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The Ecological Damage and Regulatory Dilemmas Caused by Overdeveloping Forested Areas

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Abstract. Farming areas are an indispensable part of conventional agricultural strategy. They contribute to the production of medicine and economical crops, and their scale is continuously expanding. However, intensive planting strategies can cause hazardous consequences, as the rapid expansion of farming technology and monoculture cultivation model can add a huge pressure to the mass ecosystem. These factors disrupt the local ecological balance and can further weaken the biodiversity in local region. Specifically, the conversion of primary forests into monoculture plantations disrupts multi-trophic ecological networks, triggers habitat fragmentation and pollinator population collapse, and transforms carbon sinks into carbon emission sources. This article explores the environmental impacts and regulatory challenges caused by the over development of pharmaceutical companies. The study employs literature analysis and case study methods. For the administration part, the analysis indicates the systemic problems, such as the none-transparent supply chain, market leakage, coupled with the fragmentation of national-level definitions of "forests" under the REDD+ framework, collectively gives rise to regulatory arbitrage and undermines law enforcement effectiveness. In the end of the research, the conclusion indicates the regulation of exploitation of modern farming requires the multi-party joint management to ensure the stable development of farming techniques while controlling the side effects to the ecosystem.

Keywords: carbon-absorbing plant, deforestation, ecological damage, farming strategy

1. Introduction

This study explores the environmental impacts of forest land development and monoculture planting of cash crops. Such practices are driven by the rising demand for herbal raw materials for synthetic medicine and food crops such as wheat and corn, which lead to the loss of carbon-absorbing vegetation and further threaten the global ecological environment. It is necessary to strengthen policies that government has set to regulate the firms. The research is divided into two parts. Part one focuses on In pursuit of maximizing carbon sink benefits, enterprises adopt high-density, monoculture planting structures, completely ignoring the rules of the native ecosystem, thereby impacting the ecosystem. Part two focuses on The phenomenon of 'overexploitation of plants' exposes the core pain points of the global carbon trading governance system regulatory dilemmas on both international aspect and enterprises themselves. This paper uses case analysis, comparative

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analysis and qualitative research to conclude the final result. The thesis calls for strengthening internationally unified development standards, and clarifies the necessity of enhancing supervision over enterprises' ecological impacts.

