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Construction of Eco-Compensation Policy Framework for Natural Rubber with Production and Ecological Win–Win

Zhidong Li [1], Moucheng Liu [2], Lidan Xu [1,*], Wangtengfei Teng [1] and Jihua Fang [1]

[1] Key Laboratory of Applied Research on Tropical Crop Information Technology of Hainan Province, Institute of Scientific and Technical Information, Chinese Academy of Tropical Agricultural Sciences, Haikou 571101, China; lizhidong@catas.cn (Z.L.); twtf@catas.cn (W.T.); fangjihua@catas.cn (J.F.)
[2] Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; liumc@igsnrr.ac.cn
* Correspondence: xulidan@catas.cn

Abstract: The development of the natural rubber planting industry is facing the dual challenges of protecting ecology and maintaining supply. As an effective means to internalize ecological externalities, eco-compensation is an important way to realize the sustainable development of the natural rubber industry. From the perspective of industrial development, an eco-compensation policy framework for natural rubber with a production and ecological win–win outcome was constructed. The results showed that natural rubber eco-compensation was a large-scale public institutional arrangement with the following characteristics: 1. The goals were to protect tropical rainforest and rubber garden ecology, maintain the natural rubber supply and improve the livelihoods of agricultural households. 2. The participants included the government, enterprises and agricultural households. 3. The main methods included financial transfer payments, production insurance and cooperative operations. 4. The opportunity costs of agricultural household livelihood transformation and the positive expected returns of enterprises were used as compensation standards. 5. The compensation effectiveness was evaluated through the comprehensive monitoring of tropical rainforest ecology, the rubber garden environment, land use, the planting distribution, household income and production modes. On this basis, specific policy recommendations, including developing combined planting–breeding modes, establishing a strict supervision system and setting up special expert advisory teams, were put forward. This study provides not only a theoretical basis for the design of natural rubber eco-compensation policies but also a reference for the construction of eco-compensation market mechanisms in various fields.

Keywords: natural rubber; eco-compensation; tropical agriculture; agricultural sustainability

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1. Introduction

Natural rubber (NR) has excellent comprehensive characteristics that synthetic rubber cannot replace, and it is an important industrial raw material widely used in the aviation, transportation and medical fields, among others [1–3]. The global NR growing area is located mainly in Thailand, Indonesia, Malaysia, Laos, Myanmar, Cambodia, Vietnam, China and other countries [4–6]. In addition, under specific climatic conditions, the Delta State of Nigeria, the Brazilian Amazon, southeastern Côte d'Ivoire and other regions also have natural rubber cultivation practices, making important contributions to global NR yield [7–9]. In the current production structure, small households are still among the important suppliers of NR [10]. Thus, NR not only contributes to the development

of industry but is also an important economic source for rubber-farming households in tropical areas [11].

However, the sustainable development of the NR industry is facing challenges [12]. On the one hand, NR growth has strict environmental requirements [13]. For a long time, driven by high demand and high returns, the expansion of rubber plantations triggered space competition, mainly with primary forests [14–16]. Using remote sensing technology, Wang et al. [6] found that, since 1993, there has been more than 4 million hectares of forest loss due to the rubber planting. On the other hand, owing to the impact of price fluctuations, especially the continuous decline in recent years, the income of rubber farmers is at risk [5,11]. The management of many plantations has also declined [17]. This has restricted the NR supply level to a large extent [18,19].

Faced with the multiple problems related to ecological protection, ensuring livelihoods and maintaining supply, scholars have proposed a variety of solutions based on different methods. In terms of protecting ecology, Zeng et al. [20] tested and analyzed the physical and chemical properties of the soil under different NR planting modes. The results showed that, compared with monocultures, a near-natural management mode (similar to the original forest landscape) can effectively reduce soil degradation. Fang et al. [21] noted that mixed organic agriculture can be promoted in appropriate areas to enhance the ecological function of NR gardens. From the livelihood perspective, Chen et al. [22] proposed that some social services, such as financial insurance services, have a positive impact on the improvement of rubber planters' green productivity. With respect to production, the suitability of rubber cultivation varies from place to place [23]. Compared with blind reclamation, optimizing the planting distribution (strengthening it in highly suitable areas and reducing it in unsuitable areas) may constitute a more sustainable development path [24]. In summary, upgrading the management mode, strengthening the livelihood security of rubber-growing households and optimizing the distribution of the planting area all play important roles in the sustainable development of the NR industry. However, integrating these measures, accounting for the ecology, supply and income, requires scientific institutional arrangements. Eco-compensation, as an effective basis for internalizing the externalities of the ecology and promoting the sustainable utilization of resources and economic development, is an important way to promote sustainable development [25,26].

