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Towards Net Zero: Delivering the Forestry Stabilization Wedge

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Abstract

This paper presents a comprehensive analysis of the role of forests in climate change mitigation, applying Socolow and Pacala's Stabilization Wedges framework and the Global Carbon Budget to underscore the importance of forests in broader climate stabilization strategies. Forests cover approximately 30% of the Earth's land area, but due to land use changes, deforestation today accounts for between 12% to 20% of all carbon emissions globally. This study explores recent gains in global forest conservation, while emphasizing the challenges of deforestation, and finds that international and national efforts to curb deforestation and promote reforestation are yielding positive results. The drivers of deforestation are explored, such as land-use changes for palm oil and soy plantations, which have led to deforestation and increased greenhouse gas emissions. Additionally, this paper considers the role of various stakeholders, particularly forest owners vulnerable to climate risks and forest fires. It highlights regional case studies like China's 'Grain for Green' program as successful models for balancing economic and ecological goals. Using McKinsey's Three Horizons framework, the paper then outlines immediate actions, transitional strategies, and long-term actions to deliver a forestry wedge, focusing on sustainable forest management and technological innovations for large-scale reforestation.

Keywords: Forestry, Deforestation, Reforestation, Stabilization Wedges, Carbon Budget

Introduction

Forest ecosystems are crucial as they safeguard water resources, yield economic products, preserve biodiversity, and combat climate change. Forests supply financial income, food, and medicinal support to a significant portion of the world's impoverished population [1].

Forests not only play a vital role for life on the planet, but they also soak up CO_2 for photosynthesis, store carbon, and release oxygen. With deforestation, trees are felled, and that process is inverted, releasing the sequestered carbon back into the atmosphere, thereby enhancing the greenhouse effect. Deforestation adds to the CO_2 level in the atmosphere, which has reached 424 ppm as of mid-2023 [2].

No single sector can deliver on the deep decarbonization needed. The challenge of mitigating climate change necessitates rapid implementation of sectoral transition strategies to stabilize greenhouse gas (GHG) emissions and then pursue rapid and deep decarbonization.

Socolow & Pacala's 2004 Science paper introduced the "Stabilization Wedges" framework, suggesting that the tools required to address climate change for the upcoming half-century are already available, with deforestation and reforestation being a wedge on its own [3].

Using Socolow and Pacala's Stabilization Wedges framework, the contribution of this paper is to assess and present a comprehensive mitigation plan from the forestry sector's perspective.

The first step is to assess the state of play in the sector, including the efforts across the countries where deforestation trends are most serious. Deforestation trends are analyzed, underlying factors are assessed, and recent trends in forest fires are investigated. This paper explores current reforestation efforts and recent scientific proposals for a massive global tree planting program are evaluated, and finally advancements in tree planting technologies are presented.

Materials & Methodology

Materials, Methods and Frameworks

The paper investigates the following research questions: Q1: In the context of Socolow & Pacala's Stabilization Wedges framework and the Global Carbon Budget, how do contemporary deforestation trends compare with the potential benefits of reforestation and forest conservation in mitigating climate change?

Q2: How can a three-horizon approach to a global forestry program be developed?

This paper examines the dual approach of maintaining existing forests and pursuing reforestation and afforestation, drawing on McKinsey's strategy framework, the Three Horizons.

Research Methodology

Adopting an interdisciplinary approach, this paper addresses the posed questions through a research methodology that includes a comprehensive review of recent literature, assessment reports, and policy documents related to global deforestation and reforestation trends. The amassed data will be systematically analyzed to extract insights on deforestation trajectories, technological advances, and policy-driven incentives and barriers. Consequently, this methodology will yield a coherent narrative showcasing decarbonization potential, offering valuable insights for policymakers, industry stakeholders, investors, and academics [4, 5].

Rethinking the Stabilization Wedges framework

First presented in 2004 by two Princeton scientists, The Stabilization Wedges framework explores sectoral strategies to reduce carbon emissions, stabilize atmospheric CO_2, and prevent doubling of preindustrial carbon concentrations (Figure 1). Socolow & Pacala suggested parallel action programs conceptualized as wedges in the stabilization triangle (Figure 2). Major efforts were envisaged across sectors such as transportation, wind power, and nuclear power. Deforestation and afforestation were highlighted in the paper as well.

Figure 2 showcases the "old" Stabilization Wedges framework from Socolow and Pacala, modified with my perspective. One of the 13 updated wedges — the deforestation and reforestation sector — warrants immediate focus and forms the theme of this paper.

Each "wedge" represents a substantial, comprehensive contribution to carbon reduction [6]. At a global scale, the wedges add up to a major sectoral climate action program. The wedges approach resembles the diversification approach found in modern portfolio theory, balancing assets and mitigating risk[1] [7].

