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Strong Sustainability in Forestry Development: A Case Study of the Changbai Mountain Forest Region

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Abstract. Forests are ecologically and economically indispensable, yet global forestry faces severe tensions between short-term resource exploitation and long-term ecological conservation, making the eco-economic balance a research imperative. The Changbai Mountain forest area is a representative and successful case of the shift to strong - sustainability. Its experience can be a useful reference for similar forest regions. This paper uses an integrated qualitative analysis with a mix of case studies and literature review to investigate the coordination of SDGs 8 and 15 by means of policy execution, ecological compensation mechanisms, and industrial restructuring. By means of the NFPP and ECR, Changbai Mountain shifted from overexploitation to resilient sustainability. The region has changed from depending on timber to turning ecosystem services into a business. Reconciling economic growth, which is marked by means of SDG 8, and environmental sustainability, marked by means of SDG 15, proves the workability of strong sustainability in forestry development. The research results offer context - adaptable strategies for global forest areas and emphasize the importance and feasibility of balancing ecological conservation with sustainable economic growth.

Keywords: Changbai Mountain forest region, Strong sustainability, Ecosystem services, Ecological economics, Ecological Conservation Redline (ECR)

1. Introduction

Forests around the world are facing challenges from the conflict between development and ecological sustainability. In the short term, deforestation can bring immediate financial benefits from cutting timber or clearing land. Ecologically, the benefits may be more likely to be negative in the long term. Specifically, when natural resources are depleted, the benefits of other ecosystem services such as carbon fixation, water retention and regulation [1], soil conservation [2] and biodiversity conservation [3] are diminished. In turn, the environmental effects threaten the stability and long-term economies of people who depend on forests for their livelihoods. The increase in climate-related disasters, land degradation, biodiversity loss and other forms of environmental degradation shows the need to reconsider forest development.

The United Nations SDGs include 17 goals, which are economically, socially, and environmentally interconnected. Specifically [1], SDG 15 [2] calls for protecting, restoring, and sustainably managing terrestrial ecosystems, including forests, to halt biodiversity loss and reverse

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land degradation. In order to achieve this goal, development should extend beyond extraction and extractive development models and move towards models that maintain ecological integrity. On the other hand, SDG 8 [3] calls for sustained economic growth, productive work, and decent jobs, goals that are directly related to the communities that depend on forests for their livelihoods. The challenge posed by the connection between SDG 15 and SDG 8 [4] represents a significant issue for contemporary sustainability governance when trying to construct forest management goals that protect the ecosystem while achieving sustained economic growth in the long term [5,6]. This conundrum is the starting point for analyzing the economic and ecological trade-offs discussed in this paper.

Under this context, this paper focuses on the clash between the short-term benefits of cutting timber and the long-term value of the services provided by forest ecosystems. The question is: How do the immediate financial benefits of deforestation or overmining conflict with the long-term ecological and economic benefits that healthy forests can provide? This question will be explored through the analysis of the before overlogging model and the now sustainable-development model in the Changbai Mountain forest system. The paper discusses how policies, economy and public participation together promote this green transition in the region.

Ideas such as ecosystem services, natural resources, the difference between short-term benefits and long-term ecological value are discussed based on the existing literature and mathematical data. By case studying the balance between the short-term over-logging income and the long-term sustainable economy in the Changbai Mountain region, this research can provide some practical references for the decision-making on ecological protection in forest areas with similar situations. In addition, this paper can reveal the influence of policies, economy and public participation on this green transition.

2. Theoretical framework / literature review

This paper draws on several concepts spanning environmental studies to economics, such as natural capital, and ecosystem services. Ecological economics [7] is an interdisciplinary field which considers the economy to be embedded in the ecological system. It stresses that economic activity is limited by biophysical factors and tied to natural sustaining processes. Under this framework, forests are seen as natural capital [8]. That is, they are stocks of ecological assets able to produce a continuous flow of ecosystem services. According to the Millennium Ecosystem Assessment [9], the ecosystem services framework groups these benefits. Provisioning services are forest - related products, regulating services are carbon sequestration and water regulation, supporting services are soil formation and nutrient cycling, and cultural services include tourism and the consumption of cultural experiences. These concepts, when combined, offer a comprehensive view to describe both the tangible and intangible values within forest ecosystems.

