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Study on the Classification of Forestry Infrastructure from the Perspective of Supply Based on the Classical Quartering Method

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Abstract

Complete forestry infrastructure is the material basis for the realization of forestry production, ecology, and social functions. In order to clarify the scope of duties of forest infrastructure suppliers, this paper analyzes the characteristics of forestry infrastructure from the perspective of main suppliers, and summarizes forestry infrastructure as a material engineering facility that provides public services for forestry production, forestry economics, and social and ecological functions. The classical quartering method of goods was used to classify forestry infrastructure, which is divided into four categories: private goods, crowded public goods, club goods, and pure public goods.

Keywords: forestry infrastructure; supply subject; category division; quartering method

1 Introduction

A complete forestry infrastructure is the material basis for the realization of forestry production, ecology, and social functions [1]. Many studies emphasized the importance of forestry infrastructure. A complete forestry infrastructure is the basic condition for forestry to carry out production activities, and it is beneficial to forestry farmers for production and management activities [2]- [20]. Deepening the forest tenure reform system also requires complete forestry infrastructure [21]. In addition, forest road facilities can reduce the transportation cost of forest products and speed up the circulation of forest products [22]. A complete range of forestry infrastructure is conducive to improving the utilization efficiency of forestry industry information resources [23]. The targeted construction of forestry infrastructure can also reduce logistical costs [24]. A trustworthy valuation of forest biological assets also requires development of the forest infrastructure [25]. An incomplete forestry infrastructure not only restricts the construction of forestry workstations on the grassroots level, but also restricts the

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development of forestry poverty alleviation and undermines forest farmers' confidence in forest product management, which seriously restricts the development of local forestry economies [26]- [30]. Schirmer et al. [31] reported that forestry infrastructure affects planted forests. Gandaseca and Tetsuhiko [32] argued that living facilities in forest areas should be improved to improve the living conditions of forest workers. Parzych [33] used principal component analysis, Ward cluster analysis, and correlation coefficients to study the tourism infrastructure of the Polish National Forest, and concluded that the most popular tourism and recreational facilities in the forest include forest parking lots, educational trails, and accommodation facilities.

Some studies indicated that the supply of forestry infrastructure has problems such as insufficient numbers of facilities, low infrastructure utilization efficiency, and backward facility levels in forestry infrastructure [14] [34] [35]. The supply of forestry infrastructure was suggested to be increased, the quality of forestry infrastructure supply improved, and the forestry infrastructure reasonably laid out [36]- [39].

Although the importance of forestry infrastructure is frequently mentioned, most studies simply mention it at the end of a study. Few scholars have systematically studied forestry infrastructure. Moreover, existing research has not defined and classified forestry infrastructure, nor has it studied how to improve the quantity and quality of forestry infrastructure supply. There may be three reasons. First, there are many research results on general and agricultural infrastructure. Second, forestry infrastructure is a subsystem of general infrastructure. Third, forest areas are mostly in rural areas. As a result, existing research ignores the concept and category of forestry infrastructure, and treats forestry, agricultural, and general infrastructure as equivalent. However, forest areas are mostly developed in mountainous areas, while agriculture is mostly developed in plains. Forestry and agriculture are essentially different. The nature, layout, and types of forestry infrastructure are not exactly the same as those in rural and general infrastructure. There are a series of problems in the supply of forestry infrastructure, and the actual demand for it is very large. Therefore, it is necessary to classify forestry infrastructure from a supply perspective. In order to promote the development of the forestry industry more effectively and specifically, this paper studies the category of forestry infrastructure from the perspective of a supply subject, which is different from general and rural infrastructure.

We systematically examined the literature to understand the research status and existing problems of forestry infrastructure. Then, we selected orchards, nurseries, forest parks and ecological forests, and other units for investigation. We focused on the types, construction status, and actual demand and supply status of forestry infrastructure. Available information showed that the supply of forestry infrastructure is an urgent problem to be solved. Moreover, forestry infrastructure lacks a uniform classification standard. Therefore, this paper began with the supply of forestry infrastructure and constructed a unified classification forestry infrastructure. First of all, we defined the supply subjects of forestry infrastructure. Then, on the basis of the classical quartering method of goods, we divided forestry infrastructure into four categories: private goods, club goods, crowded goods and pure public goods. This new classification provided a detailed summary of the categories of private goods, club goods, crowded goods and pure public goods.