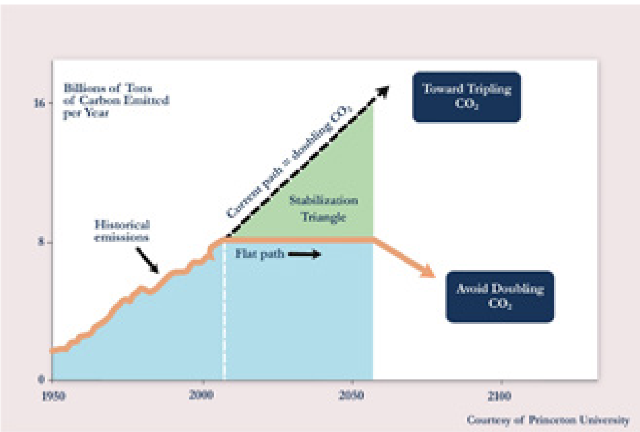

Figure 1: Stabilization Wedges framework: Doubling Path and The Stabilization Triangle

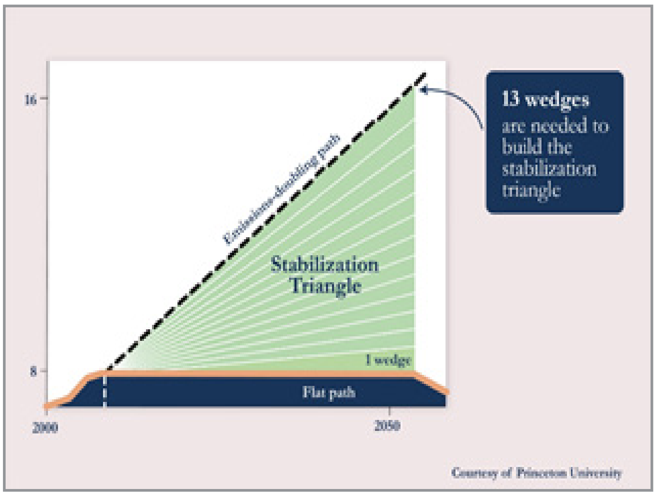

Figure 2: 13 Stabilization Wedges Fill Up the Stabilization Triangle[2]

When Socolow and Pacala published their paper in 2004, they had a portfolio of eight proven solutions that could be deployed at that time[3]. An additional 15 strategies were outlined that could reduce global carbon emissions by 1 billion tons per year by 2050—or one wedge.

In 2011, Socolow increased the stabilization wedges from seven to nine due to escalating emissions since their 2004 study[4]. As of 2023, the effort needed to stabilize emissions has grown into a more complex climate challenge, necessitating a broader range of solutions and enablers such as sustainable finance and zero carbon cities, which is explored in my upcoming book, "The Great Transition". But that is not all — the carbon budget is rapidly being exhausted which necessitates urgent action.

Adapting the Wedges to the Current Global Carbon Budget

Over the past decade, global warming has escalated at over 0.2°C per decade, culminating in an average increase of 1.14°C from 2013 to 2022. A primary driver behind this surge is the unprecedented levels of GHG; in 2021 alone, about 55 Gigatons of CO_2 equivalent ($GtCO_2e$) were released into our atmosphere.

Having only 250 $GtCO_2$ left to keep global warming below the perilous increase of 1.5°C mark, current projections suggest we will exceed the Paris Agreement threshold permanently by 2025. It is crucial to note that in July 2023, our planet already breached this threshold thrice, partly due to recurring phenomena like the El Nino effect.

To stave off the catastrophic climate impacts of a temperature rise exceeding 1.5°C, it is imperative to recalibrate our goals and act swiftly [8].

The forestry sector holds untapped potential for balancing our carbon budget, as it provides a dual approach: preventing carbon release through decreased deforestation and increasing carbon capture through expanded reforestation efforts.

Furthermore, addressing this wedge effectively necessitates a deeper understanding of its underlying drivers and potential solutions. Deforestation accelerates climate change by releasing stored carbon, whereas reforestation (planting trees on previously non-forested land) or forest restoration actively absorbs carbon, helping to neutralize emissions.

An ambitious and radical shift in our forestry perspectives is indispensable to remain within the 250 $GtCO_2$ threshold. This paper does not seek to raise alarm for the sake of it but situates itself in the emerging research field of 'catastrophic climate change' [9]. Here, researchers assess the impacts and solutions for a potential 2°C-3°C world, not least in order to prevent such a warming scenario.

Once introduced to the atmosphere, CO_2 emissions persist for an extended period, ranging from 300 to 1,000 years (Nasa.gov). Consequently, the atmospheric alterations caused by human-emitted carbon dioxide will last through the span of numerous human lifetimes. Also, for that reason, making maximum use of natural carbon sinks are of pivotal importance.

Scientists call this a critical decade: human-induced global warming rates are at their highest historical level, and 1.5°C global warming might be expected to occur or be exceeded within the next 10 years in the absence of cooling from major volcanic eruptions. Rapid and stringent GHG emission decreases could halve warming rates over the next 20 years[5] [10].

A Three-Horizon framework to Delivering on a Forestry "Stabilization Wedge"

How can we conceptualize an implementation effort within a single forestry wedge? Here, the McKinsey 3 Horizons framework is applied in the paper; a strategic model that helps organizations categorize and prioritize growth initiatives into three "horizons" based on the time frame and technological uncertainty [11].

A brief discussion of implementation looks at solutions in the near-term (1-3 years), mid-term (5 years), and long-term (over 10 years). The strategy revolves around identifying scalable case studies and examples, aptly matching the pressing demands of our shrinking carbon limits.

Discussion - What is the Current Forest Situation?

The Role of Forests in Climate Stabilization

Encompassing nearly one-third of the Earth's landmass, forests serve as indispensable regulators of our climate by storing carbon. Forests play a pivotal role in ecological balance, the safeguard of biodiversity, and climate stabilization. Globally, forests cover nearly one third of the land area and contain over 80% of terrestrial biodiversity [12].