For a long time, eco-compensation (payment for ecosystem services) has been a hot topic in the field of nature conservation and sustainability [27–29]. Related research and practice cover forests [30], grasslands [31], oceans [32], cultivated land [33] and other fields, making important contributions to global ecological protection. At present, the research of eco-compensation mainly focuses on the compensation mechanism, aiming at exploring more efficient and fairer compensation strategies. For example, Zhen et al. [34] explained the necessity of eco-compensation for different crops in the context of market constraints through model analysis, providing a scientific basis for formulating differentiated compensation standards. Shen and Yang [35] explored how water quality uncertainty affects the decision-making of watershed protection behaviors in payments for watershed services. This offered insights into linking compensation standards to expected effectiveness. Xia et al. [36] proposed an optimization method for spatial selection of eco-compensation based on ecological benefits, which helps to identify priority compensation areas in practice. In addition, there is another point that needs to be emphasized, which is the market mechanism. For eco-compensation, improving the market mechanism is not only the focus but also the difficulty. Current research focuses on adding market elements to government-led eco-compensation, including considering the supply–demand and value of ecosystem services when exploring the eco-compensation path [37,38], promoting watershed ecological

improvement through establishing a market-sharing mechanism between an upstream and downstream [39] and combining eco-compensation with asset-backed securities [40].

The above research is of great significance to the improvement of eco-compensation mechanisms. However, there are still several drawbacks. On the one hand, there is a risk of limiting the development of the industry. The general compensation idea may affect the productive capacity by limiting resource utilization. This may further intensify the contradiction between protection and development. On the other hand, the market mechanism lacks the effective participation of enterprises. Enterprises are an important part of the market and can effectively expand the source of funds for eco-compensation. However, in the current research on market mechanisms, the compensation activities with the direct participation of enterprises are rare. At this stage, NR eco-compensation is being widely called for [41–43], and scholars with different focuses have explored this topic [44–46]. Obviously, as an important industrial raw material, the eco-compensation of NR should not affect its yield and market as much as possible. This makes the effective engagement of enterprises essential. To solve this problem, this study will explore the NR eco-compensation from the perspective of industry. The industry perspective is more suitable for combining market behavior and production capacity allocation. Compared with previous studies, the development of the industry and the participation of enterprises will be considered more in this study. Eventually, a multi-stakeholder NR eco-compensation policy framework will be proposed. In the framework, multi-stakeholder engagement mechanisms will be elaborated. The framework provides a scientific reference for formulating an eco-compensation system with multiple participants and multiple strategies and for guiding the planning of the NR industry.

2. Materials and Methods

2.1. Methodology

The main method of this study is theoretical research. Through combing the previous literature, complete eco-compensation policy research could include five components, namely, compensation goals, compensation participants, compensation methods, compensation standards and compensation effects [47–49]. Therefore, focusing on these five components and referring to some typical practical experiences in tropical areas, this study constructed an eco-compensation policy framework with NR planting industry characteristics.

2.2. Research Framework

This study aims to provide policy guidance for NR eco-compensation. The above five components are sorted out according to the needs of the policy framework (Figure 1).

Before the eco-compensation policy is launched, the compensation goals should be determined first. In the policy framework of this study, the compensation goals were put forward according to the sustainable development dilemma of the NR planting industry. Then, based on these goals, the directions of the solution and the expected results were proposed.

After determining the compensation goals, the compensation paths were used to achieve the goals. The compensation paths of this study included compensation participants, compensation methods and compensation standards, which are closely related to policy design. Two questions were answered in this part. First, who are the participants? To achieve the compensation goals, this study analyzed which stakeholders should be included in compensation and what the compensation relationships between the participants should be. Second, how can participants participate effectively? The compensation methods of this study mainly explained how the compensator and the recipient should cooperate in each compensation relationship. And the compensation standards of this study

referred to the standards that the compensator needs to pay to promote the cooperation in each compensation relationship.