The remainder of this paper is organized as follows: we describe our survey data in Section 2, and analysis characteristics of forestry infrastructure in Section 3; then, we discuss the classification of forestry infrastructure in existing research in Section 4; in Section 5, we analyze the new classification of forestry infrastructure; lastly, our discussion and conclusions are in Section 6.

2 Data Sources

In order to deeply understand the function, nature, category, and supply subjects of forestry infrastructure, we selected 17 typical units such as orchards, nurseries, and forest parks for field visits, and the investigation was carried out by forum and questionnaire. Survey units covered urban and rural areas. The objects of investigation were mainly forest managers, forest farmers, and forestry station managers. The key research contents were 1). standards for infrastructure planning and design; 2). the number and distribution locations of forestry infrastructure; 3). the management of forestry infrastructure, and the operation and supervision mechanism of

forestry infrastructure; 4). the main service objects and service effects of forestry infrastructure; 5). the time from the construction of forestry infrastructure to its use; 6). the carrying capacity of forestry infrastructure; 7). the views, feelings, and cognitions of forestry operators on current policies and standards, norms, or guidance opinions; and 8). other specific materials, such as road data, including trunk lines, branch lines, climbing roads, hiking paths, recreational sports roads, and recreational medical forest roads. Specific survey information is shown in Table 1.

Table 1. Survey information.

Type of research unit	Survey Location	Research Objects
Forest park	Nanhaizi Country Park, Chang Zi Ying town, Da Xing district	Park leader and staff
Forest park	Bajia Country Park, Haidian district	Park leader and staff
Forest park	Xi Shan National Forest Park	Park leader and staff
Forest park	Badaling Forest Park	Park leader and staff
Forest park	Cui Hu National Urban Wetland Park	Park leader and staff
Ecological forest	Shallow mountain area: Kou Tou village, Qiao Zi town, Huai Rou district	Village head, villagers, and forestry station managers
Ecological forest	Deep mountain area: Huai Rou Ertai village	Village head, villagers, and forestry station managers
Ecological forest	Redstone Valley manor in Chang Ping district	Valley leader and forestry station manager
Ecological forest	Wa Li Agricultural Ecological Park in Chang Ping district	Ecopark leader and employees
Ecological forest	SongShan Nature Reserve	Head of nature reserve and protected-area staff
Ecological forest	Ecological Forest in Yan Qing mountain	Person in charge of protection unit and management staff
Collective forest farm	Collective forest farm in Xiao Hei Yu village, Chang Zi Ying town, Da Xing district	Forest farm leader and forest farm staff
Collective forest farm	Lv Jian collective forest farm	Forest farm leader and forest farm staff
Orchard	Beijing Shi Xin Wowo orchard	Head of orchard and forestry station staff
Orchard	De Yi Wei Ye orchard, Zai Xiang Zhuang village, Beifang town, Huai Rou district	Head of orchard and forestry station staff
Nursery	Beijing Fat Long Li Jing Technology Co., Ltd.	Head of nursery and forestry station staff
Nursery	YiLi First Construction Ecological Technology Co., Ltd.	Head of nursery and forestry station staff

As shown in Table 1, a total of 17 units were selected for investigation, including forest parks, ecological forests, collective forest farms, orchards, and nurseries, covering all types of forestry and related industries. Among them, there were 5 units in forest parks, 6 units in ecological forests, 2 units in collective forest farms, 2 units in orchards, and 2 units in nurseries.

3 Characteristics of Forestry Infrastructure

Forestry infrastructure refers to material engineering facilities that provide public services for forestry production and the realization of economic, social, and ecological forestry benefits. It is a public service system used to ensure that the economic, ecological, and social forestry functions of a country (or region) can be properly utilized. The concept of forestry infrastructure comprises the following main aspects: first, the basic objective is to give full play to ecological, economic, and social forestry functions; second, the basic theoretical basis is system engineering, benefit maximization, and ecological economics; third, the basic thinking is reasonable layout, unified standards, and cost savings; fourth, sustainable development is the basic principle.