Trees clean our air and protect groundwater in rural areas while improving biodiversity, soil, health, food production, and local economies in developing countries. Yet, their distribution is not uniform across the globe.

Forests are crucial for protecting biodiversity and storing carbon. The World Economic Forum in 2020 highlighted the global economy's reliance on nature, particularly within specific industries. Human actions threaten approximately 25% of evaluated species with extinction, putting at risk $44 trillion in economic value.

Industries such as construction and agriculture depend heavily on nature and face significant risks, with China, the EU, and the US being particularly vulnerable. Approximately 50% of the global $84.4 trillion GDP in 2020 relies on ecosystem services [13]. In fact, forest ecosystem services like recreation, hunting, habitat, non-timber products, and water are valued at $7.5 trillion—21% of land assets and 9% of global GDP [14].

Concentrated in regions such as the equatorial areas of Africa, the Himalayan range, the Andes in Latin America, and the Rocky Mountains in the United States, forest-rich locations have high density and rich biodiversity. Geographical clustering is central to consider when developing global forest conservation strategies.

Critical Global Forest Distribution and Conservation Initiatives

According to data from the UN Food and Agriculture Organization (FAO), forests cover approximately 30% of the Earth's land area [15]. In fact, five countries—Russia, Brazil, Canada, the United States, and China—collectively account for 54% of the world's forest cover. Tropical regions are noteworthy, comprising 45% of the total forest area globally.

Despite their intrinsic worth, forests have endured unabated deforestation, accounting for a third of the cumulative carbon emissions since 1850, and deforestation has persistently contributed to around 10% of annual emissions. Annually, 13 million hectares of forests are lost (Bonn Challenge).

One of the major initiatives related to this worth mentioning is the Bonn Challenge: a global effort to bring 150 million hectares of the world's deforested and degraded land into restoration by 2020 and 350 million hectares by 2030[6].

The UN General Assembly adopted the first-ever UN Strategic Plan for Forests on April 27, 2017. Featuring six universal and voluntary Global Forest Goals, the plan includes a target to increase forest area by 3% worldwide by 2030. If achieved, this would equate to an increase of 120 million hectares, an area over twice the size of France[7].

In this context, the sequestered 1.6 trillion tons of carbon dioxide within our forests—surpassing the amount present in our atmosphere—must be safeguarded and not released if we are to stabilize the climate and reach a net zero state[8].

Balancing Progress and Peril: A Dual Narrative of Global Forest Conservation Trends

The reduction in forested land experienced a decline over the years, decreasing from an annual loss of 7.8 million hectares in the 1990s to 4.7 million hectares per year in the 2010-2020 period. While deforestation continues in certain regions, there are instances of new forests emerging through natural expansion or intentional reforestation efforts elsewhere [16]. Global forest loss appears to have reached its peak in the 1980s. During that decade, as a consequence of deforestation, Williams approximates a loss of 150 million hectares, an area roughly half the size of India [17].

In areas outside the tropics, especially in developed countries, the amount of land covered by forests grew by 26 million hectares per year due to natural processes that allowed trees to grow back [9].

Forest areas in Russia, the US, China, and Europe are expanding, indicating growing awareness and successful conservation efforts. However, challenges of deforestation in other areas, especially tropical regions, persist. The significant forest cover in these nations makes their role in global forest conservation crucial. Collaborative strategies among these countries are vital for global forest sustainability, with their national policies setting precedents and providing scalable models for sustainable management.

As of 2022, some 73% of forests globally were owned publicly in 2015, and 22% were owned privately. Hence, protection efforts must both cater to national and local governments and private stakeholders [14].

Natural Forests Store More Carbon Than Plantation Forests

Climate policy has mainly considered carbon stocks and sequestration in forests for global warming mitigation. But it is important not to overlook changes in forest cover, structure, and composition. Researchers have highlighted that current metrics inadequately capture forests' importance for climate change mitigation and adaptation [15]. To ensure this, scientific models need to be continually strengthened.

While forests undoubtedly play a role in trapping CO_2 through their biomass and soils, it is essential to distinguish between natural forests and plantation forests. The two types of forests differ in their carbon sequestration potential, a point that is often overlooked in large-scale afforestation plans.

Recent studies indicate that estimations of afforestation potential can vary widely when variables such as food security implications are considered. Notably, natural forests have shown a higher capacity for carbon storage compared to plantation forests.

This is largely attributed to the greater biodiversity and more complex ecosystem structures found in natural forests, which lead to more stable carbon sinks. A multifaceted approach to forestry can indeed serve as a stabilizing component within a broader mitigation strategy.

While large-scale tree planting efforts are a favored technique for CO_2 reduction, implementing afforestation projects in high-productivity regions using mixed-species forests can cut emissions and enhance biodiversity. The question arises whether these should be new plantations or regenerated natural forests.

Often, poorly planned afforestation projects can lead to the degradation of natural forests, reducing their carbon sink potential. Moreover, there is opportunity in encouraging the regeneration of secondary natural forests, which can recover to store as much carbon as primary natural forests. It should be acknowledged that the full suite of ecological features, including carbon storage capacity in forests, takes centuries to develop fully. From both a climate and biodiversity perspective, priority should be given to safeguarding and restoring natural forests over planting new plantation forests.