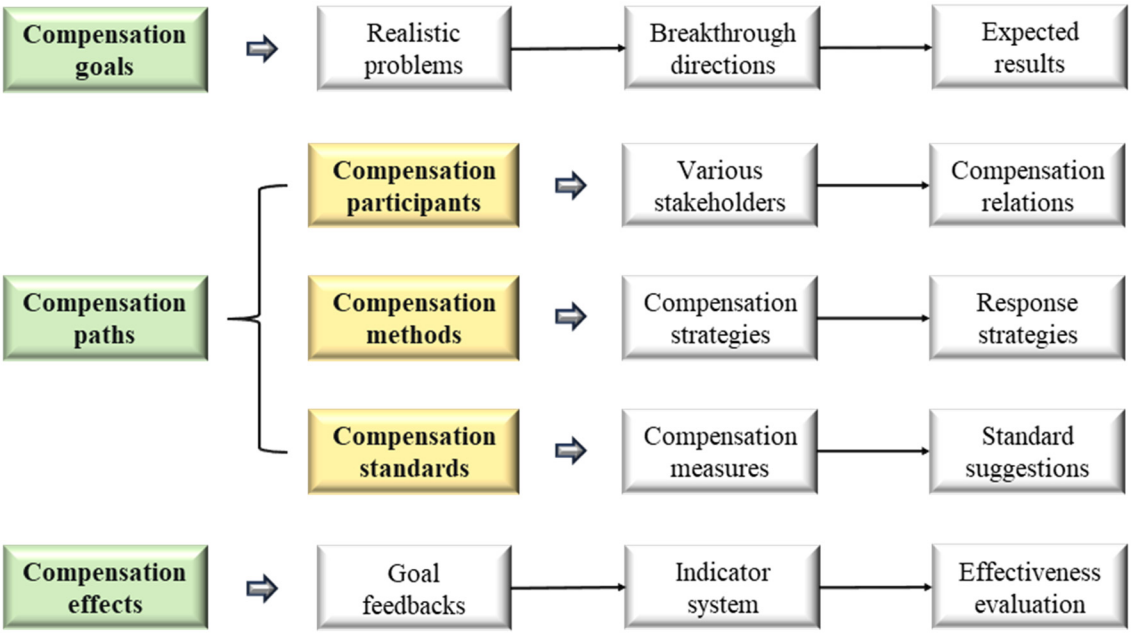


Figure 1. Research framework of NR eco-compensation.

After determining the compensation paths, the compensation effects were provided to evaluate the practice of the compensation paths. Focusing on the realization of compensation goals, an indicator system to test compensation effects was introduced. Policymakers could use the results of indicator monitoring to understand compensation effectiveness in a timely manner and adjust compensation strategies in the future.

2.3. Background and Scope of the NR Eco-Compensation Policy Framework

2.3.1. Eco-Compensation for Multiple Goals

As the name suggests, the goals of eco-compensation always include ecological protection. But in addition, under certain conditions, eco-compensation may also have the potential to promote socio-economic development [48,50]. As mentioned earlier, NR is both an important industrial raw material and a source of livelihood for many agricultural households in tropical areas. Therefore, in the policy framework of this study, compensation goals should be diverse. They must balance ecology, production and livelihood.

2.3.2. Eco-Compensation with Agricultural Households as the Core Recipients

NR growers include agricultural households and enterprises. Unlike agricultural households, enterprises often adopt large-scale production methods, and their production decisions need to be approved and supervised by relevant management departments. There are relatively few ecological incentives in this process. Based on the above, this study only considers the compensation relationship of agricultural households as NR growers.

For agricultural households, changes in the price of NR could affect their income. And financial capital, including income, is one of the important factors that affects their livelihood strategies [51–53]. Therefore, the core of the compensation paths is to encourage agricultural households to carry out ecological planting on the premise of ensuring their income.

3. Results

3.1. Goals of NR Eco-Compensation

There are three compensation goals in this study, namely ecological protection, supply maintenance and livelihood improvement (Figure 2).

