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Reforestation of Degraded Lands

[1]DR. REKHA MANDOWARA & [2]DR. KAMLESH RAWAT

[1]Principal, Government College, Raipur-Beawar, Rajasthan, India

[2]Department of Zoology, SD Government College, Beawar, Rajasthan, India

ABSTRACT: Reforestation is the natural or intentional restocking of existing forests and woodlands (forestation) that have been depleted, usually through deforestation but also after clearcutting.[1] Two important purposes of reforestation programs are for harvesting of wood or for climate change mitigation purposes.

For example, in the years 2012-2022 China restored more than 70 million hectares (700,000 km^2) of forests. China committed to plant and conserve 70 billion trees by the year 2030 as part of the Trillion Tree Campaign.[2]

KEYWORDS-reforestation, degraded, lands, climate change, campaign, wood, harvesting

I. INTRODUCTION

Reforestation means re-establishing forest that have either been cut down or lost due to natural causes, such as fire, storm, etc. According to FAO terminology the any type of reforestation activity does not contribute to an increase in forest area. Whereas, the term *afforestation* means establishing new forest on lands that were not forest before (e. g. abandoned agriculture).[3]

Purposes

For harvesting

Reforestation is not only used for recovery of accidentally destroyed forests. In some countries, such as Finland, many of the forests are *managed* by the wood products and pulp and paper industry. In such an arrangement, like other crops, trees are planted to replace those that have been cut. The Finnish Forest Act from 1996 obliges the forest to be replanted after felling.[4] In such circumstances, the industry can cut the trees in a way to allow easier reforestation. The wood products industry systematically replaces many of the trees it cuts, employing large numbers of summer workers for tree planting work. For example, in 2010, Weyerhaeuser reported planting 50 million seedlings.[5] However replanting an old-growth forest with a plantation is not replacing the old with the same characteristics in the new.[6]

In just 20 years, a teak plantation in Costa Rica can produce up to about 400 m^3 of wood per hectare. As the natural teak forests of Asia become more scarce or difficult to obtain, the prices commanded by plantation-grown teak grows higher every year. Other species, such as mahogany, grow more slowly than teak in Tropical America but are also extremely valuable. Faster growers include pine, eucalyptus, and *Gmelina*.[7]

Reforestation, if several indigenous species are used, can provide other benefits in addition to financial returns, including restoration of the soil, rejuvenation of local flora and fauna, and the capturing and sequestering of 38 tons of carbon dioxide per hectare per year.[8]

The reestablishment of forests is not just simple tree planting. Forests are made up of a community of species and they build dead organic matter into soils over time. A major tree-planting program could enhance the local climate and reduce the demands of burning large amounts of fossil fuels for cooling in the summer.[9]

For climate change mitigation

Forests are an important part of the global carbon cycle because trees and plants absorb carbon dioxide through photosynthesis. Therefore, they play an important role in climate change mitigation.[10]:37 By removing the greenhouse gas carbon dioxide from the air, forests function as terrestrial carbon sinks, meaning they store large amounts of carbon. At any time, forests account for as much as double the amount of carbon in the atmosphere.[11]:1456 Forests remove around three billion tons of carbon every year.[8] This amounts to about 30% of anthropogenic all carbon dioxide emissions.[12] Therefore, an increase in the overall forest cover around the world would mitigate global warming.

At the beginning of the 21st century, interest in reforestation grew over its potential to mitigate climate change. Even without displacing agriculture and cities, earth can sustain almost one billion hectares of new forests. This would

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remove 25% of carbon dioxide from the atmosphere and reduce its concentration to levels that existed in the early 20th century. A temperature rise of 1.5 degrees would reduce the area suitable for forests by 20% by the year 2050, because some tropical areas will become too hot.[13] The countries that have the most forest-ready land are: Russia, Canada, Brazil, Australia, the United States and China.[14]

The four major strategies are:

- Increase the amount of forested land through reforestation
- Increase density of existing forests at a stand and landscape scale
- Expand the use of forest products that sustainably replace fossil-fuel emissions
- Reduce carbon emissions caused by deforestation and degradation[11]:1456

The second strategy has to do with selecting species for tree-planting. In theory, planting any kind of tree to produce more forest cover would absorb more carbon dioxide from the atmosphere. However, a genetically modified variant might grow much faster than unmodified specimens.[15]:93 Some of these cultivars are under development. Such fast-growing trees would be planted for harvest and can absorb carbon dioxide faster than slower-growing trees.[15]:93

Impacts on temperature are affected by the location of the forest. For example, reforestation in boreal or subarctic regions has less impact on climate. This is because it substitutes a high-albedo, snow-dominated region with a lower-albedo forest canopy. By contrast, tropical reforestation projects lead to a positive change such as the formation of clouds. These clouds then reflect the sunlight, lowering temperatures.[11]:1457

Planting trees in tropical climates with wet seasons has another advantage. In such a setting, trees grow more quickly (fixing more carbon) because they can grow year-round. Trees in tropical climates have, on average, larger, brighter, and more abundant leaves than non-tropical climates. A study of the girth of 70,000 trees across Africa has shown that tropical forests fix more carbon dioxide pollution than previously realized. The research suggested almost one fifth of fossil fuel emissions are absorbed by forests across Africa, Amazonia and Asia. Simon Lewis stated, "Tropical forest trees are absorbing about 18% of the carbon dioxide added to the atmosphere each year from burning fossil fuels, substantially buffering the rate of change."[16]

As of 2008 1.3 billion hectares of tropical regions were deforested every year. Reducing this would reduce the amount of planting needed to achieve a given degree of mitigation.[11]:1456

Comparison to forest protection

Researchers have found that, in terms of environmental services, it is better to avoid deforestation than to allow for deforestation to subsequently reforest, as the former leads to irreversible effects in terms of biodiversity loss and soil degradation.[17] Furthermore, the probability that legacy carbon will be released from soil is higher in younger boreal forest.[18] Global greenhouse gas emissions caused by damage to tropical rainforests may have been substantially underestimated until around 2019.[19] Additionally, the effects of af- or reforestation will be farther in the future than keeping existing forests intact.[20] It takes much longer − several decades − for the benefits for global warming to manifest to the same carbon sequestration benefits from mature trees in tropical forests and hence from limiting deforestation.[21] Therefore, scientists consider "the protection and recovery of carbon-rich and long-lived ecosystems, especially natural forests" to be "the major climate solution".[22]

Methods

A study finds that almost 300 million people live on tropical forest restoration opportunity land in the Global South, constituting a large share of low-income countries' populations, and argues for prioritized inclusion of "local communities" in forest restoration projects.[23][24][25]

Over 90% of the world's forests regenerate organically, and more than half are covered by forest management plans or equivalents.[26][27]

Using existing trees and roots

Planting new trees often leads to up to 90% of seedlings failing. However, even in deforested areas, existing root systems often exist. Growth can be accelerated by pruning and coppicing where a few branches of new shoots are cut and often used for charcoal, itself a major driver of deforestation. Since new seeds are not planted, it is cheaper. Additionally, they are much more likely to survive as their root systems already exist and can tap into groundwater during harsher seasons with no rain.[28] While this method has existed for centuries, it is now sometimes referred to as farmer-managed natural regeneration.[29]

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Forest plantations

Plantation forests cover about 131 million ha, which is 3 percent of the global forest area and 45 percent of the total area of planted forests.[30]

Globally, planted forests increased from 4.1% to 7.0% of the total forest area between 1990 and 2015.[31] Plantation forests made up 280 million ha in 2015, an increase of about 40 million ha in the last ten years.[32] Globally, planted forests consist of about 18% exotic or introduced species while the rest are species native to the country where they are planted.