Optimistic Trend: FAO Report Reveals Global Gains in Forest Conservation

A recent report from the UN FAO provides evidence of improvements in global forest conservation. From 2000 to 2018, the world saw a net loss of 93 million hectares of forest. However, when this figure is broken down, it shows a more nuanced trend; the world lost 173 million hectares of forest but gained 80 million hectares during this period.

The challenge remains to amplify reforestation efforts and enhance conservation practices to reverse this trend. Urgent action and commitment from governments, businesses, and communities are necessary to halt deforestation and promote restoration.

Annual Deforestation Rates Decrease While Reforestation Efforts Accelerate

More promising are the annual rates of change. The report revealed that the annual rate of deforestation decreased by about 29%, falling from 11 million hectares per year in the first decade (2000–2010) to 7.8 million hectares per year in the second decade (2010–2018). On the flip side, annual gains in forest areas slightly increased from 4.2 million hectares to 4.7 million hectares per year during the same periods.

The net effect of these changes is substantial. The annual net loss, which is the difference between the number of hectares lost and gained each year, dropped dramatically. Net loss fell from 6.8 million hectares per year in the first decade to just 3.1 million hectares per year in the second. This decline signifies that not only are we losing fewer forests each year, but we are also gaining more, pointing to the efficacy of contemporary conservation efforts[9].

Therefore, the FAO report offers a cautiously optimistic view of the current state of global forest conservation. It suggests that international and national efforts to curb deforestation and promote reforestation are yielding positive results. Now, let us dive deeper into the reasons that deforestation occurs.

Identifying the Causes of Deforestation

Deforestation accounts for between 12% to 20% of all carbon emissions globally, emphasizing that forests are not just passive landscapes but dynamic ecosystems influencing the global carbon balance. Deforestation can be defined as “the conversion of forest to other land use independently whether human-induced or not”[10]. It is typically done to convert the land for agriculture, mining, or urban development. This process can result in a loss of biodiversity, disruption of carbon cycles, and changes to local and global climates.

The expansion of pastureland for beef production, cropland for soy and palm oil, and the conversion of primary forests to tree plantations for paper and pulp are some of the main drivers of deforestation in these regions[11, 12].

Expansion of pastureland has had an impact on land use in the rest of the Americas—outside Brazil, Latin America accounted for about one-fifth of deforestation. Agricultural land expansion in Africa accounted for about 17.5% of deforestation.

The agricultural expansion trend, predominantly observed in South America, Africa, and Asia, is responsible for nearly 90% of all deforestation. In fact, cropland expansion accounts for 50% of deforestation worldwide. Livestock grazing follows, causing 38.5% of global deforestation[13].

Between 1980 and 2000 more than half of the new agricultural land across the tropics was obtained by clearing intact forest [18].

Particularly, the growth of palm oil cultivation from 2000-2018 caused 7% of total global deforestation. The commodity groups most associated with deforestation were cattle meat, forestry products, palm oil, cereals and soybeans, although variation between countries and regions was large [19].

Recent efforts by institutional investors to minimize illegal palm oil companies in portfolios is urgent, with palm oil production substituting forest ecosystems acting as carbon sinks[14].

In fact, numerous asset managers such as Store Brand in Norway have pledged zero-deforestation commitments (ZDCs) to curtail carbon emissions and biodiversity losses associated with tropical commodities in their portfolios[15].

To avoid ZDCs' unintended effects and lessen the environmental impacts from palm oil, sustainable development and conservation policies and governance need to broaden their focus from rainforests to all tropical biomes [20]. To follow up on this idea, the paper discusses how biodiversity must be considered in forest restoration efforts, which are now also part of some corporate zero ZDCs.

The Amazon Is Approaching a Tipping Point Due to Deforestation and Climate Change

To deliver on a forest stabilization wedge, the loss of the Amazon's resilience compromises its role as a critical global carbon sink, which is a concern. The dieback of the Amazon rainforest serves as an upsetting example where deforestation rates have been escalating, threatening the rich biodiversity of the region. Recent evidence indicates that deforestation— when combined with a warming climate—increases the likelihood of the Amazon undergoing a pivotal transition from a humid to a dry state within the 21st century [21, 8].

In fact, agricultural expansion and land use change is harming the Amazon system's capacity to sequester excess carbon, leading to a cascading effect on the local climate with less rainfall, more drought and drying of land, each of which worsens the carbon storage potential.

In addition to clear-cutting, conversion of primary forests to managed forests and illegal logging can also increase carbon emissions from forests. Deforestation can have indirect effects on the regional climate, such as changes in the reflection of sunlight, known as local albedo, caused by a reduction in forest cover[16,-18] [22].

When the Amazon rainforest is cleared, it is often been replaced by livestock and agricultural crops, bringing new sources of emissions. This sequence of events worsens existing environmental problems, and efforts to halt deforestation in Latin America must be informed by an understanding of its complex implications for Earth's carbon cycle and broader ecological stability[19].

A recent study explored how Amazon deforestation at various scales impacts the regional climate, using three deforestation scenarios. Results indicated deforestation reduces precipitation and alters radiation, energy, and water balances, with the most significant effects seen in complete deforestation scenarios, affecting both dry and wet seasons [22].

The deterioration of the Amazon rainforest is on its own one of multiple climate tipping points that influence global climate stability with one tipping point having cascading effects on other tipping points [23].