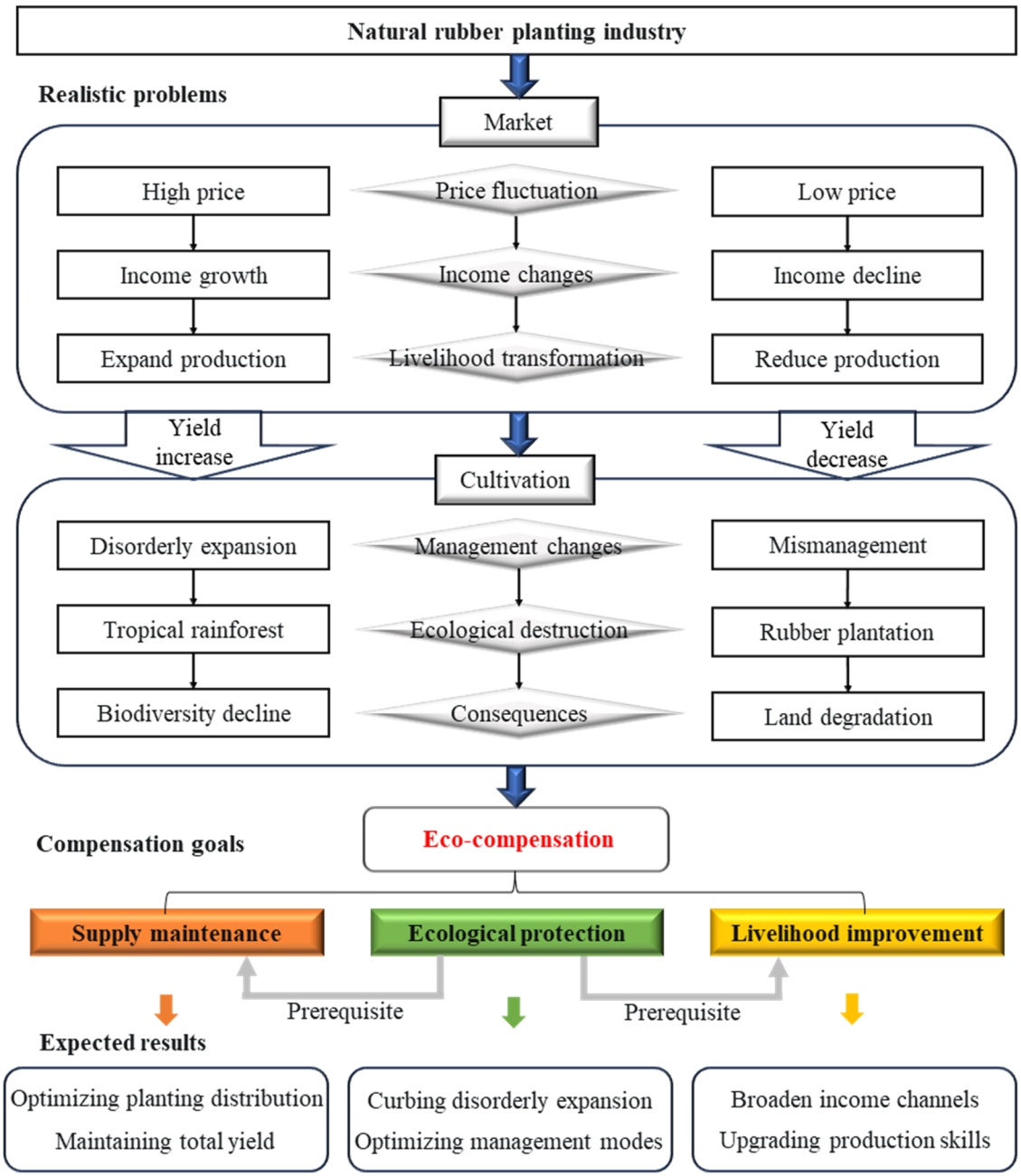


Figure 2. Diagram of compensation goals.

Ecological protection includes two aspects. The first is curbing disorderly expansion, which is to prevent agricultural households from blindly planting NR in tropical forests when the price is high. The second is optimizing management modes. This is to promote NR ecological planting while incentivizing agricultural households to maintain regular management of rubber plantations when the price is low.

With ecological protection as the fundamental goal, supply maintenance and livelihood improvement are important prerequisites. The main idea to maintain supply is to optimize planting distribution, which is for efficient use of land resources. For example, when NR

planting is limited in some unsuitable areas due to ecological protection, the NR yield could be appropriately increased in suitable areas. Finally, the total yield of NR could be effectively maintained. As for livelihood improvement, there are also two points of concern. The first is to broaden income channels, which is to secure enough income to incentivize agricultural households to change their production methods. The second is upgrading production skills, which allows agricultural households to improve their farming practices in line with eco-compensation requirements.