The highest share of plantation forest is in South America, where this forest type represents 99 percent of the total planted-forest area and 2 percent of the total forest area. The lowest share of plantation forest is in Europe, where it represents 6 percent of the planted forest estate and 0.4 percent of the total forest area. Globally, 44 percent of plantation forests are composed mainly of introduced species. There are large differences between regions: for example, plantation forests in North and Central America mostly comprise native species and those in South America consist almost entirely of introduced species.[30]

In South America, Oceania, and East and Southern Africa, planted forests are dominated by introduced species: 88%, 75% and 65%, respectively. In North America, West and Central Asia, and Europe the proportions of introduced species in plantations are much lower at 1%, 3% and 8% of the total area planted, respectively.[31]

Plantation forests are intensively managed, composed of one or two species, even-aged, planted with regular spacing, and established mainly for productive purposes. Other planted forests, which comprise 55 percent of all planted forests, are not intensively managed, and they may resemble natural forests at stand maturity. The purposes of other planted forests may include ecosystem restoration and the protection of soil and water values.[30]

Financial incentives

Policy that promote reforestation for incentives in return have shown promising results of being an effective and motivative concept to re-plant globally on a mass scale.[33] Some incentives for reforestation can be as simple as a financial compensation. Streck and Scholz (2006) explain how a group of scientists from various institutions have developed a compensated reduction of deforestation approach which would reward developing countries that disrupt any further act of deforestation. Countries that participate and take the option to reduce their emissions from deforestation during a committed period of time would receive financial compensation for the carbon dioxide emissions that they avoided.[34]:875 To raise the payments, the host country would issue government bonds or negotiate some kind of loan with a financial institution that would want to take part in the compensation promised to the other country. The funds received by the country could be invested to help find alternatives to the extensive cutdown of forests. This whole process of cutting emissions would be voluntary, but once the country has agreed to lower their emissions they would be obligated to reduce their emissions. However, if a country was not able to meet their obligation, their target would get added to their next commitment period. The authors of these proposals see this as a solely government-to-government agreement; private entities would not participate in the compensation trades.[34]:876

Another emerging revenue source to fund reforestation projects deals with the sale of carbon sequestration credits, which can be sold to companies and individuals looking to compensate their carbon footprint. This approach allows for private landowners and farmers to gain a revenue from the reforestation of their lands, while simultaneously benefiting from improved soil health and increased productivity.[35]

Alongside past financial incentive strategies, reforestation tax benefits have been another way the government has encouraged companies to promote reforestation tactics through the promises of a tax break.[36]

As many landholders seek to earn carbon credits through sequestration, their participation also encourages biodiversity and provides ecosystem services for crops and livestock.[37]

Related concepts

A similar concept, afforestation, refers to the process of restoring and recreating areas of woodlands or forests that may have existed long ago but were deforested or otherwise removed at some point in the past or lacked it naturally (e.g., natural grasslands). Sometimes the term "re-afforestation" is used to distinguish between the original forest cover and the later re-growth of forest to an area.[38] Special tools, e.g. tree planting bars, are used to make planting of trees easier and faster.

Another alternative strategy, proforestation, is similar as it can be used to counteract the negative environmental and ecological effects of deforestation through growing an existing forest intact to its full ecological potential.[39]

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Challenges and problem areas

Competition with other land uses

Reforestation competes with other land uses, such as food production, livestock grazing, and living space, for further economic growth.[40][41] Reforestation can divert large amounts of water from other activities.[42] A map created by the World Resources Institute in collaboration with the IUCN identifies 2 billion hectares for potential forest restoration. It is criticised for including 900 million hectares of grasslands.[43][44]

Environmental risks

Reforestation often has the tendency to create large fuel loads, resulting in significantly hotter combustion than fires involving low brush or grasses.[45] Reduced harvesting rates and fire suppression have caused an increase in the forest biomass in the western United States over the past century. This causes an increase of about a factor of four in the frequency of fires due to longer and hotter dry seasons.[11]

Reforestation can also reduce biodiversity leading to severe soil erosion , which if done improperly will lead to loss of water resources[46][

Effects on biodiversity

Reforesting sometimes results in extensive canopy creation that prevents growth of diverse vegetation in the shadowed areas and generating soil conditions that hamper other types of vegetation. Trees used in some reforesting efforts (e.g., *Eucalyptus globulus*) tend to extract large amounts of moisture from the soil, preventing the growth of other plants. The European Commission found that, in terms of environmental services, it is better to avoid deforestation than to allow for deforestation to subsequently reforest, as the former leads to irreversible effects in terms of biodiversity loss and soil degradation.[47]

The effects reforestation has on biodiversity is not limited to just other forms of vegetation, it can affect all forms of living organisms all contained in the present ecosystem.[48] Due to the major role trees have on ecosystems it is important to better understand components like the ecosystem, waterways, and species present in areas that are being re-planted. Prior research helps limit the depletion of biodiversity which can hinder medicinal discoveries, and alter gene flow in organisms.[41]

A debated issue in managed reforestation is whether the succeeding forest will have the same biodiversity as the original forest. If the forest is replaced with only one species of tree and all other vegetation is prevented from growing back, a monoculture forest similar to agricultural crops would be the result. However, most reforestation involves the planting of different selections of seedlings taken from the area, often of multiple species.[49][50]

Carbon stocks

There is also the risk that, through a forest fire or insect outbreak, much of the stored carbon in a reforested area could make its way back to the atmosphere.[11] Furthermore, the probability that legacy carbon will be released from soil is higher in younger boreal forest.[51] An example of this can be seen in the peatlands in Central Africa, which house an abundance of carbon in the mud called peat. Much like the forest fire or insect outbreak which can harm tropical rainforests, money can also be seen an incentive to harm forests and be paid off to protect it.[52] The mudGlobal greenhouse gas emissions caused by damage to tropical rainforests may be underestimated by a factor of six.[53] Additionally the effects of af- or reforestation will be farther in the future than those of proforestation.[54] It takes much longer − several decades − for the benefits for global warming to manifest to the same carbon sequestration benefits from mature trees in tropical forests and hence from limiting deforestation.[55] Some researchers note that instead of planting entirely new areas, reconnecting forested areas and restoring the edges of forest, to protect their mature core and make them more resilient and longer-lasting, should be prioritized.[56]

Examples by country

Asia

In China, where large scale destruction of forests has occurred, the government has in the past required that every able-bodied citizen between the ages of 11 and 60 plant three to five trees per year or do the equivalent amount of work in other forest services. The government claims that at least 1 billion trees have been planted in China every year since 1982. This is no longer required today, but 12 March of every year in China is the Planting Holiday. Also, it has introduced the Green Wall of China project, which aims to halt the expansion of the Gobi desert through the planting of trees. However, due to the large percentage of trees dying off after planting (up to 75%), the project is not very

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successful.[57] There has been a 47-million-hectare increase in forest area in China since the 1970s.[58] The total number of trees amounted to be about 35 billion and 4.55% of China's land mass increased in forest coverage. The forest coverage was 12% two decades ago and now is 16.55%.[59]

China announced two large reforestation programs, the Natural Forest Protection Program and the Returning Farmland to Forest program, in late 1998.[60]:183 The programs were piloted in Sichuan, Shaanxi, and Gansu in 1999.[60]:183 They became widely implemented in 2000.[60]:183 The Natural Forest Protection Program called for major reductions in timber harvest, forest conservation, and instituted logging bans in most of Sichuan, Yunnan, Guizhou, and Tibet.[60]:183 The program provided for alternative employment opportunities for former logging industry workers, including hiring them for reforestation work.[60]:183 The Returning Farmland to Forest program paid farmers to plant trees on less productive farmland and provided them with a yearly subsidy for lost income.[60]:183 In 2015 China announced a plan to plant 26 billion trees by the year 2025; that is, two trees for every Chinese citizen per year.[61]

Between 2013 and 2018, China planted 338,000 square kilometres of forests, at a cost of $82.88 billion.[62] By 2018, 21.7% of China's territory was covered by forests, a figure the government wants to increase to 26% by 2035. The total area of China is 9,596,961 square kilometres (see China), so 412,669 square kilometres more needs to be planted.[63] According to the government's plan, by 2050, 30% of China's territory should be covered by forests.[64]

In 2017, the Saihanba Afforestation Community won the UN Champions of the Earth Award in the Inspiration and Action category for their successful reforestation efforts,[65] which began upon discovering the survival of a single tree.[66]

From 2016 to 2021, 3976 square kilometers of forests were planted in the Tibet Autonomous Region, with plans for 20 million trees to be planted before 2023.[67]

In the years 2012-2022 China restored more than 70 million hectares (700,000 km^2) of forests. China committed to plant and conserve 70 billion trees by the year 2030 as part of the Trillion Tree Campaign.[2]

The Jane Goodall Institute launched the Million Tree Project in Kulun Qi, Inner Mongolia to plant one million trees.[68][69] China used 24 million hectares of new forest to offset 21% of Chinese fossil fuel emissions in 2000.[11]:1456

Launched in 1978 and scheduled to last until 2050, the Three Northern Protected Forest Development Program - informally known as the "Great Green Wall" - aims to eventually plant nearly 90 million acres of new forest in a 2,800-mile stretch of northern China.[70]