Second-growth forests, which are forests that are regrowing after being cut or disturbed, now cover 28.1% (or 2.4 million km2) of land in the tropical areas of Latin America, according to a 2016 study by Chazdon and others. This means that nearly a third of the forests in these areas are in a process of recovery, having previously been affected or removed due to various reasons such as logging or clearing for agriculture (Chazdon, R. L., et al., 2016).

As more people live in these areas, there's a need for more land, and often, forests are cut down to make room. In other words: the issue of deforestation and its far-reaching consequences remains a subject of serious concern. According to a 2020 study by the UN FAO, between 1990 and 2020, the world lost a total of 178 million hectares of forest, an area about the size of Libya [16]. This figure underscores the need for coordinated international efforts aimed at addressing the root causes of deforestation and forest degradation.

Deforestation Dilemma: Analyzing Trends in Pakistan

Several reasons for deforestation exist; one country case study found that deforestation in Pakistan was driven by unsustainable fuel and timber extraction, urban and rural expansion, uncontrolled livestock grazing, and energy needs from wood [24]. Between 1990 and 2020, Pakistan's population surged from 115 to 227 million. Concurrently, the nation experienced a visible reduction in forest cover, illustrating an inverse relationship with population growth.

This trend, mirrored globally, subtly highlights the delicate balance between growing human populations and habitat loss, and subsequent biodiversity loss (the World Bank)[20]. Acknowledging this correlation is crucial for devising sustainable development strategies that integrate population and conservation considerations.

Global Deforestation Crisis: Unpacking Economic Drivers and Ecological Consequences in Key Regions

Regrettably, the world's major forested regions—spanning Central Africa, the Amazon Basin, Indonesia, and Papua New Guinea—have witnessed declines in tree cover over the past decade, culminating in a net reduction in overall forest area and diminishing the carbon sink and stabilization wedge potential.

Particularly in Indonesia, widespread deforestation has been largely attributed to the expansion of palm oil plantations. Deforestation in Ko'mara, driven by human factors, results in fragmented forests, making control of deforestation difficult. Analysis reveals clumped deforestation with increasing rates from 2005-2019, indicating growing environmental concern [25]. The country suffered one of the world's highest forest loss rates, and saw its forest cover decrease from 78.3% in 1950 to 46.8% in 2017.

This is a worrying development, as Indonesia's rainforest system, like the Amazon, constitutes an important carbon sink. A recent study, assessing forest transformations from 1950-2017, highlighted that 35% of the national territory in Indonesia experienced deforestation [26].

Protected areas have been somewhat effective in slowing down deforestation but have not halted it. Deforestation has continued within these protected areas, in vulnerable regions at lower altitudes and along the coast due to the expansion of plantations.

The extensive 67-year time series data of forest transformation provided insights into geographical differences in deforestation rates, underscoring the need for more sophisticated strategies, including active local community involvement for sustainable forest management.

Indonesia's Struggle: Balancing Economic Drivers with Forest Conservation

The palm oil industry is a major economic driver for Indonesia, but it results in deforestation at the expense of biodiverse forest ecosystems. Land is cleared using slash-and-burn techniques, contributing to air pollution and greenhouse gas emissions.

Deforestation near populated areas, as well as along roads and rivers, continues to be a concern. This trend is often driven by factors such as agricultural expansion and the extraction of valuable resources such as mahogany, gold, and oil. The proximity to infrastructure like roads and rivers makes it easier and cheaper to transport these resources, aggravating the rate of forest loss.

Forest Owners Face Rising Climate Risks

In the context of the climate crisis, it is essential to consider the perspectives of stakeholders such as forest owners.

A 2020 study by plant physiologist Tim Brodribb from the University of Tasmania highlights an alarming trend: current tree mortality rates surpass the beneficial fertilization effects of a higher carbon dioxide level in the atmosphere. The implication of this is that the majority of existing trees might not be resilient enough to thrive in the projected climatic conditions four decades from now. Warm and semi-arid regions are particularly susceptible, as they exhibit sharper temperature increases coupled with declining soil moisture levels.

To offset these challenges, forest owners could consider introducing more climate-resilient tree species that are better adapted to warmer conditions and wildfires[21].

Escalation of Global Wildfires Compromises Forestry's Carbon Sink Potential and Elevates GHG Emissions

Over the recent decade, a surge in wildfire occurrences has been noted in various global regions, including California, Canada, the Mediterranean, Siberia, and Australia. This upsurge is attributable to factors like increased temperatures, elongated fire seasons, and erratic weather patterns influenced by phenomena such as El Niño, with climate change serving as a significant catalyst.

These wildfires not only hinder the ability of forests to act as effective carbon sinks but also directly contribute to the atmospheric accumulation of GHG emissions, undermining efforts to mitigate climate change. The burning of forest biomass releases stored carbon dioxide back into the atmosphere, diminishing the net carbon sink potential of forests and exacerbating the global carbon budget.

The June 2020 Arctic fires exemplify this detrimental trend. These fires were more intense than those in June 2019 and far exceeded the fire activity in the region from 2003 to 2018. This intensified activity induced large-scale releases of carbon from thawing permafrost, further compromising the atmospheric carbon balance[22-25].

The 2019-2020 Australian bushfires, highlighted by the World Wildlife Fund, stand as a particularly catastrophic example of climate-induced conflagrations. The fires not only obliterated an estimated 1.5 billion wild animals and portions of protected territories but also impaired the regions' carbon sink capability[26]. With their impacts visible from space, these fires released massive amounts of carbon dioxide, equating to the annual emissions of the European Union.