3.2. Paths of NR Eco-Compensation

According to the above research framework, the compensation paths in this study include three main aspects: compensation participants, compensation methods and compensation standards.

There are three compensation participants in this study, namely, the government, agricultural households and enterprises (Figure 3). There is a compensation relationship between any two participants, and the agricultural households are always the recipients.

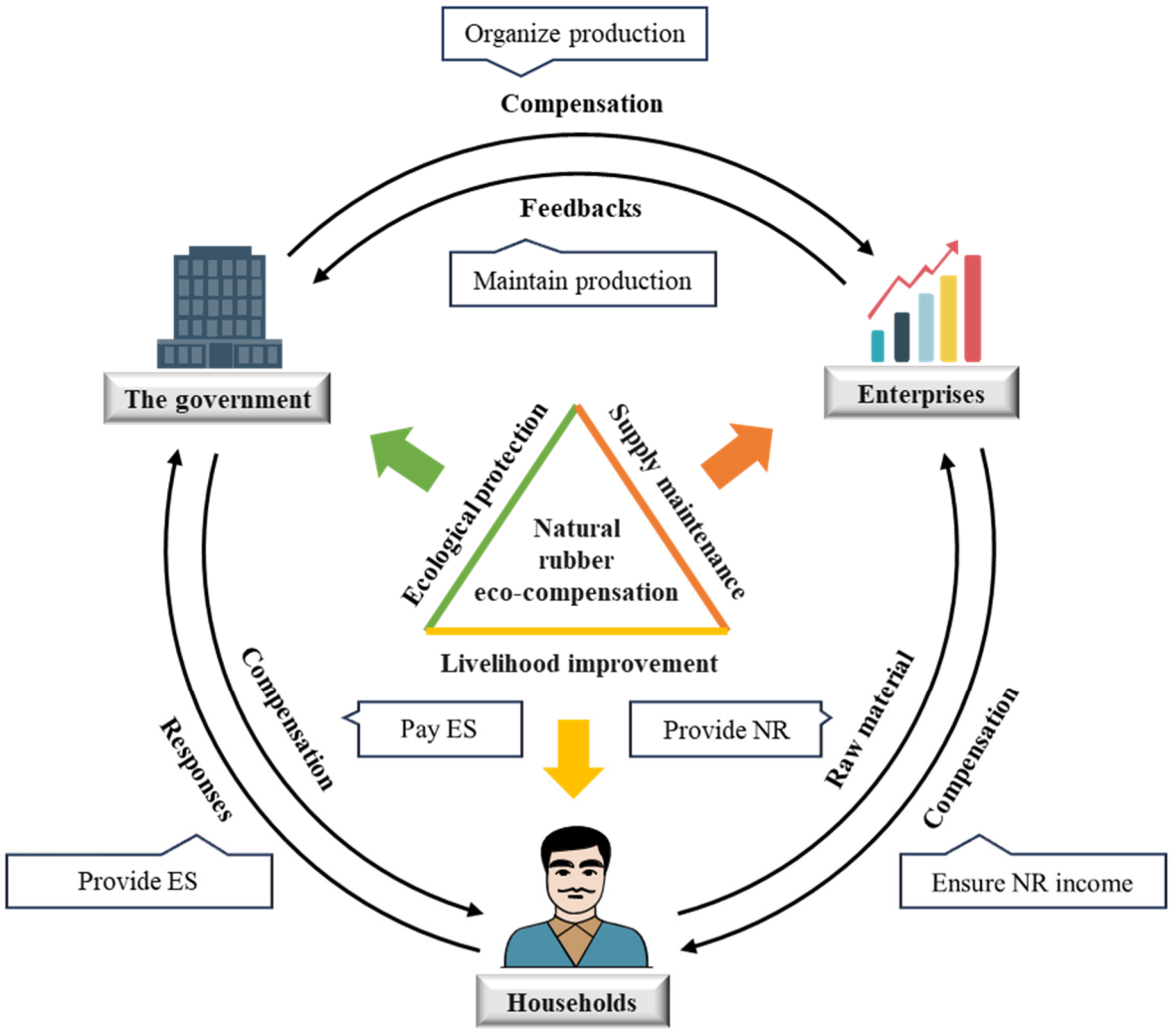


Figure 3. Diagram of compensation participants and their relationships.