India

Jadav Payeng had received national awards for reforestation efforts, known as the "Molai forest". He planted 1400 hectares of forest on the bank of river Brahmaputra alone.[71] There are active reforestation efforts throughout the country. In 2016, India had more than 50 million trees planted in Uttar Pradesh and in 2017, more than 66 million trees planted in Madhya Pradesh.[72] In addition to this and individual efforts, there are startup companies, such as Afforest,[73] that are being created over the country working on reforestation.[74] Lots of plantation are being carried out in the Indian continent but the survivability is very poor especially for massive plantations, with less than 20% survivability rate. To improve the forest cover and to achieve the national mission of forest cover of 33%, there is a need to improve the methods of plantation. Rather than mass planting, there is a need to work on performance measurement & tracking of trees growth. Taking this into consideration, a non-profit organisation Ek Kadam Sansthan in Jaipur is leading the development of a module of mass tracking for plantations. The pilot has been done successfully and the organisation is hoping to implement nationwide by the end of 2021.[75]

Japan

The Ministry of Agriculture, Forestry and Fishery explain that about two-thirds of Japanese land is covered with forests,[76] and it was almost unchanged from 1966 to 2012.[77] Japan needs to reduce 26% of green house gas emission from 2013 by 2030 to accomplish Paris Agreement and is trying to reduce 2% of them by forestry.[78]

Mass environmental and human-body pollution along with relating deforestation, water pollution, smoke damage, and loss of soils caused by mining operations in Ashio, Tochigi became the first environmental social issue in Japan, efforts by Shōzō Tanaka had grown to large campaigns against copper operation. This led to the creation of 'Watarase Yusuichi Pond', to settle the pollution which is a Ramsar site today. Reforestation was conducted as a part of afforestation due to inabilities of self-recovering by the natural land itself due to serious soil pollution and loss of woods consequence in loss of soils for plants to grow, thus needing artificial efforts involving introducing of healthy soils from outside. Starting from around 1897, about 50% of once bald mountains are now back to green.[79]

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Pakistan

The Billion Tree Tsunami was launched in 2014 by planting 10 billion trees, by the provincial government of Khyber Pakhtunkhwa (KPK) and Imran Khan, as a response to the challenge of global warming. Pakistan's Billion Tree Tsunami restored 350,000 hectares of forests and degraded land to surpass its Bonn Challenge commitment.[80]

In 2018, Pakistan's prime minister Imran Khan declared that the country will plant 10 billion trees in the next five years.[81]

In 2020, the Pakistani government launched an initiative to hire 63,600 laborers to plant trees in the northern Punjab region, with indigenous species such as acacia, mulberry and moringa. This initiative was meant to alleviate unemployment caused by lockdowns to mitigate the spread of COVID-19.[82][83]

Philippines

In 2011, the Philippines established the National Greening Program as a priority program to help reduce poverty, promote food security, environmental stability, and biodiversity conservation, as well as enhance climate change mitigation and adaptation in the country. The program paved the way for the planting of almost 1.4 billion seedlings in about 1.66 million hectares nationwide during the 2011-2016 period. The Food and Agriculture Organization of the United Nations ranked the Philippines fifth among countries reporting the greatest annual forest area gain, which reached 240,000 hectares during the 2010–2015 period.[84][85]

Thailand

Efforts are being made in Thailand to restore the land after 800,000 hectares of forest have been destroyed in exchange for cash crop land to grow maize.[86] Agroforestry has become part of the solution to fix the damage caused by deforestation. Agroforestry would affect the agriculture and atmosphere in Thailand in numerous ways. By planting a combination of different tree species, these trees are able to change the microclimatic conditions.[86] Nutrient cycling also occurs when trees are incorporated in the agricultural system.[86] It is also probable that the soil erosion that occurred as a result of deforestation can be mediated when these trees are planted.[86]

Europe

Armenia

The Armenia Tree Project was founded in 1994 to address environmental and economic concerns related to Armenia's dwindling forests. Since its founding, the organization has planted more than 6.5 million trees in communities throughout Armenia.[87]

Iceland

Prior to the deforestation of Iceland in the Middle Ages, some 40% of the land was forested.[88] Today, the country is about 2% forested, with the Icelandic Forest Service aiming to increase that share to 10% through reforestation and natural regrowth.[89]

Ireland

In 2019 the government of Ireland decided to plant 440 million trees by 2040. The decision is part of the government's plan to make Ireland carbon neutral by 2050 with renewable energy, land use change and carbon tax.[90]

Ireland is also driven to increase sustainable timber consumption while also adding more eco friendly work positions.[91] They also have taken efforts to limit the use of methane emissions by signing a pledge to draw back methane use by 30%.[92]

Germany

By the 14th century, forests in heavily populated areas had been devastated by industry, many of which required wood for their activities.[93] Peter Stromer (1310-1388), lord of the Stromer trading and commercial company, was spurred by this shortage to "conduct forest culture experiments".[93] In 1368 he successfully sowed fir and pine seeds in the Nuremberg Reichswald, which over time ended the wood shortage and established the "triumph of the pine in the Nuremberg Reichswald" (at the expense of other deciduous trees).[93] The "doctrine of coniferous sowing" spread widely through forestry regulations and other writing at the time.[93]

Reforestation is required as part of the federal forest law. 31% of Germany is forested, according to the second forest inventory of 2001–2003. The size of the forest area in Germany increased between the first and the second forest inventory due to forestation of degenerated bogs and agricultural areas.[94]

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United Kingdom

Since the 1980s, 8.5 million trees have been planted in the United Kingdom in an area of the Midlands around the villages of Moira and Donisthorpe, close to Leicester. The area is called The National Forest.[95] An even larger reforestation project, called The Northern Forest, is beginning in South Yorkshire. It aims to plant 50 million trees.[96] Despite this, the UK government has been criticized for not achieving its tree planting goals.[97][98] There have also been concerns of non-native tree planting disturbing the ecological integrity and processes of what would be a native habitat restoration.[99]

Middle East

Israel

Since 1948, large reforestation and afforestation projects were accomplished in Israel. 240 million trees have been planted. The carbon sequestration rate in these forests is similar to the European temperate forests.[100]

Israel and only one other country was documented to have a net increase of forestation in the 2000's. This type of progress could be attributed to the social practices that Israel incorporates into their society.[101][

Lebanon

For thousands of years Lebanon was covered by forests; one particular species of interest, *Cedrus libani* was exceptionally valuable and was almost eliminated due to lumbering operations.[102] Many ancient cultures along the Mediterranean Sea harvested these trees including the Phoenicians who used cedar, pine and juniper for boat building, the Romans, who cut them down for lime-burning kilns, and the Ottomans, who used much of the remaining cedar forests of Lebanon as fuel in steam trains in the early 20th century.[103] Despite two millennia of deforestation, forests in Lebanon still cover 13.6% of the country, and other wooded lands represent 11%.[104]

Law No. 558, which was ratified by the Lebanese Parliament on April 19, 1996, aims to protect and expand existing forests, classifying all forests of cedar, fir, high juniper, evergreen cypress and other trees, whether diverse or homogeneous, whether state-owned or not as conserved forests.[105]

Since 2011 more than 600,000 trees, including cedars and other native species, have been planted throughout Lebanon as part of the Lebanon Reforestation Initiative, which aims to restore Lebanon's native forests.[106] Projects financed locally and by international charity are performing extensive reforestation of cedar being carried out in the Mediterranean region, particularly in Lebanon and Turkey, where over 50 million young cedars are being planted annually.

The Lebanon Reforestation Initiative has been working with tree nurseries throughout Lebanon since 2012 to grow stronger seedlings with higher survival rates.[107]

Turkey

Of the country's 78 million hectares of land in total the Ministry of Agriculture and Forestry aims to increase Turkey's forest cover to 30% by 2023.[108]

4000 years ago Anatolia was 60% to 70% forested.[109] Although the flora of Turkey remains more biodiverse than many European countries deforestation occurred during both prehistoric[110] and historic times, including the Roman[111] and Ottoman[112] periods.

Since the first forest code of 1937 the official government definition of 'forest' has varied.[113] According to the current definition 21 million hectares are forested, an increase of about 1 million hectares over the past 30 years, but only about half is 'productive'.[114] However, according to the United Nations Food and Agriculture Organization definition of forest[115] about 12 million hectares was forested in 2015,[116] about 15% of the land surface.