2. Ecological degradation caused by unsustainable forest development

2.1. Critical strike to the biodiversity due to the deprivation of forested areas

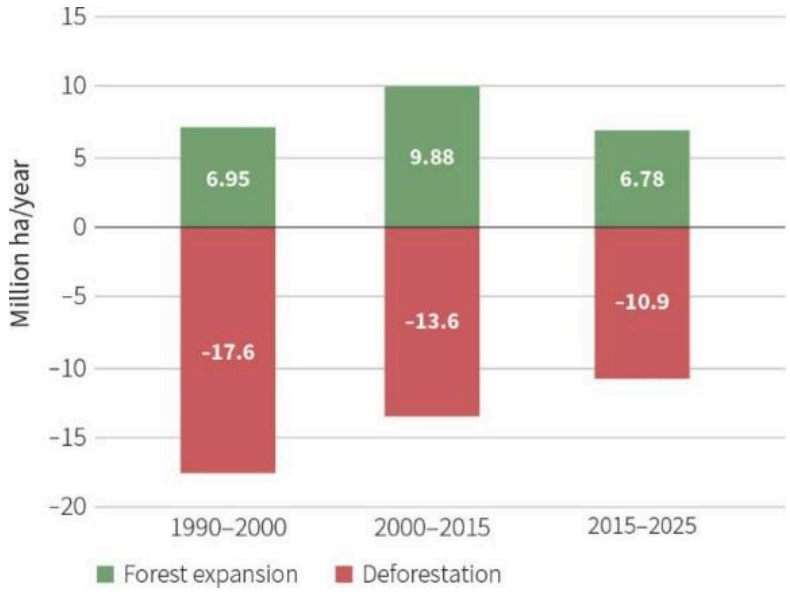

Figure 1. Annual rate of forest expansion and deforestation, 1990-2025

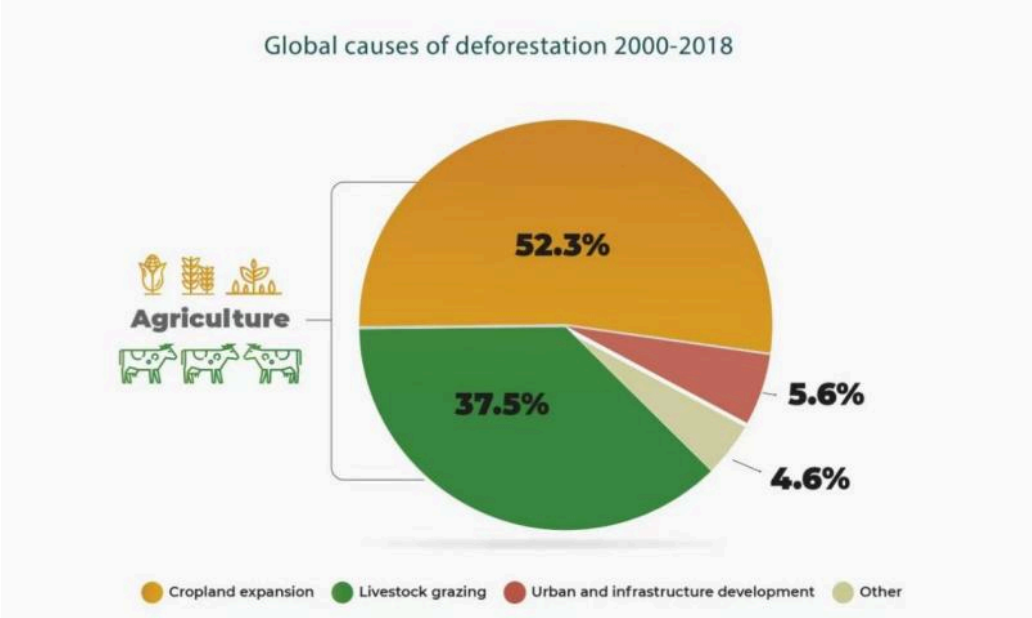

Figure 2. proportion of various use of forest exploitation from (FRA 2020 Remote Sensing Survey)

According to the graphs, the rate of deforestation far exceeds the rate of forest expansion across all three monitoring cycles, revealing a sustained net loss of natural forest biomes worldwide. Figure 1 quantifies this persistent imbalance: annual deforestation reached 17.6 million hectares between

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1990 and 2000, while forest expansion only hit 6.95 million hectares per year. From 2000 to 2015, deforestation slowed moderately to 13.6 million hectares annually, yet the peak of forest regrowth merely climbed to 9.88 million hectares. By 2015-2025, both metrics declined synchronously, with annual deforestation remaining at 10.9 million hectares against a shrinking forest expansion volume of 6.78 million hectares. In every phase, cleared woodland could not be offset by newly restored forest cover, generating a cumulative deficit in native forest habitat over three decades [1].

Figure 2, sourced from the FRA 2020 Remote Sensing Survey, further unpacks anthropogenic drivers of forest clearance between 2000 and 2018. Cropland expansion accounts for 52.3% of total global deforestation, followed by livestock grazing at 37.5%, with urban infrastructure development and other minor land uses contributing 5.6% and 4.6% respectively [1]. In major herbal production zones across Asia and Africa, more than 75% of cleared forest land is transformed into agricultural plots for food crops and medicinal monocultures, a pattern largely driven by pharmaceutical firms' surging demand for large-volume herbal raw materials [2]. Unlike traditional diversified smallholder farming, corporate pharmaceutical cultivation adopts uniform high-density monoculture systems, which require complete removal of complex native mixed forests to standardize growing conditions for target medicinal herbs [3]. Such wholesale forest clearing dismantles the layered, interdependent ecological framework unique to undisturbed primary forests, triggering cascading losses of regional biodiversity [4].

Intact primary forests operate as multi-layered, self-regulating ecological networks that support complete trophic chains and symbiotic species interactions, hosting countless organisms ranging from arboreal mammals, avian pollinators and beetle invertebrates to understory shrubs, ferns and soil microorganisms [4]. Tall canopy trees provide nesting shelters for squirrels, owls and cavity-dependent insects; native bushes supply seasonal fruit and nectar resources for pollinators and herbivores; leaf litter, animal faeces and decomposing carcasses are broken down by soil biota to form humus, delivering steady natural fertiliser for understory plant communities [5]. Intricate ecological feedback loops, including natural pest suppression, nitrogen fixation and cross-species pollination, maintain stable species coexistence within undisturbed forest landscapes [6].

When pharmaceutical enterprises convert forested land into herbal monoculture plantations, this delicate natural balance is entirely erased. Logging teams fell mature native trees, bulldoze all indigenous shrubs and plough topsoil homogeneously to eliminate competing wild vegetation, replacing heterogeneous native flora with a single medicinal crop species [7]. This large-scale habitat simplification initiates two interconnected biodiversity crises: habitat loss and habitat fragmentation. Continuous forest blocks are split into isolated, disconnected fragments separated by expansive monoculture fields, severing wildlife migration corridors and blocking gene flow between separated animal populations [8]. Confined to small, disconnected woodland patches, forest-specialist species face dual pressures of food scarcity and heightened exposure to predators, leading to mass starvation and local population extirpation [9] .