The compensation between the government and agricultural households is the core of the framework, which is aiming to achieve ecological protection and livelihood improvement. Agricultural households provide ecosystem services (ES) by protecting forests and optimizing planting methods. The government is the purchaser of ES. This is because the

beneficiaries of ES are often difficult to define, so it is convenient for the government to buy ES as a representative of the beneficiaries.

Compensation between enterprises and agricultural households is aiming to achieve NR supply maintenance and livelihood improvement. Agricultural households are NR providers, and enterprises are NR purchasers.

As for the compensation between the government and enterprises, the main responsibility of the government is to organize enterprises and agricultural households to establish a long-term compensation relationship. Enterprises maintain the production of rubber products to meet the needs of industrial development.

After determining the compensation participants, it is necessary to establish joint promotion mechanisms for ecological protection, industrial development and the livelihood of agricultural households through effective institutional arrangements, reasonable compensation methods and scientific compensation standards (Table 1).

Table 1. Summary of compensation methods and compensation standards.

Compensation Relations	Compensation Forms	Compensation Methods	Expected Responses	Compensation Standard Basis
Government–household	Fund compensation	Financial transfer payments	Agricultural households no longer blindly expand their NR plantations in rainforests	The development opportunity costs of agricultural households
	Technological compensation	Providing production equipment and production training	Agricultural households optimize their production methods according to the guidance of eco-compensation	The actual cost of updating equipment and organizing training
Enterprise–household	Income insurance	Signing price insurance agreements	Agricultural households keep planting NR when the price is low	The expected NR price of agricultural households
	Cooperative operation	Participating with agricultural households in production activities	Agricultural households maintain NR cultivation on their farmland	The expected income of agricultural households
Government–enterprise	Subsidies and tax cuts	Introducing policies for subsidies and tax cuts	Enterprises continue to provide compensation to agricultural households	Ensure that the enterprise has positive expected returns
	Organization	Regulation and coordination	Maintain long-term and friendly compensation relationships between enterprises and agricultural households	The operating costs of setting up ecological posts

In the government–household compensation relationship, there are generally two kinds of compensation: blood transfusion (dominated by fund support) and hematopoiesis (dominated by industry support) [54]. In the policy framework of this study, blood transfusion compensation could be used to protect rainforests. The government pays agricultural households at opportunity costs, preventing them from blindly increasing NR yield in the forest. Hematopoiesis compensation could be used to protect the ecology of rubber gardens. The government provides agricultural households with technology and equipment to help agricultural households improve farming practices. As for the specific measures to protect the ecology of the rubber garden, it is worth trying to develop agroforestry. The practice of

many NR growing areas has proved that agroforestry production not only helps to improve ecological protection but also contributes to food security [55–57].

In the enterprise–household compensation relationship, the enterprise's responsibility is to maintain the total NR yield and optimize the planting distribution, mainly through two mechanisms. The first is insurance. When the price of NR is low, enterprises and agricultural households can achieve mutual benefits by signing insurance agreements. The core of the agreement is that agricultural households provide adequate NR to enterprises, whereas enterprises provide acceptable NR price to agricultural households. Similar insurance is already happening in China [58]. The second is cooperative production. When agricultural households' enthusiasm for production decreases, the "1+4" mode from Laos, in which agricultural households provide land and the enterprises hire labor, provide capital, technology and market access, could be referred to promote the cooperation between agricultural households and enterprises [10]. Then, enterprises and agricultural households distribute income according to agreements. It is worth noting that, unlike ordinary market actions, the insurance and the cooperative operation of enterprises must favor agricultural households in suitable areas. If not, it will be difficult to optimize the planting distribution.

For the government–enterprise compensation relationship, the government should provide organization and supervision functions for market transactions between enterprises and agricultural households. On the one hand, eco-compensation requires additional investment by enterprises. The government could provide support through subsidies and tax cuts to ensure that the compensation activities of enterprises and agricultural households are supported. On the other hand, the government could establish long-term ecological posts to supervise and coordinate possible disputes between participants.

3.3. Effects of NR Eco-Compensation

Based on the compensation goals, this study proposed an indicator system to test the compensation effects (Table 2).