The amount of greenhouse gas emissions by Turkey removed by forests is very uncertain.[117]:489 As of 2019 however a new assessment is being made with the help of satellites and new soil measurements and better information should be available by 2020.[117] According to the World Resources Institute "Atlas of Forest Landscape Restoration Opportunities" 50 million hectares are potential forest land, a similar area to the ancient Anatolian forest mentioned above.[118] This could help limit climate change in Turkey. To help preserve the biodiversity of Turkey more sustainable forestry has been suggested.[109] Improved rangeland management is also needed.[119]

National Forestation Day is on 11 November but, according to the agriculture and forestry trade union although volunteers planted a record number of trees in 2019, most had died by 2020 in part due to lack of rainfall.[120]

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North America

Canada

Natural Resources Canada (The Department of Natural Resources) states that the national forest cover was decreased by 0.34% from 1990 to 2015, and Canada has the lowest deforestation rate in the world.[121] The forest industry is one of the main industries in Canada, which contributes about 7% of Canadian economy,[122] and about 9% of the forests on earth are in Canada.[123] Therefore, Canada has many policies and laws to commit to sustainable forest management. For example, 94% of Canadian forests are public land, and the government obligates planting trees after harvesting to public forests.[124]

United States

It is the stated goal of the US Forest Service (USFS) to manage forest resources sustainably. This includes reforestation after timber harvest, among other programs.[125]

United States Department of Agriculture (USDA) data shows that forest occupied about 46% of total U.S. land in 1630 (when European settlers began to arrive in large numbers), but had decreased to 34% by 1910. After 1910, forest area has remained almost constant although U.S. population has increased substantially.[126] In the late 19th century the U.S. Forest Service was established in part to address the concern of natural disasters due to deforestation, and new reforestation programs and federal laws such as the Knutson-Vandenberg Act (1930) were implemented. The U.S. Forest Service states that human-directed reforestation is required to support natural regeneration and the agency engages in ongoing research into effective ways to restore forests.[127]

As for the year 2020, United States of America planted 2.5 billion trees per year. At the beginning of the year 2020, a bill that will increase the number to 3.3 billion, was proposed by the Republican Party, after President Donald Trump joined the Trillion Tree Campaign.[128]

South America

Costa Rica

Through reforestation and environmental conservation, Costa Rica doubled its forest cover in 30 years.[129]

Costa Rica has a long-standing commitment to the environment. The country is now one of the leaders of sustainability, biodiversity, and other protections. It wants to be completely fossil fuel free by 2050.[130] The country has generated all of its electric power from renewable sources for three years as of 2019. It has committed to be carbon-free and plastic-free by 2021.[131]

As of 2019, half of the country's land surface is covered with forests. They absorb a huge amount of carbon dioxide, combating climate change.[132]

In the 1940s, more than 75% of the country was covered in mostly tropical rainforests and other indigenous woodlands. Between the 1940s and 1980s, extensive, uncontrolled logging led to severe deforestation. By 1983, only 26% of the country had forest cover. Realizing the devastation, policymakers took a stand. Through a continued environmental focus they were able to turn things around to the point that today forest cover has increased to 52%, two times more than 1983 levels.

An honorable world leader for ecotourism and conservation, Costa Rica has pioneered the development of payments for environmental services. Costa Rica's extensive system of environmental protection has been encouraging conservation and reforestation of the land by providing grants for environmental services. The system is not just advanced for its time but is also unparalleled in the world. It received great international attention.

Costa Rica doubled its forest cover in 30 years using its system of grants and other payments for environmental services, including compensation for landowners. One of the main programs established in Costa Rica was the Forest Promotion Certificate in 1979 and is funded by international donations and nationwide taxes.[133][134] The initiative is helping to protect the forests in the country, and is now helped pass both the Forest Law in 1986 and FONAFIFO in 1990 which insures the continuity of the conservation programs.[133]

Costa Rica's ambitious reforestation initiatives have transformed the landscape, fostering biodiversity, carbon sequestration, and sustainable land management practices.[135]

Peru

Approximately 59% of Peru is covered by forest.[136] A history of political turmoil and the government's inability to enforce environmental regulations has led to the degradation of the forest and environment in Peru. A military coup in

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1968 caused a loss of economic mobility in the Talara region and sparked a boom in illegal logging due to the lack of alternative economic opportunities.[137] Illegal mining and logging operations are responsible for a great deal of Peru's deforestation and environmental damage.[138] The Peruvian government has not been able to enforce an environmentally conscious mining formalization plan to protect the Amazon forest in the Madre de Dios region. The 1980s were known in Peru as the "lost decade" due to a nationwide internal conflict and severe economic crisis almost destroying the country and resulting in the state losing control over several regions.[138] Many areas in Peru, including Madre de Dios, had no state presence until the government initiated a movement to 'conquer and populate the Amazon,' with the hopes of minimizing illegal and informal mining operations that had expanded in the region and were polluting the Amazonian rivers and the destroying of its forests.[138]

Reforestation initiatives have expanded in the country since. In Peru, reforestation is essential to preserving the livelihoods of rural communities because much of the population relies on the forest in some way.[139] Deforestation also disproportionally affects indigenous communities in Peru, which is why reforestation efforts are essential for the protection of many communities' livelihoods.

Sub-Saharan Africa

One plan in this region involves planting a nine-mile width of trees on the Southern Border of the Sahara Desert for stopping its expansion to the south.[140] The Great Green Wall initiative is a pan-African proposal to "green" the continent from west to east in order to battle desertification. It aims at tackling poverty (through employment of workers required for the project) and the degradation of soils in the Sahel-Saharan region, focusing on a strip of land that is 15 km (9 mi) wide and 7,500 km (4,750 mi) long from Dakar to Djibouti.[141] As of May 2020, 21 countries joined the project, many of them are directly affected by the expansion of the Sahara desert. It should create 10 millions green jobs by 2030.[142][143]

In 2019, Ethiopia begun a massive tree planting campaign "Green Legacy" with a target to plant 4 billion trees in one year. In one day only, over 350 million trees were planted.[144]

Nigeria

Forest nursery located in the compound of the Federal University of Agriculture, AbeokutaReforestation in Nigeria employs both natural and artificial methods.Reforestation involves the deliberate planting of trees and restoring forested areas that have been depleted or destroyed. It involves a planned restocking of the forest to ensure sustainable supply of timber and other forest products.[145][146] Reforestation, in essence, involves replenishing forests to guarantee a consistent and sustainable supply of timber and various other forest resources. This objective can be accomplished through either natural regeneration techniques or artificial regeneration methods.[147] Both of these approaches have been utilized in the reforestation efforts within Nigeria's forests.[147] At the initiation of the reforestation program in Nigeria, the natural regeneration approach was chosen for two primary reasons.[147] Firstly, it aimed to preserve the rainforest in its original state by allowing it to regenerate naturally from the existing seed bank in the soil. Secondly, and of significant importance, this method was selected due to budgetary constraints, as there were insufficient funds available to establish plantations through direct means.[147]

Organizations and programs

- Ecosia is a non-profit organisation based in Berlin, Germany, that has planted over 100 million trees worldwide as of July 2020.
- Trees for the Future has assisted more than 170,000 families, in 6,800 villages of Asia, Africa and the Americas, to plant over 35 million trees.[148]
- Ecologi is an organisation that offers its members ways to support climate change solutions. This includes offsetting their carbon emissions and tree planting. So far over 50 million trees have been planted through Ecologi, as well a more than 2.2 million tonnes of CO2e reduced.[149]
- Wangari Maathai, 2004 Nobel Peace Prize recipient, founded the Green Belt Movement which planted over 47 million trees to restore the Kenyan environment.[150]
- Team Trees was a 2019 fundraiser with an initiative to plant 20 million trees. The initiative was started by American YouTubers MrBeast and Mark Rober, and was mostly supported by YouTubers. The Arbor Day Foundation will work with its local partners around the world to plant one tree for each dollar they raise.[151]
- Trees For Life (Brooklyn Park) is a state based organisation, which was established back in 1981 and delivers conservation, revegetation and community training programs. It now has thousands of active supporters[152] and energizes activity within communities.[153]