Similarly, the record-breaking 2020 fires in Brazil's Pantanal, the world's largest wetland, and the relentless "zombie fires" in Siberia's permafrost regions released unprecedented amounts of stored carbon. These releases not only diminished the crucial carbon sequestration function of these unique ecosystems but also added to the already heightened levels of atmospheric GHGs.

In the face of climate change, regions like California, Canada, the Mediterranean, Siberia, and Australia have recurrently grappled with severe fires over the last decade. This global phenomenon, driven by changing climate dynamics, poses a dual threat by both undermining the carbon sink potential of global forest reserves and contributing significantly to GHG emissions.

Examining Forestry Solutions

China's "Grain for Green": A Model for Global Forest Restoration?

Afforestation and reforestation are two distinct approaches aimed at enhancing forest cover. Afforestation refers to the process of introducing trees on lands previously devoid of forest cover, such as agricultural or barren areas, with the objective of generating new forest ecosystems [27].

Conversely, reforestation pertains to the restoration or regeneration of trees in regions that have seen forest cover loss, whether due to human activities like deforestation and clear-felling, or natural events such as hurricanes. The primary aim of reforestation is to reinstate or substitute trees in locations that were previously forested.

In the context of global climate concerns, it is pertinent to spotlight effective strategies that underscore the importance of forest regeneration. China has emerged as a prominent actor in afforestation efforts. Notably, the commitment made in December, 2020 by President Xi Jinping aimed to enhance the forest stock volume by 6 billion cubic meters from its 2005 level by the year 2030. The successful "Grain for Green" program pays farmers to convert croplands to woodlands[27].

The “Grain for Green” initiative in China has facilitated the restoration of forest landscapes across approximately 28 million hectares of previously agricultural and degraded lands. This program has necessitated an investment exceeding 40 billion USD, impacting around 124 million individuals, predominantly in China's mountainous and hilly areas where a significant proportion of farmers reside.

Global Implications and Unintended Consequences of Afforestation Efforts

In the broader global context, as restoration endeavors gain momentum, scholars are turning their attention to China's achievements for insights to fulfill the objectives of the Bonn Challenge, which envisions the restoration of 350 million hectares by 2030.

To achieve carbon reduction and neutralization goals, China's forest sector's potential role is crucial. Between 2006–2020, forests and harvested wood products sequestered and stored significant carbon, offsetting 11.76% of national emissions. Future offsets are projected, supporting aggressive nature-based solutions and carbon accounting for meeting Paris Agreement targets [28].

Other nations, such as South Korea, India, Vietnam, and Chile, have likewise demonstrated commendable progress in augmenting their forested areas. However, related literature reveals certain adverse outcomes linked to these afforestation activities, including unforeseen ramifications on local water supplies.

Reforestation in the eastern United States has been linked to local cooling of both land and air temperatures, according to analysis from various data sources. Young, regrowing forests, especially those aged 25-50 years, showed the strongest cooling effects, contributing to slower warming trends in the EUS. This suggests that reforestation could be a valuable strategy for mitigating the impact of climate change globally [29].

The Importance of Biodiversity Considerations in Forest Restoration and Reforestation

Both forest restoration and reforestation are crucial in sequestering carbon and mitigating climate change, but their carbon sink capabilities can vary depending on several factors. Forest restoration involves revitalizing existing degraded forests, and the restored areas might sequester carbon more quickly initially, as there are often already mature trees present, which are effective carbon sinks. Here, the goal is to enhance the health of the entire ecosystem, leading to a more resilient carbon sink in the long term [30].

Forest restoration often emphasizes preserving biodiversity, leading to forests that are more resilient to pests, diseases, and climate change, indirectly supporting effective carbon sequestration over time [31]. Facing intertwined biodiversity and climate crises, forest restoration offers a dual remedy; it is imperative for forest owners to focus on enhancing biodiversity outcomes. Reforestation has clear benefits with regards to carbon sequestration [32]. Newly planted trees take time to grow and mature before they can effectively sequester significant amounts of carbon. The carbon sequestration rate can be substantial in the long term, but it depends on the tree species planted, management practices, and the purpose of reforestation.

Species selection also matters. Planting fast-growing species such as eucalyptus, polar or pine might sequester carbon quickly, but these fast-growing species may not support the biodiversity of the original forest, particularly not if they are planted in monocultures. Biodiverse forests are more resilient and provide a sustainable carbon sink over time.

Both reforestation and forest restoration contribute to carbon sequestration, but the effectiveness of each as a carbon sink depends on the management approach, species selection, and the preservation of biodiversity. Forest restoration may offer quicker and more resilient carbon sequestration benefits due to the presence of mature trees and an emphasis on ecosystem health, whereas reforestation is vital for long-term carbon capture, especially in areas where forests have been completely removed.

Regenerative Forestry: A New Carbon Sink Solution?

Regenerating forests, especially after deforestation or degradation, is more than just planting trees. Traditional reforestation often falls short of restoring the complex ecological dynamics and carbon sequestration capabilities of native forests.

Enter regenerative forestry, which aims to address these challenges, turning forests into effective carbon sinks. This method diverges from conventional ones by focusing on entire ecosystems, not just tree cover. It aims to conserve, restore, and enhance the ecological integrity of forests, introducing native species, restoring water flows, and more.