The collapse of pollinator communities creates a secondary feedback loop that further erodes native plant diversity. As wild bees, butterflies and beetles lose floral food sources in cleared zones, their population sizes contract sharply, reducing pollination services for remaining understory native plants [2]. Simultaneously, the drastic reduction in wildlife biomass cuts organic nutrient inputs to forest soil; combined with over-reliance on synthetic fertilisers and herbicides in monoculture farming, soil organic carbon and microbial diversity degrade rapidly, eliminating the natural fertility required for native vegetation to regenerate spontaneousl [5] .

From a long-term ecosystem resilience perspective, primary native forests hold far stronger self-repair capacity than artificial pharmaceutical plantations. Deep-rooted native tree networks stabilise

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soil during intense rainfall to mitigate erosion and retain groundwater reserves through prolonged droughts [10]. By contrast, shallow-rooted medicinal herb monocultures lack these hydrological and soil protection functions. Repeated cycles of forest clearance for herbal cultivation gradually degrade regional land resilience: soil runoff intensifies during rainstorms, while groundwater depletion accelerates under arid conditions, gradually transforming cleared territories into nutrient-poor wastelands with minimal ecological function [11]. Most critically, tropical and subtropical primary forests contain thousands of endemic, poorly documented medicinal and rare species that face permanent extinction once their habitats are cleared—an irreversible loss of global genetic resources that limits future pharmaceutical and ecological research potential [12] .

2.2. Biogeochemical consequences of carbon sink destruction

Forest ecosystems function as primary regulatory components within the global carbon cycle due to their high capacity for biomass carbon sequestration [13]. Through the mechanism of photosynthesis, foliar tissues absorb atmospheric carbon dioxide, converting inorganic carbon into stable organic compounds stored across living biomass architectures, including root networks, stems, and canopies. A significant fraction of this sequestered carbon is subsequently transferred to the soil substrate via litterfall and root exudation, creating long-term soil organic carbon pools [14]. As long as the net primary productivity exceeds the cumulative loss from autotrophic and heterotrophic respiration, these terrestrial ecosystems function as net carbon sinks, mitigating greenhouse gas concentrations in the atmosphere.

Corporate-driven deforestation abruptly disrupts this metabolic sequence. The removal of biomass eliminates the active photosynthetic surface area available for future carbon drawdown, while the combustion or decomposition of cleared timber converts stored carbon back into atmospheric carbon dioxide [13]. The resulting escalation in net global emissions accelerates positive climate feedback loops, intensifying thermal forcing, driving ocean acidification through elevated marine carbon absorption, and threatening crucial marine and terrestrial ecosystem services [15]. These macro-environmental alterations significantly increase survival stress across all biological strata, inducing volatile hydrological cycles that manifest as extreme droughts and catastrophic flooding events, which directly threaten human security and socio-economic infrastructure [15].

3. Regulation obstacles

3.1. Dilemmas for firm

One of the most harsh parts for the companies to regulate is the supply chain. "Companies face a constant debate about whether to engage with non-compliant suppliers or simply exclude them from their supply chains. While excluding these suppliers might create a "clean" supply chain for the focal company, it risks causing "leakage". Leakage occurs when non-compliant production is not actually eradicated but is instead just displaced from direct to indirect suppliers, or shifted to other buyers" [16]. "Leakage" refers to the situation where illegal suppliers that excessively extract resources such as logs and herbs from forests sell these materials to firms with lower compliance standards instead of to those with higher ones. This trend indicates the huge defect hiding behind the industry. Van der Ven and Barmes' [17] comparison of the cases of soybean in Brazil, palm oil production in Indonesia and pangasius aquaculture in Vietnam demonstrates the importance of studying the interaction between public and private initiatives". "They find a strikingly similar

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pattern of interaction between these cases. When private initiatives are launched in a commodity-exporting country, the initial government response tends to be favorable by stimulating compliance with the private initiative [17]. Beyond supply chain leakage, pharmaceutical firms face structural internal conflicts between carbon credit economic incentives and ecological compliance obligations, a tension amplified by the monoculture planting model for medicinal raw materials. Multinational pharmaceutical corporations pursue high-density single-species herbal plantations to maximize certified carbon sink yields, yet such operations routinely breach native forest protection rules by clearing mixed natural woodland to expand cultivation zones [16]. Even when enterprises establish internal environmental auditing departments, asymmetric information across multi-tiered suppliers cripples effective oversight: small-scale forest harvesters and herbal farmers operating in remote tropical and subtropical zones often lack standardized land-use documentation, making geospatial traceability of deforestation-linked raw materials nearly unfeasible without costly cross-border monitoring infrastructure [18].