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- Many companies are trying to achieve carbon offsets by nature-based solutions like reforestation, including mangrove forests and soil restoration. Among them are Microsoft and Eni. Increasing the forest cover of Earth by 25% will offset the human emissions in the last 20 years. In any case it will be necessary to pull from the atmosphere the CO_2 that already have been emitted. However, this can work only if the companies will stop new emissions and stop deforestation.[154]
- The largest reforestation nursery in Alberta, Canada is Coast to Coast Reforestation and they recently finished producing their billionth tree seedling in 2023. https://c2ctrees.com/
- The 2020 World Economic Forum, held in Davos, announced the creation of the Trillion Tree Campaign, which is an initiative aiming to plant 1 trillion trees across the globe. The implementation can have big environmental and societal benefits but needs to be tailored to local conditions.[155]
- The forest landscape restoration strategy seeks to rehabilitate landscapes and repair marginal and degraded areas in order to generate productive forest landscapes that are resilient and long-term. It aims to guarantee that diverse ecological and land-use functions are restored, safeguarded, and preserved over time.[26][156]

II. DISCUSSION

Forest restoration is defined as "actions to re-instate ecological processes, which accelerate recovery of forest structure, ecological functioning and biodiversity levels towards those typical of climax forest"[1] i.e. the end-stage of natural forest succession. Climax forests are relatively stable ecosystems that have developed the maximum biomass, structural complexity and species diversity that are possible *within the limits imposed by climate and soil and without continued disturbance from humans* (more explanation here). Climax forest is therefore the target ecosystem, which defines the ultimate aim of forest restoration. Since climate is a major factor that determines climax forest composition, global climate change may result in changing restoration aims.[2] Additionally, the potential impacts of climate change on restoration goals must be taken into account, as changes in temperature and precipitation patterns may alter the composition and distribution of climax forests.[3]

Forest restoration is a specialized form of reforestation, but it differs from conventional tree plantations in that its primary goals are biodiversity recovery and environmental protection.[4][5]

Forest and landscape restoration (FLR) is defined as a process that aims to regain ecological functionality and enhance human well-being in deforested or degraded landscapes.[6] FLR has been developed as a response to the growing degradation and loss of forest and land, which resulted in declined biodiversity and ecosystem services.[6] Effective FLR will support the achievement of the Sustainable Development Goals.[6] The United Nations Decade on Ecosystem Restoration (2021–2030) provides the opportunity to restore hundreds of millions of hectares of degraded forests and other ecosystems.[6] Successful ecosystem restoration requires a fundamental understanding of the ecological characteristics of the component species, together with knowledge of how they assemble, interact and function as communities[7]

Scope

Forest restoration may include simply protecting remnant vegetation (fire prevention, cattle exclusion etc.) or more active interventions to accelerate natural regeneration,[8] as well as tree planting and/or sowing seeds (direct seeding) of species characteristic of the target ecosystem. Tree species planted (or encouraged to establish) are those that are typical of, or provide a critical ecological function in, the target ecosystem. However, wherever people live in or near restoration sites, restoration projects often include economic species amongst the planted trees, to yield subsistence or cash-generating products.

Forest restoration is an inclusive process, which depends on collaboration among a wide range of stakeholders including local communities, government officials, non-government organizations, scientists and funding agencies. Its ecological success is measured in terms of increased biological diversity, biomass, primary productivity, soil organic matter and water-holding capacity, as well as the return of rare and keystone species, characteristic of the target ecosystem. However, according to FAO, restoration activities face economic barriers ranging from a lack of large-scale funding available on behalf of governments to the limited resources and technical capacity of smallholders.[9]

Economic indices of success include the value of forest products and ecological services generated (e.g. watershed protection, carbon storage etc.), which ultimately contribute towards poverty reduction. Payments for such ecological services (PES) and forest products can provide strong incentives for local people to implement restoration projects.[10] Active restoration has been shown to accelerate the carbon recovery of human-modified tropical forests by as much as 50%.[11]

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According to FAO's *The State of the World's Forests 2020*, large-scale forest restoration is needed to meet the Sustainable Development Goals and to prevent, halt and reverse the loss of biodiversity. While 61 countries have, together, pledged to restore 170 million hectares of degraded forest lands under the Bonn Challenge, progress to date is slow. Forest restoration, when implemented appropriately, helps restore habitats and ecosystems, create jobs and income and is an effective nature-based solution to climate change. Moreover, according to FAO, forest and landscape restoration yields many benefits for the climate, including greenhouse gas emissions sequestration and reduction.[9] The United Nations Decade on Ecosystem Restoration 2021–2030, announced in March 2019, aims to accelerate ecosystem restoration action worldwide.[12]

Opportunities for forest restoration

Forest restoration is appropriate wherever biodiversity recovery is one of the main goals of reforestation, such as for wildlife conservation, environmental protection, eco-tourism or to supply a wide variety of forest products to local communities.[13] Forests can be restored in a wide range of circumstances, but degraded sites within protected areas are a high priority, especially where some climax forest remains as a seed source within the landscape. Even in protected areas, there are often large deforested sites: logged over areas or sites formerly cleared for agriculture. If protected areas are to act as Earth's last wildlife refuges, restoration of such areas will be needed.[4][5]

Many restoration projects are now being implemented under the umbrella of "forest landscape restoration" (FLR),[14] defined as a "planned process to regain ecological integrity and enhance human well-being in deforested or degraded landscapes". FLR recognizes that forest restoration has social and economic functions. It aims to achieve the best possible compromise between meeting both conservation goals and the needs of rural communities.[15] As human pressure on landscapes increases, forest restoration will most commonly be practiced within a mosaic of other forms of forest management, to meet the economic needs of local people.

A recent focal area for forest restoration efforts is within the urban context, where both people and biodiversity will benefit, however this context presents unique challenges.[16]

Natural regeneration

Tree planting is not always essential to restore forest ecosystems. A lot can be achieved by studying how forests regenerate naturally, identifying the factors that limit regeneration and devising methods to overcome them. These can include weeding and adding fertilizer around natural tree seedlings, preventing fire, removing cattle and so on. This is "accelerated" or "assisted" natural regeneration.[17] It is simple and cost-effective, but it can only operate on trees that are already present, mostly light-loving pioneer species. Such tree species are not usually those that comprise climax forests, but they can foster recolonization of the site by shade-tolerant climax forest tree species, via natural seed dispersal from remnant forest. Because this is a slow process, biodiversity recovery can usually be accelerated by planting some climax forest tree species, especially large-seeded, poorly dispersed species. It is not feasible to plant all the tree species that may have formerly grown in the original primary forest and it is usually unnecessary to do so, if the framework species method[18][19] can be used.

In some exceptional cases, particularly some Alaskan boreal forests, the long-term recovery from wildfires could offset the carbon emitted during the fires due to a change in tree species if the trees persist, prove to become part of resilient biomes and are about as numerous as the former forests'.[20][21]

Protecting regeneration areas from browsing animals

Forest in the process of restoration face many challenges, such as seed and nutrient availability, but are notable susceptible to browsing animals. Although browsing animals are necessary in maintaining the understory of forests, they can easily over-grave a freshly replanted swath of forest, where young samplings are easily accessible. Over-grazing is particularly problematic in this case as the samplings and other young plants may be damaged beyond the point of recovery, resulting in a decrease in biodiversity. Care must be taken to use "deer fencing" to protect the regeneration area, or where not financially possible, to plant trees which prioritize structural growth and recovery.[22]

Post-fire regeneration

In large parts of the world, forest fires cover a heavy toll on forests. That can be because of provoked deforestation in order to substitute forests by crop areas, or in dry areas, because of wild fires occurring naturally or intentionally. A whole section of forest landscape restoration in linked to this particular problem, as in many cases, the net loss of ecosystem value is very high and can open the drop to an accelerated further degradation of the soil conditions through erosion and desertification. This indeed has dire consequences on both the quality of the habitats and their related

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fauna. Nevertheless, in some specific cases, wild fires do actually allow to increase the biodiversity index of the burnt area,[23] in which case the Forest Restoration Strategies tend to look for a different land-use.[24]

Forest restoration projects

A study finds that almost 300 million people live on tropical forest restoration opportunity land in the Global South, constituting a large share of low-income countries' populations, and argues for prioritized inclusion of "local communities" in forest restoration projects.[25][26][27] Project Drawdown lists the restoration of tropical forests as one of the most important solutions for climate change mitigation due to its extraordinary potential to sequestrate carbon and recommends that "local communities need to have a stake in what is growing, if restoration is to sustain."[28] A recent FAO publication reports that Indigenous Peoples are among those facing the greatest risk to their well-being and livelihoods from the effects of climate change, and therefore must be centred in forest restoration and conservation.[9]

Ashland Forest Resiliency Stewardship Project

The Ashland Forest Resiliency Stewardship Project (AFR)[29] is a decade long, science-based project launched in 2010 with the intent of reducing severe wildfire risk, but also protecting water quality, old-growth forest, wildlife, people, property, and the overall quality of life within the Ashland watershed. The primary stakeholders in this cooperative restoration effort are the U.S. Forest Service, the City of Ashland, Lomakatsi Restoration Project, and The Nature Conservancy.[30] The project was launched with initial funding from the Economic Recovery stimulus, and received funding from the Forest Service Hazardous Fuels program and the Joint Chiefs Landscape Restoration Partnerships program to back the project through 2016.