As a subsystem of infrastructure systems, forestry infrastructure has the common nature of general and agricultural infrastructure. However, forestry and agriculture have different production targets and geographical locations. The layout, foci, and types of forestry infrastructure are all different from those of agricultural and general infrastructure. General and agricultural infrastructure mainly serve economic development and agricultural production, and are closely linked to human production activities. Forestry infrastructure mainly serves the ecological function of forestry and is closely linked with people's leisure tourism. Therefore, forestry infrastructure has special characteristics, and detailed characteristic analysis is as follows.

3.1 *Small and Scattered Forestry Production Facilities*

Woodland is mostly in mountainous areas, which are relatively scattered and in which it is difficult to achieve large-scale operations. Therefore, most domestic forestry production activities have not yet achieved large-scale mechanization. Most production-type forestry infrastructure uses flexible and compact facilities. In addition, in order not to damage forest land or affect the growth of forest trees, forestry infrastructure usually covers a small area, and adopts the layout of small size and large quantity.

3.2 *Focus on Ecological Facilities*

With increasing attention to climate change, forests' ecological functions are also increasingly emphasized. Complete forestry infrastructure is conducive to promoting the healthy growth of forests. For example, forest care facilities can promote forest growth. Forest fire prevention facilities can reduce the incidence of forest fires, and facilities used for forest pest control are helpful in reducing the incidence of forest pests. Complete forestry infrastructure can also provide good conditions for forest tourism, such as gazebos, rest benches, parking lots, fitness trails, and other facilities.

3.3 *Naturalness of Facility Construction*

Different from agricultural infrastructure, large-scale forest land is generally far away from people's living areas, mainly for protection, supplemented by development and utilization. The construction of forestry infrastructure is mainly to protect the healthy growth of forests, and provide a good living environment for wild animals and plants in the forest.

3.4 *Insufficient Willingness to Construct Facilities*

On the one hand, forest land is relatively remote and mountainous. The labor cost of building forestry infrastructure is relatively large. On the other hand, compared with agricultural activities, the input–output ratio of forestry is relatively low. Therefore, many forest farmers choose to go out to work and reduce their investment in forestry. As a result, the supply of forestry infrastructure is insufficient, the quality of forestry infrastructure is not high, and the layout of forestry infrastructure is unreasonable.

In summary, forestry infrastructure is not exactly the same as agricultural and general infrastructure, but it has its own characteristics. Research results of the other two types are not completely applicable to forestry infrastructure, which should be studied as a separate subject. The classification of forestry infrastructure is the

basis for subsequent research in the field. Therefore, it is necessary to study its classification.

4 Classification of Forestry Infrastructure in Existing Studies

4.1 *Classification of Forestry Infrastructure in Standard for Infrastructure Construction of State-Owned Forest Farms*

The Standard for Infrastructure Construction of State-Owned Forest Farms classified forestry infrastructure according to its nature: first, public service facilities, including forest farm office buildings, police stations, and office buildings in industrial areas, as well as roads, water supply and drainage, power supply, heating, sanitation, office facilities, and other equipment provided for public facilities; second, living service facilities, including workers' personal housing and the provision of roads, water supply and drainage, power supply, heat supply, sanitation, and other facilities for residential areas; third, production infrastructure supporting facilities, including houses, roads, water, electricity, communications, and other facilities and equipment that provide services for forestry production, such as seedling breeding, afforestation, forest protection, fire prevention, pest control, and scientific research and monitoring.

In summary, the Standard for Infrastructure Construction of State-Owned Forest Farms divided forestry infrastructure into three categories: public service, living service, and production service facilities. This classification method covers life, production, and public services, and the research scope is relatively comprehensive. However, this classification method is only applicable to infrastructure in state-owned forest farms, and is not completely applicable to infrastructure in collective forest farms.