These interdisciplinary concepts are key in this research since traditional economic theory is not able to account for the full value of forest systems or the long - term effects of environmental degradation. Traditional economics considers natural resources as inputs that can be substituted [10]. Technological inventions or human - made products can take their place, as long as the combined capital of economic development and ecological values stays the same. Rooted within the weak sustainability framework [11], this assumption doesn't take into account that forest ecosystems are biophysically joined systems. Their natural capital elements, namely vegetation, soil structure, wildlife populations, water cycles, and microclimates, interact in ways artificial substitutes can't copy. This is the main point of view of strong sustainability [11], the approach of this research. Specifically, forests have stock characteristics, and threshold effects limit their capacity to recover

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from deforestation [12]. The irreversibility of soil degradation and biodiversity loss makes it costly and difficult to restore. Economic frameworks focusing on explicit market returns or economic degradations can't fully show the ecological damages, without taking these long - term and not immediately obvious environmental risks into account. In this context, ecological economics provides a framework that fully acknowledges short - term timber revenue and long - term ecosystem values.

These theoretical bases are directly related to the research question of this paper, which studies the balance between short - term timber income and long - term economic worth of ecosystem services. Ecological economics allows for a systematic comparison between short - term logging and long - term ecological benefits by seeing forests as natural capital that produces various ecological and economic values over time. The framework of ecosystem services gives a structure to analyze the ecological and economic benefits lost as a consequence of environmental degradation. Overall, interdisciplinary ideas show the conflict between weak and strong sustainability models, represented by short - term timber revenue and long - term ecosystem services' values. It's shown that forest management decisions can't be fully understood without including ecological factors in economic analysis. In the view of ecological economics, since the free market fails to incorporate the irreversible and irreplaceable values of ecosystem services, the Ecological Conservation Redline (ECR) policy implemented in the Changbai region aims to enforce measures to regard natural capital as irreplaceable forest assets, regulate economic activities, and promote natural capital restoration.

3. Case study – Changbai Mountain

3.1. Background

The Changbai Mountain range, a volcanic region bordering North Korea, is particularly renowned for its pristine temperate mixed forests, dramatic vertical vegetation zones, and the iconic Heaven Lake. Its rich reserves of pinus koraiensis and spruce made it a prime logging target in the mid 20th century. Decades of harvesting in the previous century led to a significant reduction in its old-growth forests, increased runoff and sedimentation, and habitat fragmentation for species like the manchurian tiger. The region exemplified the paradox of economically vulnerable communities exploiting the rich natural resources, primarily the timber stocks, for local development, thereby creating an imbalance between economic growth and sustainability.

3.2. Imbalance of economic development and ecological protection

In 1896, the forest area of Changbai Mountain range alone had 4.5 million hectares, with a timber volume of 1 billion cubic meters. However, by 1944, the forest area was only 3 million hectares, and the timber volume was only 600 million cubic meters. In 50 years, the timber volume of Changbai Mountain decreased from 1 billion to 600 million cubic meters, with a reduction of 400 million cubic meters [13]. This generated significant timber revenue in the short term.

Excessive production of timber inevitably led to excessive logging of forest resources. Based on estimates of Changbai Mountain's actual carrying capacity, its annual production plan should be 3.449 million cubic meters. However, from the 1960s to the early 21st century, the average annual over-exploitation of about 1 million cubic meters. In the long term, the timber production far exceeded the carrying capacity of the natural capital. This caused slower regeneration rate rates than extraction rates resulting in a forest resource crisis and reducing the profitability of timber logging in

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the longer term. This is an irreversible trend that will cause a breakdown of Changbai Mountain's ecosystem services, which are non-replaceable and of extremely high economic value.

Economically, the deterioration of forest natural capital has led to a continuous decline in the availability of timber, with logging areas becoming increasingly distant and high-quality timber becoming scarcer. This resulted in rising production costs and decreasing profitability. In the early 1950s, the production cost for 1 cubic meter of timber for collection, transportation, and storage was less than ¥20. By 1986, this cost had reached ¥109, increasing by 5 times. For example, for the Baihe Forestry Bureau, the rising production cost, coupled with NFPP that caps the amount of timber logging, caused a short-term profit decrease of 1.49 billion RMB from 1997 to 2003. Thus, without further action, the ecosystem would continue degrade, and the profitability would decline further. The launch of NFPP was necessary to curb this environmental and economic crisis, despite the initial economic burden triggered by a reduction in timber logging, because the economic and environmental losses of ecosystem services degradation will be far more significant.