Located in the dry forests of southern Oregon, the threat of wildfire is a reality for land managers and property owners alike. The boundaries of the city of Ashland intersect with the surrounding forest in what is referred to as the wildland–urban interface (WUI).[31] Historically, the forests of this region experienced a relatively frequent fire return interval, which prevented buildup of heavy fuel loads.[32] A century of fire exclusion and suppression on federal lands in the Pacific Northwest has led to increased forest density and fuel loads, and thus a more persistent threat of devastating wildfire.[33]

The AFR project has implemented restoration techniques and prescriptions that aim to replicate the process of ecological succession in dry, mixed-conifer forests of the Pacific Northwest. The approach involves a combination of fuels reduction, thinning small-diameter trees, and carrying out prescribed burns. Priority is given to maintaining ecological function and complexity by retaining the largest and oldest trees, preserving wildlife habitat and riparian areas, and protecting erodible soils and maintaining slope stability.

Since its inception in 2010, the AFR project has provided educational experiences to thousands of students and has benefitted the local community by creating jobs and providing workforce training. About 13,000 acres treated in the AFR project was in maintenance status as of February 2022, and Oregon's Landscape Resiliency Program, established through Senate Bill 762, is funding brush cutting and low-intensity burns to ecologically benefit a fire-adapted forest.

Accelerating forest regeneration with Agricultural Waste

In 1998, Costa Rican initiatives were set to regenerate deforested areas, formerly used as cattle pasture. This land was compacted and the soil was depleted, making natural regeneration more difficult. As a partnership with agricultural waste disposals, approximately 12 000 Mg of orange peels and pulp were applied to a 3 hectare segment of the former pastures. This addition of biomass to the soil allowed for a 176% increase in woody plant growth, increased species richness, tripled tree evenness (measured through the Shannon Index), and significantly elevated soil nutrient levels, measured at 2 and 16 years following the application (Truer *et al*. 2018).[34] A significant increase in canopy closure was also observed using hemispheric topography, further suggesting that agricultural waste may play a larger role in future forest restoration.

Forest landscape restoration

Forest landscape restoration (FLR) is defined as “a planned process to regain ecological integrity and enhance human well-being in deforested or degraded landscapes”.[35] It comprises tools and procedures to integrate site-level forest restoration actions with desirable landscape-level objectives, which are decided upon via various participatory mechanisms among stakeholders. The concept has grown out of collaboration among some of the world's major international conservation organizations including the International Union for Conservation of Nature (IUCN), the World Wide Fund for Nature (WWF), the World Resources Institute and the International Tropical Timber Organization (ITTO).

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Aims

The concept of FLR was conceived to bring about compromises between meeting the needs of both humans and wildlife, by restoring a range of forest functions at the landscape level. It includes actions to strengthen the resilience and ecological integrity of landscapes and thereby keep future management options open. The participation of local communities is central to the concept, because they play a critical role in shaping the landscape and gain significant benefits from restored forest resources. Therefore, FLR activities are inclusive and participatory.[36]

Desirable outcomes

The desirable outcomes of an FLR program usually comprise a combination of the following, depending on local needs and aspirations:

- identification of the root causes of forest degradation and prevention of further deforestation,
- positive engagement of people in the planning of forest restoration, resolution of land-use conflicts and agreement on benefit-sharing systems,
- compromises over land-use trade-offs that are acceptable to the majority of stakeholders,
- a repository of biological diversity of both local and global value,
- delivery of a range of utilitarian benefits to local communities including:
  - a reliable supply of clean water,
  - environmental protection particularly watershed services (e.g. reduced soil erosion, lower landslide risk, flood/drought mitigation etc.),
  - a sustainable supply of a diverse range of forest products including foods, medicines, firewood etc.,
  - monetary income from various sources e.g. ecotourism, carbon trading via the REDD+ mechanism and from payments for other environmental services (PES)[37]

Activities

FLR combines several existing principles and techniques of development, conservation and natural resource management, such as landscape character assessment, participatory rural appraisal, adaptive management etc. within a clear and consistent evaluation and learning framework. An FLR program may comprise various forestry practices on different sites within the landscape, depending on local environmental and socioeconomic factors. These may include protection and management of secondary and degraded primary forests, standard forest restoration techniques such as "assisted" or "accelerated" natural regeneration (ANR) and the planting of framework tree species to restore degraded areas, as well as conventional tree plantations and agroforestry systems to meet more immediate monetary needs.[38][39][40]

The IUCN hosts the Global Partnership on Forest Landscape Restoration,[41] which co-ordinates development of the concept around the world.

In 2014, the Food and Agricultural Organization of the United Nations established the Forest and Landscape Restoration Mechanism.[42] The Mechanism supports countries to implement FLR as a contribution to achieving the Bonn Challenge[43] - the restoration of 150 million hectare of deforested and degraded lands by 2020 - and the Convention on Biological Diversity Aichi Biodiversity Targets[44] - related to ecosystem conservation and restoration.

In partnership with the Global Mechanism of the United Nations Convention to Combat Desertification, FAO released two discussion papers on sustainable financing for FLR in 2015. *Sustainable Financing for Forest and Landscape Restoration: The Role of Public Policy Makers* provides recommendations and examples of FLR financing for countries.[45] *Sustainable Financing for Forest and Landscape Restoration - Opportunities, challenges and the way forward* provides an overview of funding sources and financial instruments available for FLR activities.[46]

Financing

To finance the planning and implementation of forest and landscape restoration (FLR) activities, the Food and Agriculture Organization of the United Nations (FAO) has identified diverse financial mechanisms that tailor to different stages of the FLR process and cover the transaction and the scaling-up of enterprises for sustainable restoration.[47] Several options are available to finance restoration.[47] To meet the unique demands of individual FLR projects, it is critical to identify the best landscape financing strategy.[47] Financial options that generate diverse incentives for local actors may either be for-profit mechanisms, such as debt or loans, or not-for-profit mechanisms which include grants, fiscal policies, or expenses by the public sector.[47] According to FAO, bridging the gap between

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smallholders and investors, coordinating investment, promoting local ownership of FLR financing strategies, and the development of bankable projects and blended financial mechanisms generate positive outcomes for FLR impact at scale.[47]

III. RESULTS

A tree plantation, forest plantation, plantation forest, timber plantation or tree farm is a forest planted for high volume production of wood, usually by planting one type of tree as a monoculture forest. The term *tree farm* also is used to refer to tree nurseries and Christmas tree farms.

Plantation forestry can produce a high volume of wood in a short period of time. Plantations are grown by state forestry authorities (for example, the Forestry Commission in Britain) and/or the paper and wood industries and other private landowners (such as Weyerhaeuser, Rayonier and Sierra Pacific Industries in the United States or Asia Pulp & Paper in Indonesia). Christmas trees are often grown on plantations, and in southern and southeastern Asia, teak plantations have recently replaced the natural forest.

Industrial plantations are actively managed for the commercial production of forest products. Industrial plantations are usually large-scale. Individual blocks are usually even-aged and often consist of just one or two species. These species can be exotic or indigenous. The plants used for the plantation are often genetically altered for desired traits such as growth and resistance to pests and diseases in general and specific traits, for example in the case of timber species, volumic wood production and stem straightness. Forest genetic resources are the basis for genetic alteration. Selected individuals grown in seed orchards are a good source for seeds to develop adequate planting material.

Wood production on a tree plantation is generally higher than that of natural forests. While forests managed for wood production commonly yield between 1 and 3 cubic meters per hectare per year, plantations of fast-growing species commonly yield between 20 and 30 cubic meters or more per hectare annually; a Grand Fir plantation in Scotland has a growth rate of 34 cubic meters per hectare per year (Aldhous & Low 2020), and Monterey Pine plantations in southern Australia can yield up to 40 cubic meters per hectare per year (Everard & Fourt 1974). In 2000, while plantations accounted for 5% of global forest, it is estimated that they supplied about 35% of the world's roundwood.[1]

Growth cycle

In the first year, the ground is prepared usually by the combination of burning, herbicide spraying, and/or cultivation and then saplings are planted by human crew or by machine. The saplings are usually obtained in bulk from industrial nurseries, which may specialize in selective breeding in order to produce fast growing disease- and pest-resistant strains.