The approach's cornerstone is sustainable harvesting and natural regeneration, allowing forests to recover and promoting biodiversity without planting specific trees. This strategy not only offsets carbon emissions released during initial land-use changes but, over time, allows regenerated forests to exceed the carbon storage potential of those restored using traditional methods.

Beyond Carbon Sequestration: Co-Benefits of a Holistic Approach

Furthermore, regenerative forestry has the advantage of contributing to long-term forest resilience, thereby providing co-benefits like enhanced biodiversity, improved water quality, and increased habitat for wildlife. These attributes make it an attractive option for policymakers who aim for multifaceted solutions to climate change and ecological degradation.

Regenerative forestry holds the potential to significantly impact our broader strategies for climate change mitigation and biodiversity conservation. However, climate change could potentially reduce the effectiveness of reforestation in serving as a climate ally.

A recent study employing a specific model explored tree regrowth in Central America's tropical regions. The findings revealed that with increasing warmth, exceeding an average of

29°C, new tree growth rates and carbon uptake decrease. Specifically, these trees may only grow half as much in arid regions and may see a reduction of about 10% in wetter areas by 2100. This suggests that in a warming world, newly planted forests might not offer as substantial climate benefits as previously anticipated [33].

Could a Global Tree Planting Program Remove Two-Thirds of All Emissions?

Tree planting initiatives are gaining traction as a viable method for offsetting anthropogenic CO_2 emissions in the quest to achieve net-zero emissions.

The scientist Tom Crowther and his colleagues published a paper in 2019, suggesting that a global tree-planting program could absorb two-thirds of all human-made emissions currently in the atmosphere (Crowther, T., et al., 2019). Crowther's study estimated Earth could accommodate an additional trillion trees on land not used for agriculture or urban areas, with the potential to remove 200 billion tons of carbon over 50-100 years.

The study found 1.7 billion hectares of treeless land—equivalent to the combined size of the US and China—where 1.2 trillion native tree saplings could grow. Crowther argues that forest restoration is the top climate change solution and could be realized in an area about the size of China. Tropical areas could have 100% tree cover, while other areas would be more sparsely covered. Grazing land was included in the analysis, but not crop fields or urban areas[29].

Examining the Feasibility: Critiques and Counterarguments

Crowther's article caused a great deal of discussion and responses from Berwyn, B., and from Bastin [34, 35]. Bastin argues that Crowther's optimism regarding the proposed tree-planting program is misplaced; Crowther's projection, which considers a scenario where the human population is almost nonexistent, is irrelevant when evaluating the potential of natural tree cover to serve as a carbon sink. Thus, it is an approximated natural forest potential, which is not so realistic with 8 billion people on the planet. There is also debate about the method of estimating the uptake of CO_2.

Multiple Benefits of Tree Planting and Real-world Implications

The potential for tree planting could take place in areas previously degraded or sparsely vegetated. Planting trees offers more than just carbon sequestration; it improves air and water quality, provides wildlife habitats, and offers cooling spaces in the summer. It may also increase rainfall, offering a counter to deforestation's adverse effects on weather patterns.

Therefore, even with 3 trillion trees already existing, a net loss of 10 billion trees occurs annually due to deforestation. Tree planting remains a vital component in addressing climate change and has the potential to revitalize degraded or sparsely vegetated areas.

With cities and urbanity growing, it is noteworthy that the U.S. Environmental Protection Agency highlight that planting trees is effective when it comes to curtailing urban heat islands, which has been documented in recent research[30] [36].
Tree planting is a powerful tool and one of the solutions in the diversified wedge framework to address climate change. In short, despite the 3 trillion trees in the world, there is still a net loss of 10 billion trees each year due to deforestation[31].

What can forest owners do? Proactive steps can be taken by forest owners to mitigate the risks of climate change. By planting resilient species and using adaptive management techniques, forest owners can ensure that their forests remain healthy and productive in the face of a changing climate[32] [37].

A Three-Phased Approach to Rolling out a Global Forestry Wedge

Navigating Forest Sustainability Through McKinsey's 3 Horizons framework

In this last section, the paper takes on a more speculative, yet action-oriented approach, in order to actually deliver the forestry wedge.

Halting deforestation and engaging in reforestation can be situated within Horizon 1, as these are immediate, urgent actions that provide short-term, tangible benefits and address current challenges.

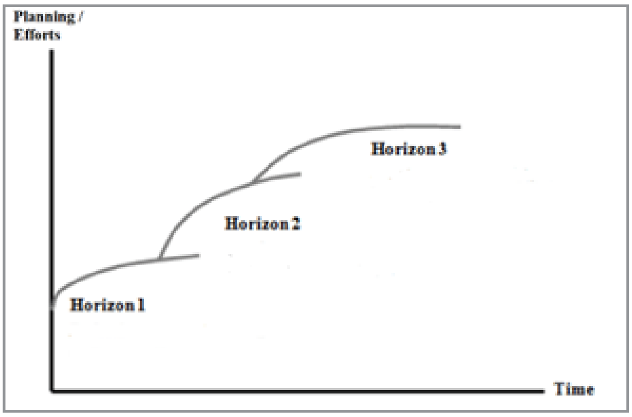

Figure 3: A Simple McKinsey Three Horizons framework

Horizon 1: Immediate Actions and Policy Measures
In Horizon 1, spanning the present and the next 3-5 years, a primary goal is the protection of existing forests. In the context of climate stabilization, it is imperative to thoroughly grasp and enhance our comprehension of how existing forests contribute to carbon sequestration. Given the rising threats of physical climate risks like wildfires, proactive forest fire management takes on paramount importance. It is essential not only for safeguarding existing forest resources but also for preserving their capacity to act as carbon sinks.