3.3. Policy implementation - eco-compensations

The transformation was anchored by the implementation of the Natural Forest Protection Program (NFPP), which aimed to achieve a full-scale logging ban by 2017, paired with economic mechanisms to mitigate livelihood impacts from lost timber revenue. In the short term, the immediate cessation of logging led to reduced economic income and disrupted employment. Meanwhile, the once logging-dependent forest farms in remote areas faced economic hardships, since the logging ban limited connectivity to external areas. This could foster resentment, and some residents would resort to illegal logging, which exacerbated environmental degradation and increases subsequent restoration costs. To address these issues and avoid such backlash, eco-compensation measures were core components of the NFPP, with compensation set at ¥1000 per cubic meter of timber. Additionally, the Forestry Bureau offers ¥15 million to incentivize contributions to ecological protection, ensuring the NFPP's sustainability and economic incentives (NPA and NFGA) [14]. Through such a stable process of policy implementation, the program's long-term benefits, such as carbon sink trading and water conservation services, are more gradual in materializing.

3.4. Economic transformation toward strong sustainability

3.4.1. ECR policy and NFPP policy

The Ecological Conservation Redline policy was rigorously applied. Vast regions of Changbai Mountain's core area, including its watersheds and biodiversity hotspots, were demarcated as zones where commercial development and logging are prohibited. This shift reflects a decline in the social discount rate (SDR) and a reorientation of time preference: future ecological values were assigned greater weight, rather than being heavily discounted as in short-term extraction models. In these regions, the value of ecological conservation outweighs short-term timber profits, highlighting the stance of 'strong sustainability'. With protection secured, the region pivoted to capitalizing on the sustainable usage of ecosystem services. In Figure 1, the amount of logging has been decreasing continuously since 1998, the start of NFPP's implementation. This transformation toward strong sustainability was achieved, not at the expense of Jilin's economic growth. This suggests that the opportunity cost of ecological preservation --- the short-term logging profits --- can be outweighed by long-term ecological and economic benefits under a low social discount rate.

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Aligning with the ECR policy, the Changbai Mountain region has transformed from generating timber logging revenue to leading sustainable economic growth through the secondary and third industries. This continuous gravitation toward ecological protection translates into changes in the economic income sources of local residents (as shown in Figure 2). With the primary industry dwindling in response to ECR, the secondary industries and third industries were expanded to compensate for the lost revenue. This impacted the local economic activities by making the ecosystems' provisioning and cultural services key income sources for the local communities. Notably, this addresses the negative externalities of overlogging, which caused ecological damage and unsustainable economic growth. Meanwhile, this process also generates positive externalities, including improved ecological health and expanded industry growth, which continually offer ecological and economic growth.

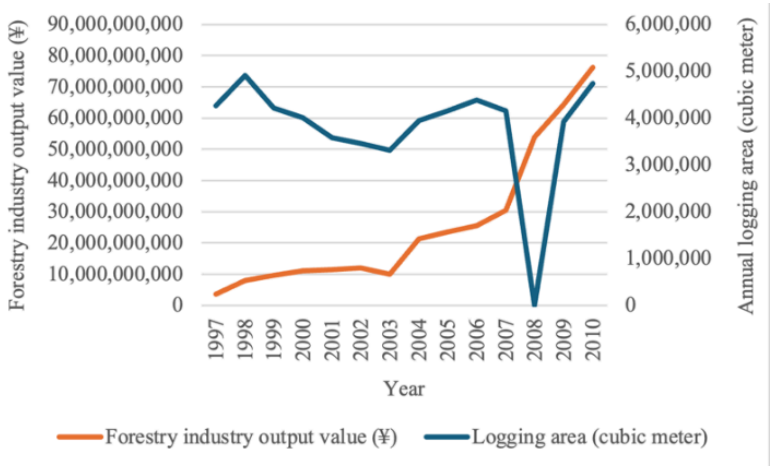

Figure 1. Amount of timber logging and total output value of the forestry industry in Jilin (1997-2010) [15]