- In the first few years until the canopy closes, the saplings are looked after, and may be dusted or sprayed with fertilizers or pesticides until established.
- After the canopy closes, with the tree crowns touching each other, the plantation is becoming dense and crowded, and tree growth is slowing due to competition. This stage is termed 'pole stage'. When competition becomes too intense (for pine trees, when the live crown is less than a third of the tree's total height), it is time to thin out the section. There are several methods for thinning, but where topography permits, the most popular is 'row-thinning', where every third or fourth or fifth row of trees is removed, usually with a harvester. Many trees are removed, leaving regular clear lanes through the section so that the remaining trees have room to expand again. The removed trees are delimbed, forwarded to the forest road, loaded onto trucks, and sent to a mill. A typical pole stage plantation tree is 7–30 cm in diameter at breast height (dbh). Such trees are sometimes not suitable for timber, but are used as pulp for paper and particleboard, and as chips for oriented strand board.
- As the trees grow and become dense and crowded again, the thinning process is repeated. Depending on growth rate and species, trees at this age may be large enough for timber milling; if not, they are again used as pulp and chips.
- Around year 10-60 the plantation is now mature and (in economic terms) is falling off the back side of its growth curve. That is to say, it is passing the point of maximum wood growth per hectare per year, and so is ready for the final harvest. All remaining trees are felled, delimbed, and taken to be processed.
- The ground is cleared, and the cycle can be restarted.

Some plantation trees, such as pines and eucalyptus, can be at risk of fire damage because their leaf oils and resins are highly flammable.[2][3] Conversely, an afflicted plantation can in some cases be cleared of pest species cheaply through the use of a prescribed burn, which kills all lesser plants but does not significantly harm the mature trees.

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Types

Christmas tree farms

A Christmas tree farmer in the U.S. state of Florida explains the pruning and shearing process of cultivation to a government employee.

Christmas tree cultivation is an agricultural, forestry, and horticultural occupation which involves growing pine, spruce, and fir trees specifically for use as Christmas trees.

The first Christmas tree farm was established in 1901, but most consumers continued to obtain their trees from forests until the 1930s and 1940s. Christmas tree farming was once seen only as a viable alternative for low-quality farmland, but that perception has changed within the agriculture industry. For optimum yield and quality, land should be flat or gently rolling and relatively free of debris and undergrowth.

A wide variety of pine and fir species are grown as Christmas trees, although a handful of varieties stand out in popularity. In the United States, Douglas-fir, Scots pine and Fraser fir all sell well. Nordmann fir and Norway spruce sell well in the United Kingdom, the latter being popular throughout Europe. Like all conifers, Christmas trees are vulnerable to a range of pests.

The final stage of cultivation, harvesting, is carried out in a number of ways; one of the more popular methods is the pick-your-own tree farm, where customers are allowed to roam the farm, select their tree, and cut it down themselves. Other farmers cultivate potted trees, with balled roots, which can be replanted after Christmas and used again the following year

Eucalyptus

"...Eucalyptus groves seen in the region today (Atlantic Rainforest, 7/8th of which is gone) were planted where there was previously no forest cover. They're poor in biodiversity but contributed to the expansion of forest cover."— Fabien Hubert Wagner, forest cover study lead author at National Institute for Space Research - INPE Brazil

In the 20th century, scientists around the world experimented with *Eucalyptus* species. They hoped to grow them in the tropics, but most experimental results failed until breakthroughs in the 1960s-1980s in species selection, silviculture, and breeding programs "unlocked" the potential of eucalypts in the tropics. Prior to then, as Brett Bennett noted in a 2010 article, eucalypts were something of the "El Dorado" of forestry. Today, *Eucalyptus* is the most widely planted type of tree in plantations around the world,[4] in South America (mainly in Brazil, Argentina, Paraguay and Uruguay), South Africa, Australia, India, Galicia, Portugal and many more.[5]

Teak

Teak tree plantationPlantation teak is a tropical hardwood tree from the genus *Tectona*, endemic to Southeast Asia that is exclusively planted for the purpose of forestry management, for either commercial timber plantations or ecological restoration. Although the genus Tectona is native to the tropical regions of Southeast Asia, primarily Indonesia, Myanmar, India, Bangladesh and Thailand, the cultivation of plantation teak is economically viable in other tropical regions such as Central America.

Tree farming and climate change

A forest sequesters carbon in its trees. The forest removes carbon dioxide from the air as trees grow and returns it to the air as trees die and rot or burn. As long as the forest is experiencing net growth, the forest is reducing the amount of carbon dioxide, the leading greenhouse gas, from the air. Furthermore, if timber is regularly removed from the forest and turned into lasting wood products, those products continue sequestering carbon, while the replacement tree farm trees absorb more carbon dioxide, thus effecting a continuous reduction in greenhouse gas.

Because tree farms are managed to enhance rapid growth, a tree farm tends to sequester carbon more quickly than an unmanaged forest, considering only the sequestration side of the equation and not the carbon release due to rot, fire, or harvest.[6] The fact that managed woodlands tend to be younger and younger trees grow faster and die less contributes to this distinction.[7]

While tree farms absorb large amounts of CO_2, the long-term sequestration of this carbon depends on what is done with the harvested materials. Forests continue to absorb atmospheric carbon for centuries if left undisturbed.[8]

The USDA has an online calculator for how much carbon is sequestered in various types of forests.[9]

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CO_2 and forest health

Carbon dioxide is a primary building material for plant tissue and is required to make plants grow fast and strong, so presumably higher levels of CO_2 in the air as a result of burning fossil fuels would make forests grow faster. Duke University did a study where they dosed a loblolly pine plantation with elevated levels of CO_2.[10] The studies showed that the pines did indeed grow faster and stronger. They were also less prone to damage during ice storms, which is a factor that limits loblolly growth farther north. The forest did relatively better during dry years. The hypothesis is that the limiting factors in the growth of the pines are nutrients such as nitrogen, which is in deficit on much of the pine land in the Southeast. In dry years, however, the trees do not bump up against those factors since they are growing more slowly because water is the limiting factor. When rain is plentiful trees reach the limits of the site's nutrients and the extra CO_2 is not beneficial. Most forest soils in Southeastern region are deficient in nitrogen and phosphorus as well as trace minerals. Pine forests often sit on land that was used for cotton, corn or tobacco. Since these crops depleted originally shallow and infertile soils, tree farmers must work to improve soils.

Natural forest loss

Many forestry experts claim that the establishment of plantations will reduce or eliminate the need to exploit natural forest for wood production. In principle this is true because due to the high productivity of plantations less land is needed. Many point to the example of New Zealand, where 19% of the forest area provides 99% of the supply of industrial round wood. It has been estimated that the world's demand for fiber could be met by just 5% of the world forest (Sedjo & Botkin 1997). However, in practice, plantations are replacing natural forest, for example in Indonesia. According to the FAO, about 7% of the natural closed forest being lost in the tropics is land being converted to plantations. The remaining 93% of the loss is land being converted to agriculture and other uses. Worldwide, an estimated 15% of plantations in tropical countries are established on closed canopy natural forest.

In the Kyoto Protocol, there are proposals encouraging the use of plantations to reduce carbon dioxide levels (though this idea is being challenged by some groups on the grounds that the sequestered CO_2 is eventually released after harvest).

Ownership

As of 2019, an estimated 49% of forests in the United States are owned by families.[11]

Notable corporations include Greenwood Resources, which is owned by TIAA-CREF.[12]

Criticisms of plantations

In contrast to a naturally regenerated forest, plantations are typically grown as even-aged monocultures, primarily for timber production.

- Plantations are usually near- or total monocultures. That is, the same species of tree is planted across a given area, whereas a natural forest would contain a far more diverse range of tree species.
- Plantations may include tree species that would not naturally occur in the area. They may include unconventional types such as hybrids, and genetically modified trees may be used sometime in the future.[13][*cl*] Since the primary interest in plantations is to produce wood or pulp, the types of trees found in plantations are those that are best-suited to industrial applications. For example, pine, spruce and eucalyptus are widely planted far beyond their natural range because of their fast growth rate, tolerance of rich or degraded agricultural land and potential to produce large volumes of raw material for industrial use.
- Plantations are always young forests in ecological terms. Typically, trees grown in plantations are harvested after 10 to 60 years, rarely up to 120 years. This means that the forests produced by plantations do not contain the type of growth, soil or wildlife typical of old-growth natural forest ecosystems. Most conspicuous is the absence of decaying dead wood, a crucial component of natural forest ecosystems.