As natural forests play a significant role in carbon sequestration, policymakers should be cautious to avoid unintentional damage to these carbon sinks. It might be necessary to alter forest structures, particularly in regions prone to drought and wildfires, to minimize risks. Forest owners need to implement mitigation strategies to address climate change risks actively.

In the first horizon, more systematic reforestation and forest restoration is planned and collaboration efforts under the Bonn Challenge are relaunched. As the UN reports a large land area, comparable to twice the size of China, that is seriously degraded by climate change, the urgent need for large-scale, collaborative restoration through reforestation is realized[34] [38].

Horizon 2: Emerging Technologies and Long-term Strategies
Moving to Horizon 2, sustainable forest management practices and technologies such as satellite monitoring of deforestation are employed.

Recognizing tropical deforestation's major role in climate change and its rapid acceleration via satellite measurements, Clare Balboni from London School of Economics and accompanying researchers reviewed methodological advances, developed deforestation models, and integrated features characterizing deforestation in developing nations. The study offers a foundation for examining tropical deforestation's economic aspects, requiring more research [39].

The development of eco-friendly deforestation-free products emerge as opportunities, driving down the demand for the products that cause deforestation. Public-private partnerships increasingly deliver on enhanced forestry finance and tax incentives are be provided to private forest owners to encourage tree planting. More tree planting and reforestation begin to place on designated low-productivity farmland. Collaboration and incentives will be of the essence to achieve sufficient scale[35].

Reforestation is crucial for climate change mitigation. Extensive research indicates that planting billions of trees globally is an effective strategy for addressing the climate crisis. Although Crowther's study is subject to debate, it introduces a noteworthy proposition. Identifying and better mapping of areas devoid of trees, but suitable for cultivating native saplings, is a practical and essential initiative. This approach requires further exploration by national and local governments committed to making meaningful contributions to climate change mitigation efforts[36].

Horizon 3: Scaling for Impact
In Horizon 3, which is more than a decade away, the imperative to stabilize the climate hinges on successfully realizing the goals set in Horizons 1 and 2. In this phase, the critical factors are scale and effective implementation. A potentially transformative technological solution on the horizon is industrial-scale reforestation through the use of drone technology [40]. Drones have the potential to revolutionize forest replanting by efficiently dispersing seeds in remote areas. This innovation has also attracted startups with ambitious promises of planting billions of trees, which could help address labor shortages in this endeavor [41-50].

A specific program has been developed by Dendra Systems, a British company founded by ex-NASA employees. They utilize AI-guided drones, which can plant up to 100,000 trees a day[37]. Expanding this program could dramatically speed up reforestation efforts. By mapping areas and identifying prime planting locations, these drones fire seed pods containing a growth medium and nutrients into the ground to speed up plant growth.

Drone-planting can support existing efforts in the reforestation process, contributing to biodiversity and reducing greenhouse gas emissions. Here, the need to restore degraded forests and create new forests will be central to store carbon, but using diverse and mixed species to ensure resilience against pests. Also ensuring the survival of these new trees will be crucial, which is why a holistic approach, that includes protecting existing forests, managing human activities leading to deforestation, and safeguarding newly planted trees, and integrating biodiversity protection will be essential for long-term success [38-40][51-58].

Conclusion: A Multidimensional Examination of Forest Climate Mitigation Strategies

This investigation applied the stabilization wedges framework to analyze forests' climate mitigation role. It found deforestation and reforestation strategies essential for climate stability. UN FAO data showed natural forests outperform plantation forests in carbon sequestration. Between 2000 and 2018, while 93 million hectares were lost, 80 million were regained, showing global conservation progress. Land-use changes, notably for palm oil and soy, drove deforestation. The article highlighted forest owners as stakeholders, and showcased China's "Grain for Green" as a model strategy.

This paper also examined reforestation initiatives and their role in addressing climate change while highlighting potential challenges, such as land-use competition. Effective forest management strategies can improve these concerns. With strategic investments, forestry can yield economic returns and support conservation efforts. The current situation shows encouraging trends, but ongoing deforestation in critical zones remains concerning, necessitating a nuanced approach.

Given the rising prevalence of wildfires, the study underscored reforestation, and preservation's significance. With urban expansion and climate concerns, land use assessment and judicious forest management are imperative for maintaining carbon sink capabilities and biodiversity protection.

This study delineated immediate and long-term strategies using McKinsey's 3 Horizons framework, emphasizing immediate actions, emerging technologies, and sustainable practices in the short term, and identifying the need for scaling reforestation efforts in the long term. Technological innovations were recognized as promising for achieving scale.

In the end, safeguarding forests, halting deforestation and engaging in reforestation is a three-horizon approach, but forms all together just one wedge: one piece of the climate puzzle, but it is a difficult wedge to deliver: Balancing deforestation trends with climate goals, our forests' future rests not on seedlings alone, but also on strategic implementation.

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End Notes

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