Ecological protection focuses on the spatial competition between rubber gardens and the tropical rainforest, as well as the ecological conditions of rubber gardens. To maintain the ecological function of the tropical rainforest, changes in forest area and fragmentation need to be monitored over time. There are three aspects for optimizing the production modes in rubber gardens. First, in view of the problem of agricultural nonpoint source pollution, the volume of agricultural resources used by agricultural households should be monitored. Second, in view of the problem of farmland abandonment, whether agricultural households prune rubber trees and tap rubber at appropriate times should be monitored. Third, in view of the promotion of ecological agriculture, the degree to which agricultural households popularize mixed organic agriculture should be monitored.

Supply maintenance involves optimizing the planting distribution and maintaining the total NR yield. There are two key points in the process of transferring NR plantations from unsuitable areas to suitable areas. On the one hand, the total and proportional changes in the NR yield in the two types of areas should be tracked, and the overall situation of alternative planting should also be tracked. On the other hand, to effectively and appropriately use land in suitable areas, it is necessary to comprehensively consider the local resource-bearing capacity and quantify the yield gap for NR. In addition, to maintain the total yield and ensure the development of the NR industry, total yield and self-sufficiency rates should be monitored.

Table 2. Indicator system for compensation effect evaluation.

Compensation Goals	Expected Results	Monitoring Objects	Monitoring Indicators
Ecological protection	Curbing disorderly expansion	Tropical rainforest	NR Expansion area/rate Natural forest reconstruction area/rate Forest fragmentation index
	Optimizing management modes	All rubber gardens	Fertilizer and pesticide use Pruning frequency Rubber tapping frequency Crop planting rate Livestock breeding rate
Supply maintenance	Optimizing planting distribution	Unsuitable areas	Land transfer area/rate Alternative planting area/rate
		Suitable areas	Proportion of total yield Reclamation rate Yield gap
	Maintaining total yield	All rubber gardens	Total yield Self-sufficiency rate
Livelihood improvement	Broaden income channels	All households	Rubber plantation income Under-forest income Financial compensation income Enterprise compensation income Other income
	Upgrading production skills	All households	Training frequency Equipment replacement rate

Livelihood improvement focuses on changes in agricultural household income and production methods. The effectiveness of broadening income channels could be tested by monitoring the income structure. The progress of agricultural households in upgrading production skills could be judged by monitoring the production training frequency and equipment replacement rate.

In summary, an evaluation and monitoring system for the eco-compensation effects of NR in different regions is proposed, with a total of 3 goals, 6 perspectives and 22 indicators. Monitoring the changes in these 22 indicators can aid in objectively evaluating the current compensation situation, identifying existing problems and guiding future improvement strategies.

4. Discussion

On the basis of theoretical analysis and related practices, a policy framework for NR eco-compensation that accounts for ecology, production and livelihood was constructed. The framework includes three core elements: compensation goals, compensation paths and compensation effects.

The perspective of industrial sustainable development is an important innovation of this study. It allows enterprises to play a significant role in eco-compensation. Compared with the previous literature, there are some differences in this study. For example, Li et al. [47] summarized that the eco-compensation goals for grassland in China include ecological protection and livelihood improvement and did not consider supply maintenance. This difference is due to the demand for NR. As an important industrial raw material, maintaining NR supply is also an essential consideration in this study. Regarding the compensation paths, Shen et al. [59] considered agricultural households' willingness to participate in compensation when determining the compensation standard.

This is not directly mentioned in this study. However, the NR eco-compensation framework of this study involves insurance and cooperative agreements between agricultural households and enterprises. These activities have taken into account the willingness of agricultural households.

As for compensation effects, the monitoring of eco-compensation is crucial to achieving the compensation effects [60]. Therefore, this study put forward an indicator system of NR eco-compensation to provide a scientific basis for supervision and management. Especially for the monitoring of supply maintenance, an indicator of the yield gap was introduced. The yield gap reflects the gap between the actual yield and the theoretical yield and is widely used in agriculture [61–63]. Dynamic monitoring of changes in yield gaps could help managers assess the effectiveness and limits of optimizing planting distribution.

In addition, stakeholders are an inevitable topic in the study of eco-compensation [48,64,65]. Eco-compensation from an industry perspective may also involve more stakeholders, such as consumers and environmental protection organizations. The policy framework of this study aims to protect the ecology while maintaining the supply of NR and the normal operation of processing enterprises. From this point of view, the framework may help stabilize the price of NR products to a certain extent, with less impact on consumers. As for environmental protection organizations, they often play an important role in ecological protection [66]. For NR eco-compensation, environmental protection organizations could contribute to the process of raising funds and evaluating effectiveness.