In the 1970s, Brazil began to establish high-yield, intensively managed, short rotation plantations. These types of plantations are sometimes called fast-wood plantations or fiber farms and often managed on a short-rotation basis, as little as 5 to 15 years. They are becoming more widespread in South America, Asia and other areas. The environmental and social impacts of this type of plantation has caused them to become controversial. In Indonesia, for example, large multi-national pulp companies have harvested large areas of natural forest without regard for regeneration. From 1980 to 2000, about 50% of the 1.4 million hectares of pulpwood plantations in Indonesia have been established on what was formerly natural forest land.

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The replacement of natural forest with tree plantations has also caused social problems. In some countries, again, notably Indonesia, conversions of natural forest are made with little regard for rights of the local people. Plantations established purely for the production of fiber provide a much narrower range of services than the original natural forest for the local people. India has sought to limit this damage by limiting the amount of land owned by one entity and, as a result, smaller plantations are owned by local farmers who then sell the wood to larger companies. Some large environmental organizations are critical of these high-yield plantations and are running an anti-plantation campaign, notably the Rainforest Action Network and Greenpeace.

IV. CONCLUSION

Land rehabilitation as a part of environmental remediation is the process of returning the land in a given area to some degree of its former state, after some process (industry, natural disasters, etc.) has resulted in its damage.
Many projects and developments will result in the land becoming degraded, for example mining, farming and forestry.

Mine rehabilitation

Modern mine rehabilitation aims to minimize and mitigate the environmental effects of modern mining, which may in the case of open pit mining involve movement of significant volumes of rock. Rehabilitation management is an ongoing process, often resulting in open pit mines being backfilled.

After mining finishes, the mine area must undergo rehabilitation.

- Waste dumps are contoured to flatten them out, to further stabilize them against erosion.
- If the ore contains sulfides it is usually covered with a layer of clay to prevent access of rain and oxygen from the air, which can oxidize the sulfides to produce sulfuric acid.
- Landfills are covered with topsoil, and vegetation is planted to help consolidate the material.
- Dumps are usually fenced off to prevent livestock denuding them of vegetation.
- The open pit is then surrounded with a fence, to prevent access, and it generally eventually fills up with groundwater.
- Tailings dams are left to evaporate, then covered with waste rock, clay if need be, and soil, which is planted to stabilize it.

For underground mines, rehabilitation is not always a significant problem or cost. This is because of the higher grade of the ore and lower volumes of waste rock and tailings. In some situations, stopes are backfilled with concrete slurry using waste, so that minimal waste is left at surface.

The removal of plant and infrastructure is not always part of a rehabilitation programme, as many old mine plants have cultural heritage and cultural value. Often in gold mines, rehabilitation is performed by scavenger operations which treat the soil within the plant area for spilled gold using modified placer mining gravity collection plants.

Also possible is that the section of the mine that is below ground, is kept and used to provide heating, water and/or methane. Heat extraction can be done using heat exchangers, that convey the heat to a nearby city (hence making it be used for district heating purposes.[1] Water can be harvested from the mine as well (mines are often filled with water once the mine has been shut down and the pumps no longer operate). Methane is also often present in the mine shafts, in small quantities (often around 0,1%). This can still be recovered though with specialised systems.[2][3][4] An added advantage of recovering the methane finally is that the methane does not come into the atmosphere, and so does not contribute to global warming.

Mine rehabilitation market

Depending on the country, mining companies are regulated by federal and state bodies to rehabilitate the affected land and to restore biodiversity offset areas around the mines.[5][6]

Mine rehabilitation, a legal obligation for mining companies in Australia for which they are required to pay bonds, could be a source of considerable employment generation and economic investment in regional areas, if governments were willing to enforce the laws covering the process.[7][8][9][10]

Before mining activities begin, a rehabilitation security bond must be provided.[11] The Australian mine rehabilitation bonds totals $9.49bn, with the state of NSW bond totalling $2.68 billion in 2019. The size of mining security bonds has

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been questioned by NSW's Auditor General [12] as being insufficient to cover the complete costs associated with mine rehabilitation activities.

In addition to operational mine rehabilitation activities, often referred to as 'progressive rehabilitation', abandoned mines are also restored. The financing for restoration of abandoned mines is drawn from operating mines as well as public sources. The cost of reclaiming the abandoned mines in the US is estimated at $9.6bn.

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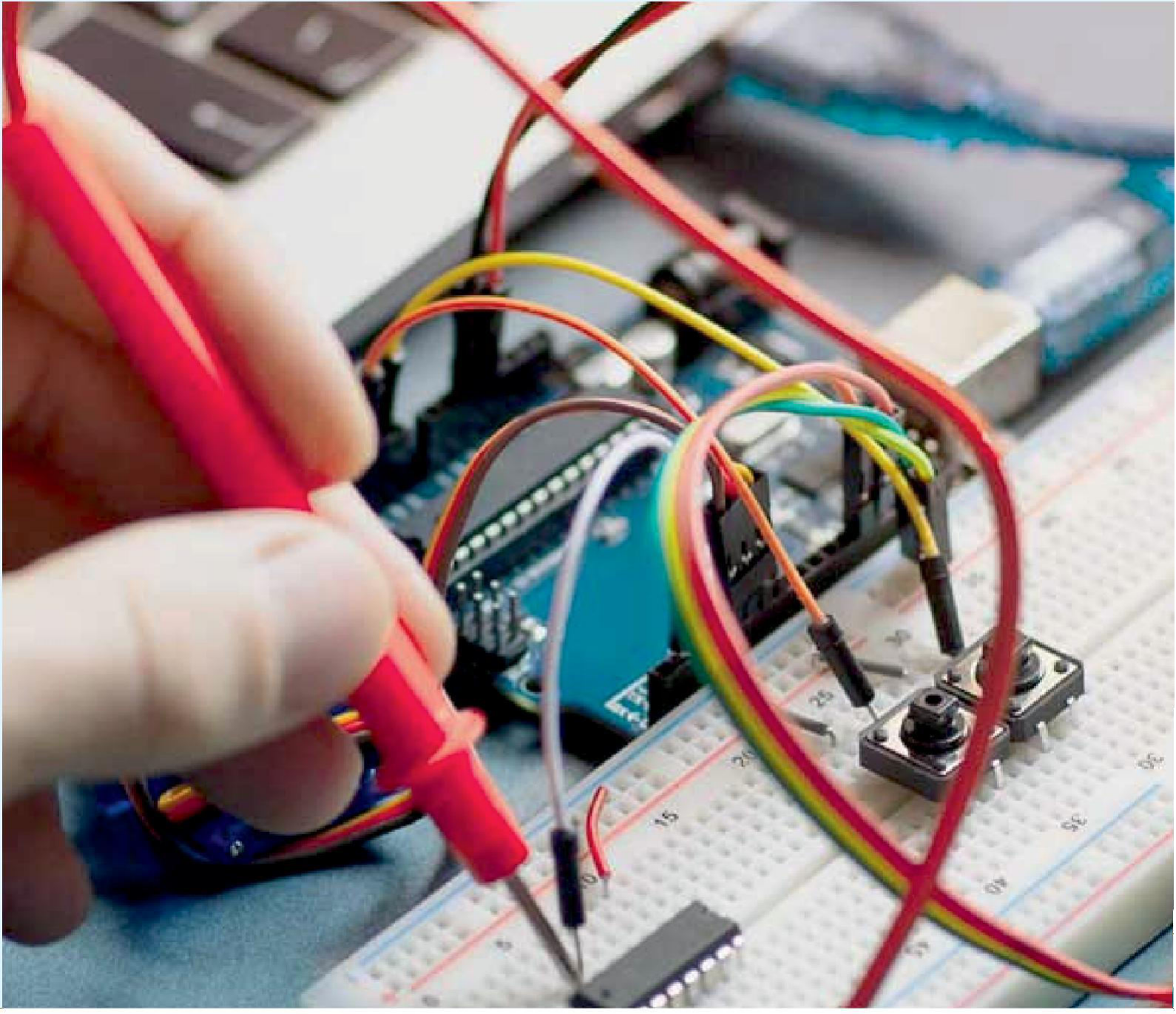

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