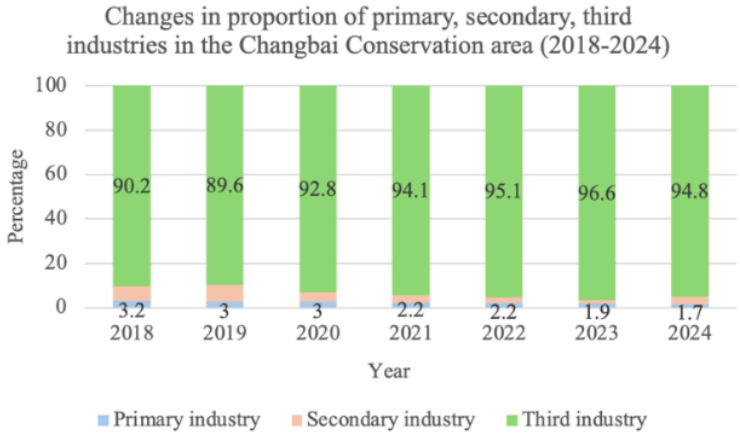

Figure 2. Proportion of primary, secondary, third industries in the Changbai area (2018-2024) [16-18]

3.4.2. Ecosystem services

Cultural Services: Ecotourism became the cornerstone of the new economy. The unique volcanic landscape, the culturally significant Tianchi, and the region's ethnic Korean heritage were packaged

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into a powerful tourism attraction. Visitor numbers and tourism revenue surged, effectively compensating for the reduction of timber income. The magnitude of tourism and associated economic growth, since the implementation of the green transition policy frameworks, is continually increasing and projected to experience further growth in the future. In Fig 3, from 2015 to 2024, the Changbai Mountain region experienced a steady increase in tourist numbers and tourism revenue, except for the COVID-19 period, when tourism was significantly impacted. The continuous growth suggests the strong sustainability model has potential for development in a sustained manner. This is a significant source of economic income for local tourism, which compensates for the temporary loss of timber revenue and incentivizes long-term adoption of the green policies [19].

Figure 3. Number of tourists in Changbai Mountain range (2015-2024) [20]

Provisioning Services: Due to the reduction of logging activities and consequently the decrease of timber revenue, the Changbai Mountain shifted its commercial focus to non-timber forest products (NFTPs), such as ginseng, chanterelle mushrooms, reishi mushrooms, and wild vegetables. These NFTPs have more vulnerable roots compared to trees, thus these NFTPs need to be carefully protected to ensure sustainable growth and commercial usage. After the full-scale ban of commercial logging in the region, the Changbai Mountain Forestry Corporate's planting and harvesting of NFTPs significantly increased from ¥12,351,000 in 2014 to ¥42,538,000 the growth being as much as 2.5 times [20,21]. Meanwhile, similar growth trends are observed for other corporations in the region as well. The market value of NFTPs directly ties community income to the long-term health of the forest floor and soil ecology. By preserving the local ecology through restoring the natural capital and enhancing the forest's supporting services, such as its water resources and soil quality, NTFPs of better quality and higher quantity are yielded. This sustainable approach unlocks greater economic potential [22], incentivizing long-term ecological preservation for long-term economic income through sustainably commercializing NTFPs.

3.4.3. Adjustment of industrial structures

The Changbai Mountain region has successfully transformed ecosystem services into economic income, driven by market demand for ecotourism, NTFPs, and other products. The growth of the ecotourism industry has generated spillover effects for surrounding farmers and merchants, as increased tourist numbers translate to more business opportunities. For NTFPs, compliance with ECR policies and strong sustainability principles enables sustainable harvesting and enhances economic value. Through this transformation, the intangible value of ecosystem services has been converted into long-term, tangible economic income, creating a more diversified economic model

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grounded in strong sustainability. As shown in Figure 4, since the implementation of the NFPP policy in 1998, the number of employees in timber logging industry has steadily declined on a national level. According to the National Report on Forest Protection and Sustainable Management, during the 1990s, with a decrease of employment in logging and an increase in employment in forest management, ecological sustainability is successfully restored in the Changbai region [23]. Afterward, the need for sustained economic compensations drove the development of market economy, encouraging workers to transition into cultural and provisioning service sectors. The expansion of the secondary and third industries corresponds to such economic transformation (Figure 2). This economic diversification across secondary and tertiary industries reduces reliance on a single sector, thus enhancing economic stability. By reducing vulnerability to fluctuations in timber prices, resource depletion, or policy restrictions, the diversified economic structure supports sustainable economic growth in the Changbai Mountain region.