4.2 *Classification of Forestry Infrastructure in Regulation on the Implementation of the Forestry Law of the People's Republic of China*

According to relevant national forestry laws (the Regulations on the Implementation of the Forestry Law of the People's Republic of China), engineering facilities were divided into six categories according to the specific functions of facilities provided for forestry production: First, facilities for cultivating and producing seeds and seedlings. Second, facilities for storing seeds, seedlings, and timber. Third, skidding and transport roads. Fourth, forestry research, experiment, and demonstration bases. Fifth, facilities for wild animal and plant protection, forest protection, forest pest control, forest fire prevention, and timber quarantine. Sixth, facilities for water, power, heat, and gas supply, and communication.

This classification categorized forestry infrastructure from the perspective of facility function. The advantage is that the function of each facility is indicated. However, this classifies forestry infrastructure from the perspective of forestry production, focusing on the classification of production facilities, and lacks guidance on public service, living, and ecological facilities.

4.3 *Classification of Forestry Infrastructure in Guide to Urban Forest Infrastructure Construction*

Fan et al. [40] divided a plain ecological forest infrastructure into buildings, roads, water conservancy, signs, border enclosures, supporting facilities, and machinery on the basis of the functions of forestry infrastructure in the Guide to Urban Forest Infrastructure Construction. There are 7 primary classifications and 35 secondary classifications.

The classification of the guide is relatively detailed by using two-level classification to comprehensively summarize the types of urban forest infrastructure, but it does not cover the forestry infrastructure unique in rural collective forests, such as wildlife channels and eco-bridges. The findings are not entirely applicable to the classification of rural forestry infrastructure.

4.4 Problems with Current Classification of Forestry Infrastructure

Existing studies had different emphases on the basis of the classification of forest infrastructure, mainly from the perspective of forest ownership relationship or geographical location. Therefore, there are problems such as incomplete type classification and no classification levels. The Standards for the Construction of State-Owned Forest Farm Infrastructure do not consider the forestry infrastructure of collective forests, and the scope of application is relatively narrow. The Regulations on the Implementation of the Forestry Law of the People's Republic of China focus on the classification of forestry production infrastructure, but have no clear classification of public service, living service, and ecological service facilities. The Guide to Urban Forest Infrastructure Construction focuses on the classification of forestry infrastructure in urban forests, and does not fully consider the forestry infrastructure in rural collective and ecological forests.

In summary, the current classification of forestry infrastructure has a limited scope of application and lacks guidance for studying its supply.

5 New Classification of Forestry Infrastructure

5.1 Necessity for New Classification of Forestry Infrastructure

Survey results showed that problems of forestry infrastructure supply is prominent, such as unification of land occupation standards for facility construction, complex approval procedures for facility construction, conflict between the nature of the land for facility construction and the nature of forest land, and inadequate funding for facility construction and maintenance. Especially in recent years, a large number of forestry infrastructures have been demolished due to illegal construction. Various forestry operators have urgent need for rationally planned forestry infrastructures.

The fundamental reason for the supply problem of forestry infrastructure lies in that the scope of responsibility of each supply subject is not clear. As a result, some facilities may be unaccountable, and each supplier considers them outside their responsibility, or there are too many supply subjects of the same kind of facilities, which leads to the failure of some to adhere to their responsibilities, and to the waste of resources and funds.

Existing studies simply classified forestry infrastructure from forest tenure or location, and detailed types of forestry infrastructure are not listed. On the other hand, the application scope of existing classification is limited. Moreover, existing classifications lack theoretical guidance for researching the supply of forestry infrastructure.

To sum up, in order to help solve the supply problem and study the supply mechanism of forestry infrastructure, it is necessary to add a new classification of forestry infrastructure from the perspective of supply.

5.2 Theoretical Basis of New Classification of Forestry Infrastructure

In the classical quartering method of goods, according to their competitiveness and exclusiveness, general goods are divided into private, crowded public, club, and pure public goods, among which crowded public and club goods can also be called quasipublic. Personal belongings are competitive and exclusive, crowded public goods are competitive and nonexclusive, club items are noncompetitive and exclusive, and pure public goods are noncompetitive and nonexclusive [41]–[43].

The competitiveness of goods means that an increase in consumers lead to an increase in production costs. Each additional or personal item increases the production costs. Exclusiveness means that only those who pay consideration for a good can use it, so sovereignty is clear, and "free riding" is avoided.

