. IoT devices may include sensors in forested regions where information on temperature, humidity, moisture content of the soil and air quality could be acquired in real time. This stream of data can give an accurate picture of the status of ecosystems to the forest managers in real-time hence efficient means of combating calamities such as fires, pestilence or even unlawful enrichment of forests.

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For instance, by equipping sensors on Internet of Things (IoT), they can be used to keep checking on the areas of forests that are experiencing some early signs of disease or stress that are signs of larger environmental problem. Such sensors have the capability to activate automatic features in buildings to immediately notify local authorities when there is a fire thus allowing them to intervene before a small fire becomes a big problem. Also, IoT is helpful in tracking down the population densities of species while offering crucial information needed to protect species from endangered extinction.

The application of blockchain has great promising in regard with the problems associated with the illicit logging and irrational utilization of forest resources. Using blockchain, the source of origin of timber and other forest products can be followed from the point of production to the consumer. This technology can help ensure that products sourced for the market were gotten from sustainable sources hence limiting the demand for and use of ILO products. The future vision of blockchain usage indicates that consumers will be able to track back the footprint they have left on the environment when making a purchase.

For example, a consumer buying furniture might be able to use the platform built with the aid of a blockchain to check out the origin of the wood and ascertain that it was harvested from an accredited sustainable source. In carbon trading system, supposed credits from forest conservation and restoration projects are traded on an open and secure network which has the effect of giving motivation to fund forest protection.

In the case of the green technology in forests, the implementation of the tools depends not only on the different innovations in technology but the cooperation of governments, technology engineers, businesses, and forest people. Improvements in the future are going to require more coordinated action by different ministries and other actors in developing coherent policies and subsidies aimed at promoting the establishment of green technologies.

For example, political authorities will have to offer more encouragements for commercial companies and resident population to implement and practice sustainable policies and behaviours in the future. These policies may include provision of grant for cleaner technologies, provision of tax credits to sustainable businesses and supporting local development of conservation technologies. Moreover, more collaboration in terms of international relations will be important when it comes to the scaling of green technologies which are crucial in areas in the world most vulnerable to forest loss.

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Local people should therefore get involved in the use of the above technologies in conservation of the forests. Local people and especially those from indigenous and rural settings have many traditional practices and policies about forest and they can form an important policy in observation of forests- policy. Technology should continue to socially enable these communities, giving them the tools and the knowledge to make the most of green technologies. Integrating local people's knowledge with green technologies to managed forests proves to be more effective than the conventional approaches to forest management.

The trend towards sustainability in the financial sector means that green finance will play a major role in the implementation of green technologies in the preservation of the forests. The availability of green bonds, impact investments, and forest carbon credits as the tools for financing forest conservation will support the innovative use of the green technologies. These financial tools will ensure that funds for conservation are sourced while at the same time tying financial rewards of different businesses to the need to preserve the environment. However, over time, forest carbon markets might grow even more, which could result to more investment towards the forest conservation and restoration. These markets would create the financial motive for countries and businesses and communities to practice sustainable forest management to support global climate change goals. Furthermore, existing cooperation between financial institutions and technology companies may enable creation of green technologies, sustaining an infinite loop of development and investment necessary for long term environmental health.

6. CONCLUSION

Green technology can be a driving force for the process of revolution change in the field of forest conservation and management. When applied to forest governance, these innovations – AI, IoT, blockchain, green finance – can greatly improve monitoring and enforcement and boost sustainability. These technologies include real time data gathering, resource optimization and transparent provision of supply chain data in responding to challenges of increasing environmental degeneration especially deforestation and loss of biodiversity.

However, the success depends upon clear policies, financial incentives, and coordination among different tiers of government, industries, and subnational entities. So going forward one can suggest the following issues that will act as guidelines in policies of enshrinement of such technologies: Finally, by considering green technologies as instruments for the accomplishment of

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broader environmental and economic objectives it is possible to defend forests, fight climate change and advance sustainable development to allow forests fulfil their multiple ecological, social and economic functions for people in the present and in the future.

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