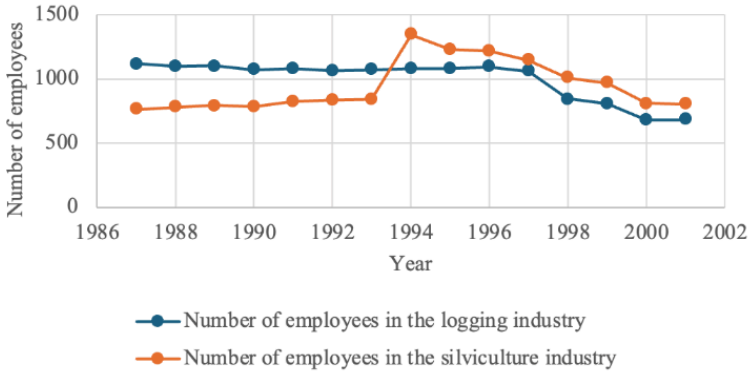

Figure 4. Number of employees in the logging industry and silviculture industry in China (1986-2002) [23]

Compared with other ecological protection regions in China [24], the Changbai Mountain's economic transformation toward strong and sustainable growth stands out particularly for its unique synergy of policy coordination, diversified economic pathways, and community-driven market participation. The Changbai Mountain region leverages the NFPP with the ECR policies to reinforce government-led ecological compensation and conservation efforts, it also adopts a market-oriented ecological compensation mechanism. This encourages the local community to leverage the ecosystem services in an ecologically and economically sustainable manner, diversifying livelihoods into NTFP harvesting, ecotourism, and other service sectors. This market participation enables economic growth and community satisfaction with the NFPP and ECR policies.

3.5. Comparison with Qilian Mountain case

By contrast, certain regions like the Qilian Mountain conservation region instead rely on a top-down policy enforcement model with the central government directly involved. For the community members, any obstruction or delay in the preservation process would results in explicit political consequences. As a result of the effective implementation of multiple complementary policies in the region, the ecological stability of 752,700 hectares of grassland has been steadily enhanced, and water bodies covering 52,100 hectares have become more stable. However, it is worth noting, although this top-down, accountability-driven policy framework has effectively curbed overmining, in the long term, this framework can push the region into a weak sustainability dilemma economically. The prohibition of the region's major industry mining is already resulting in

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significant reductions in revenue and tax. After the commencement of ecological preservations and mine closure, the general public budget revenue of Tizhou County decreased by 40%, and the regional GDP of the Tianjun County declined by several times [25]. This governance approach, ignoring the urgent need for community economic transition, is not economically sustainable. Consequently, in the past decades, this has induced public dissatisfaction and persistent illegal mining despite established policies, undermining preservation efforts while weakening economic stability in the Qilian Mountain region.

The strict, top-down approach applied in the Qilian Mountain is a necessary political measure due to its severely degraded ecosystem and ecologically fragile ecosystem. Premature large-scale development such as ecotourism can cause irreversible harm, making strict protection unavoidable at this stage. Given its urgent ecological priorities, such political approach is both understandable and essential. Only after ecological conditions restoration can the region gradually incorporated market-oriented elements from the Changbai Mountain model to pursue more balanced sustainability. In general, the comparison between Changbai Mountain and Qilian Mountain cases clearly highlights the uniqueness and success of the former's model. The Changbai Mountain case effectively combines the NFPP and ECR policies with a market-oriented economic model, enabling a smoother transition to a green and diversified economy. This model places individual livelihoods and economic transformations on the same level as conservation goals, providing a blueprint for preservation regions such as the Qilian Mountain to reference in the future effort to enhance economic and ecological sustainability simultaneously.

3.6. Avoided losses and impacts

The results demonstrate a successful revival of local ecology while maintaining a positive profile of local economic development. Ecologically, forest cover and quality have improved, with forest cover having increased by 15% since NFPP and ECR policy implementation. At present, the forest coverage rate in the Changbai Mountain Protection Development Zone reaches 87.7%, and the forest coverage rate within the Changbai Mountain National Nature Reserve exceeds 95%. Specifically, the distribution area of Changbai pine, a second-class nationally protected species, has expanded from 200 km^2 in 2015 to 342.19 km^2 in 2020 [26]. Meanwhile, the proportion of days with good environmental air quality in the area is 98.7%, and the water quality of the source areas meets standards at 100% [27].