Van der Ven and Barmes [17], further identify a contradictory public-private coordination trap within corporate governance frameworks. When pharmaceutical brands launch voluntary zero-deforestation sourcing pledges, host governments in herb-exporting developing economies initially offer administrative support to help suppliers meet private compliance benchmarks. However, local administrative authorities frequently relax enforcement standards once corporate monitoring recedes, as monoculture medicinal plantations deliver critical rural tax revenue and employment. This creates a regulatory loophole: firms can showcase formal supplier compliance records for third-party carbon auditors, while unregulated secondary harvesting and forest clearing persist within the same production regions. For pharmaceutical enterprises focused on cost control, investing in full-spectrum supply chain verification generates substantial operational overhead; without uniform global penalties for leakage, many firms opt for superficial compliance rather than systemic supply chain reform [16]. Additionally, carbon market certification schemes create distorted incentives: firms may offset ecological harm from forest clearance by purchasing low-quality carbon credits from unrelated reforestation projects, decoupling corporate accountability from on-the-ground forest protection outcomes [5, 19].

3.2. Cross-border and international forest governance dilemmas

Global forest governance systems fail to establish binding unified standards for pharmaceutical plantation-driven deforestation, forming the second core regulatory barrier to curbing overdevelopment of carbon-absorbing forest land. The dominant international forest regime, REDD+ (Reducing Emissions from Deforestation and Forest Degradation), suffers from structural normative fragmentation across sovereign jurisdictions, undermining consistent restriction of medicinal crop expansion [20]. Under the UNFCCC framework, each nation independently defines "forest land," "carbon sink vegetation," and permissible agricultural conversion thresholds; Southeast Asian nations with massive herbal export industries adopt loose land-clearing definitions that classify monoculture medicinal plantations as "carbon-positive restoration," while European and North American states enforce far stricter native woodland protection rules [19]. This definitional mismatch enables regulatory arbitrage: pharmaceutical corporations shift raw material production to countries with lax forest laws to evade rigorous ecological oversight.

Unilateral regional trade regulations, such as the EU Deforestation Regulation (EUDR), attempt to fill this standardization gap yet trigger geopolitical sovereignty conflicts that weaken global coordination [21]. Major medicinal herb exporters including Indonesia, Malaysia and Peru contest the EUDR's extraterritorial due-diligence mandates, arguing the regulation imposes Western

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ecological norms on Southern agricultural economies without accounting for local livelihood dependencies on forest-based crop cultivation [22]. Cross-border enforcement gaps compound this tension: no supranational body holds authority to penalize corporations or nation-states for transboundary deforestation leakage, and carbon trading markets lack centralized auditing systems to verify whether corporate carbon sink claims from pharmaceutical plantations displace deforestation activity to neighboring territories [23].

3.3. Practical strategy to regulate

Establishing several limitations is simple and powerful for reducing the administrative dilemmas. First, governments should enforce mandatory full traceability rules for herbal raw material supply chains and establish unified geospatial monitoring platforms to curb deforestation leakage [16]. Second, heavy financial penalties and carbon credit disqualification shall be imposed on enterprises that source materials from unregulated forest plots, eliminating superficial compliance behaviors. Second, international bodies such as UNFCCC and FAO need to harmonize cross-border forest definition standards and revise the REDD+ framework to restrict monoculture medicinal plantations from being counted as qualified carbon sink projects [20]. Third, standardized cross-border due diligence consistent with the EUDR framework should be globally promoted, balancing ecological protection and the livelihood demands of forest-dependent agricultural communities to achieve coordinated ecological, economic and climate governance.

4. Conclusion

This study demonstrates that the overdevelopment of forested areas, driven by expanding pharmaceutical supply chains and commercial monoculture farming, causes severe, cascading ecological degradation. Converting primary forests into simplified agricultural plots dismantles multi-tiered canopy architectures, severing trophic interactions, accelerating biodiversity loss, and destabilizing local soil-hydrological systems. Crucially, this land-use shift transforms vital terrestrial carbon sinks into net greenhouse gas emission sources, exacerbating global climate vulnerability. At the governance level, efforts to curb these environmental externalities encounter systemic barriers. Corporations face severe supply chain opacity and market leakage, where non-compliant production simply shifts to low-standard buyers. Internationally, regulatory arbitrage persists due to fragmented definitions of "forest land" under REDD+ and geopolitical tensions regarding extraterritorial trade mandates like the EUDR. Overcoming these dilemmas necessitates a multi-tiered governance framework that mandates full supply-chain traceability, harmonizes cross-border conservation definitions, and enforces strict penalties against non-compliance within carbon markets.

Despite these insights, this research has specific limitations. The analysis relies largely on macro-level literature synthesis and global datasets, lacking localized empirical field data from specific regional pharmaceutical supply networks. Additionally, the socio-economic trade-offs confronting smallholder farmers under strict regulatory compliance remain under-examined. Future research should integrate micro-level geospatial tracking to empirically map supply chain leakage in real time. Research should also quantify the socio-economic impacts of unilateral trade regulations on forest-dependent communities, informing equitable, cross-border governance solutions.

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