As for the limitations of this study. On the one hand, the policy framework in this study was based on theoretical analysis. Even if the design of some of the measures in the framework was inspired by existing agricultural production, the compatibility of these measures with eco-compensation policies and the ultimate policy effects still need to be verified by practice. On the other hand, this study proposed a comprehensive compensation effectiveness evaluation system. However, in some cases, especially when smallholder farmers are dispersed, such monitoring can be costly, resulting in a significant increase in the workload of eco-compensation policies. Therefore, the necessity and focus of evaluation should be fully considered in practice.

5. Conclusions and Policy Recommendations

5.1. Conclusions and Prospects

From the perspective of the development of the NR planting industry, a policy framework of eco-compensation for NR was constructed. In the framework, the direct participation of the enterprise was realized and compensation paths to avoid reducing the total NR yield in the eco-compensation process were designed. It includes five aspects: compensation goals, compensation participants, compensation methods, compensation standards and compensation effects. The results show that NR eco-compensation is a large-scale public institutional arrangement with the following characteristics: 1. The goals were to protect tropical rainforest and rubber garden ecology, maintain the NR supply and improve the livelihoods of agricultural households. 2. The main participants included the government, enterprises and agricultural households. 3. The main methods included financial transfer payments, production insurance and cooperative operations. 4. The opportunity costs of agricultural household livelihood transformation and the positive expected returns of enterprises were used as compensation standards. 5. The compensation effectiveness was evaluated through the comprehensive monitoring of tropical rainforest ecology, the rubber garden environment, land use, the planting distribution, household income and production modes. The highlight of the framework is the construction of a multi-participant NR eco-compensation system. This study could not only directly support eco-compensation system

design in rubber-producing areas but also provide a new perspective for the establishment of market mechanisms for eco-compensation in other fields.

Combining the contributions and limitations of this study, future research could focus on the following three aspects. The first is the synergy between NR eco-compensation and other policies. Compensation policies require a lot of money and labor. Effective coordination with other policies could help reduce costs. The second is the baseline study of different planting areas. Remote sensing technology and field research should be used to analyze the natural and economic conditions of each NR planting area and finally determine the functions and responsibilities of each planting area in ecological protection and production maintenance. The third is the emergency mechanism. For example, if the price of NR fluctuates sharply, the cooperation between agricultural households and enterprises could be affected. In this case, what strategies should be adopted to ensure the smooth progress of eco-compensation policy.

5.2. Policy Recommendations

Finally, NR eco-compensation may have a long way to go from theory to practice. There are still many details that need to be worked out in the coordination between the three participants. To address challenges that may arise in policy implementation, such as fundraising, benefit distribution and implementation efficiency, the following three specific recommendations for NR eco-compensation could be considered.

1. Developing combined planting–breeding modes

The compensation measures to popularize the combined planting–breeding modes could help improve cost reduction and efficiency. Eco-compensation that simply limits farmers' development opportunities may require long-term fund investment, which is a challenge for the sustainability of compensation benefits. Research showed that the development of the combined planting–breeding modes not only contributes to ecological protection but also improves the income of agricultural households [67–70]. It means that this is a hematopoiesis compensation path to long-term positive development through short-term investment. Therefore, in view of the environmental management of the rubber gardens, it is suggested to promote combined planting–breeding modes.

2. Establishing a strict supervision system

Strengthening supervision could help improve the efficiency of policy implementation. For various compensation policies, regular supervision and clear provisions on rewards and penalties are needed. There are three main aspects of supervision in NR eco-compensation: First, agricultural households that have received compensation should change their production methods according to the requirements. Second, enterprises receiving compensation should ensure that the funds are used for compensation activities. Third, compensation agreements between the participants must be legal and effective.

3. Setting up special expert advisory teams

The practice of NR eco-compensation is inseparable from the expert advisory team. To make sure the compensation goes smoothly, they have many missions. For example, the government may need their assistance to introduce a series of relevant standards and regulations to ensure the effective implementation of compensation measures and optimize the distribution of benefits among various participants. For problems found during the evaluation of compensation effectiveness, they need to formulate countermeasures and submit them to the relevant management departments. Last but not least, they need to keep analyzing NR international policies, summing up relative practice experience and contributing to the optimization of future compensation strategies.

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Data Availability Statement: All the data are available in the tables and figures in the manuscript.

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