The return of indicator species, including the manchurian tigers signals ecosystem recovery and biodiversity restoration. The variety of flora and fauna in the Changbai Mountain region is constantly increasing, with ungulates including sika deer and roe deer growing in number year by year. Among them, the relative abundance indices of sable, red deer, and roe deer have significantly increased, rising from 0.92, 1.33, and 3.00 in 2019 to 1.67, 2.13, and 10.54, respectively, by 2025. Additionally, the return of the manchurian tigers indicates that the ecological environment of the reserve is recovering and the food chain structure is sufficient to support the survival of these top predators.

Economically, the local community has transitioned from logging to employment in the tourism industry and NTFP value chains, which demonstrates the economic viability of a strong sustainability model. Specifically, the tourism industry has experienced a 250% growth in economic income thus far, aligning closely with SDG8. Changbai Mountain illustrates that when unique cultural and provisioning services are strategically marketed, ecological protection can directly fuel robust economic growth. It serves as a perfect example of successfully balancing economic growth and ecological preservation, suggesting that ecological economics principles may be applicable for

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regulating similar temperate mountain forest ecosystems as well. Figure 5 shows regressions analyses indicating upward trend within 3 years of policy implementation in the Changbai Mountain. This proves that economic investment and political efforts in ecological protection do not necessarily indicate negative externalities. Unlike traditional models of opportunity costs, where investing in ecological preservation means forgoing economic gains, ecological development and economic growth in these policy frameworks do not trade off with each other. Instead, such green investments enable diversified and resilient economic growth through the sustainable monetization of ecosystem services.

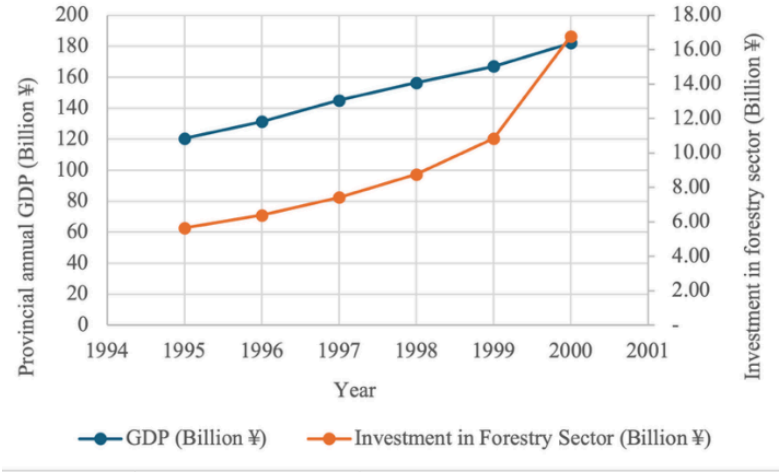

Figure 5. Jilin Province's annual investment in the forestry sector and annual GDP growth (1995-2000) [23,28]

4. Limitations

Although the Changbai Mountain case robustly demonstrates the possibility of strong sustainability in reconciling ecological protection and economic growth, it also has inherent limitations that limit its replicability and emphasize the necessity of context-specific adaptation for different regions.

First, the replicability of governance models is limited by the local economic condition. The economic cost of ecological model of Changbai Mountain faces great challenges for replicability. It is dependent on continuous eco-compensation. For example, NFPP compensates loggers with ¥1, 000 for every cubic meter of banned logging and gives ecological protection incentive funds of ¥15 million per year . It is not easy for some areas to provide such fiscal inputs, and areas attempting to replicate such subsidy models will probably face policy unsustainability.

Second, the ecological model is successful because of the capacity that many forest conservation areas lack. Changbai Mountain's market-oriented transformation of ecological value into tourism and NTFP revenue depends on mature regulations and markets. Its capacity to package volcanic landscape, ethnic culture, and high-value NTFPs into marketable products has been developed through years of investment in tourism and brand building. Forest conservation areas lacking such capacities will see either lax enforcement or failed economic transition when they attempt to replicate models from Changbai Mountain.

Finally, despite the above limitations, this study is still very meaningful. It distills transferable principles for reconciling ecological protection and economic growth—transferable principles that transcend the specific Changbai Mountain context. It demonstrates that strong sustainability requires targeted strategies and diversified economic support, ranging from government eco-compensations

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to community economic income diversification, ranging from ECR to NFPP and other rigorous policy management. All of these economic transformations collectively reduce the dependence on short-term timber extraction, which is typical in weak sustainability models. Therefore, it resonates with the global Paris Agreement, SDG 15, and SDG 8 by mitigating short-term livelihoods with long-term ecological and economic sustainability. For other similar forest systems, the Changbai Mountain case provides guidance for forest conservation areas seeking to transform from weak sustainability models into strong sustainability development models.

5. Discussion

The economic development of Changbai Mountain shows how successful economic diversification could make ecological restoration possible with the support of strong sustainability. Unlike local communities dependent on the logging industry, ecotourism brought sustainable economic income and ecological restoration to local communities. Ecotourism not only provides financial support and resources, but also more visitors and markets to enrich people's lives in other ways. All of these integrated attractions increased tourism revenue by 250%, and the new jobs fully compensated for the forbidden logging. This transition shows that strong sustainability not only facilitates the implementation of SDG 15, but also strongly links to SDG 8.

The Changbai Mountain case demonstrates the global trend of giving priority to the integrity of ecosystems to reduce climate change, as described in the Paris Agreement and the 2030 SDGs. The Paris Agreement initiative to reduce greenhouse gas emissions is fully aligned with the success of the regions in restoring forests. The 15% increase in forest cover in the regions shows how protecting local natural capital also contributes to global climate change.

Furthermore, the Changbai Mountain case shows how strong sustainability in SDG 15 is closely linked to SDG 8. It represents the global historical issue of the imbalance between developing the economy and protecting the ecology. Based on the foundation of political managements, including the NFPP and ECR policies, the regions achieved ecological restoration and economic development through ecological compensation programs and sustainable commercialization of ecosystem services. As the deadline of 2030 SDGs approaches, we believe that nations facing similar problems will find the Changbai case useful, and strong sustainability provides a feasible solution for global nations.

In order to balance economy and environment, the Changbai Mountain case provides insights for future practices in the following three dimensions.

First, non-substitutable natural capital, such as timber stock in Changbai Mountain.

Second, government compensation programs cannot be sustainable on a global scale or in the long term, especially for economically vulnerable regions. Therefore, in order to reduce dependence on government subsidies or eco-compensation in the long term, regions should rely on market-based compensation, such as carbon trading, ecotourism, and sustainable commercialization of local ecosystem services. This market conversion is feasible for regions with marketable ecological services.

As climate change becomes more severe, it is important to foster balanced and region-specific conservation to create political economy where strong sustainability develops.

6. Conclusion

This case study of Changbai Mountain's ecological and economic transitions is a concrete response to the global sustainable development challenges raised at the outset of this paper — most notably

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the trade-off between ecological value and economic development in a traditional economics model. This puts SDG 8 and SDG 15 in opposition when developing forest regions. As a typical showcase of weak sustainability's limitations, Changbai Mountain's overlogging proved that treating natural capital as a substitutable asset leads to irreversible ecological degradation and a long-term decline in timber-industry profitability, which fails to account for the non-replicable value of local ecosystem services. In contrast, the region's transition to strong sustainability enables long-term regional development, supported politically and economically by the Ecological Conservation Redline, the Natural Forest Protection Program, and market-oriented usage of ecosystem services. By examining policy interventions and market expansion strategies, this case study translates the theoretical frameworks of natural capital and ecosystem services into context-adaptable strategies. Globally, for forest regions grappling with the conflict between ecological health and economic revenue, the Changbai model offers a pragmatic reference. It aligns well with global agendas including the Paris Agreement and the SDGs, specifically SDG 8 and SDG 15. This case study underscores the universal significance of integrating ecological protection into economic decision-making. It thus stands as a compelling testament to how adopting strong sustainability can turn the long-perceived tension between ecological conservation and economic growth into a synergistic global development path for equitable and resilient development. However, due to time and resource constraints, the paper has not established a comprehensive quantitative evaluation system for the intangible values of the ecosystem services, and the economic conversion efficiency of these ecological values still needs to be measured with more sophisticated econometric models to delve from the currently macro framework into more nuanced perspectives on a micro level. In future applications of the study's findings, this nuanced exploration will further strengthen the model's empirical rigor and enhance its adaptability for diverse forest ecosystems worldwide.

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