According to the competitiveness and exclusiveness of goods, their supply subject can be defined. Due to the competitiveness and exclusivity of private goods, private provision is more profitable for itself, so the supply subject is generally private. Pure public goods are noncompetitive and nonexclusive, that is, they can be used without payment. If provided by the private party, they cannot make ends meet. Therefore, the supply subject is generally the government. Quasipublic goods have the attributes of both private and pure public goods.

Therefore, the supply subject can be either private or the government.

This paper classifies forestry infrastructure on the basis of the classical quartering method of goods. It can clarify the main supply of all kinds of forestry infrastructure and the supply scope of the main supply. Table 2 is a detailed description of the quartering method.

Table 2. Classical quartering method of goods.

	Exclusive	Nonexclusive
Competitiveness	1) Private goods, e.g., food, clothing, housing, transportation, and other supplies, and the production of enterprises.	2) Crowded public goods, e.g., crowded streets, central parks, and small squares.
Noncompetitiveness	3) Club goods, e.g., toll roads, parks, and bridges.	4) Pure public goods, e.g., national defense, justice, administration, and public health.

5.3 New Classification of Forestry Infrastructure

Considering the supply status of forestry infrastructure, on the basis of the classical quartering method of goods, this paper divides forestry infrastructure into four primary categories: private, crowded public, club, and pure public goods. Among them, the forestry infrastructure of crowded public goods and that of club goods are collectively referred to as quasipublic goods forestry infrastructure. Each primary classification corresponds to a detailed secondary classification. There are 46 items in the secondary category, namely, 10 items in the private goods category, 16 items in the crowded goods category, 9 items in the club goods category, and 11 items in the pure public goods category. Specific classifications are shown in Table 3.

Table 3. Detailed classification of forestry infrastructure.

Class I	Class II
Personal goods	Comprehensive simple house
	Tool storeroom
	Design water tank or reservoir
	Main garden roads and entrance roads
	Border identification
	Entrance sign
	Regional geographical indication
	Cistern
	Transfer facility
	Hard fence
Crowded public goods	Public toilet
	Rest bench
	Parking lot
	Walking trail
	Trials for hiking and fitness
	Stairway
	Pedestrian bridge
	Bicycle path

	Fireproof road Animal passage Ecological covered bridge Takeyama road Cycling road Skid road Forest management road Motorized driveway
Club public goods	Communication facilities Power supply facilities Water-saving irrigation facilities Reclaimed water irrigation facilities Infiltration facilities Water storage and reuse facilities Antiseepage channel Drainage facilities Low-pressure water pipeline
Pure public goods	Trash can Street light Ancient tree or wood sign Water treatment facilities Pest monitoring facilities Forest and ecological monitoring facilities Fire observation tower Key animal activity track monitoring equipment Patrol roads Forest fire-fighting water facilities Collective forest entrance and signs

The classification of forestry infrastructure based on the four parts of goods has a wider scope of application for both urban and rural forests, state-owned forest farms and collective forests, and plains and mountains. The new classification divides forestry infrastructure into primary categories and classifies the specific items in each category in detail. This helps to clarify the supply subject of each forestry infrastructure and the responsibility scope. For example, foresters are responsible for private goods, the government and social personage are responsible for pure public goods, and crowded public and club goods are provided by the government and social personage.

5.4 Analysis on Supply Subjects and Their Supply Scope of Forestry Infrastructure

On the basis of the above-mentioned new classifications, this paper performed preliminary analysis on supply subjects and their scope of supply of the four forestry infrastructures. Through literature and field research, the paper initially defined that the main supply subjects of forestry infrastructure are forest farmers, forestry enterprises, government departments, and social celebrities.

5.4.1 Forest Farmers and Their Supply Scope

Forest farmers are the main supply subject of private goods forestry infrastructure. Because this type of forestry infrastructure is both competitive and exclusive, forest farmers can benefit by providing such facilities alone. Therefore, forest farmers build private goods forestry infrastructure in accordance with the needs of their

own forestry operations.

5.4.2 Forestry Enterprises and Their Scope of supply

Many forest farms have set up forestry enterprises such as forestry cooperatives and forest product trading companies. In order to promote the development of the forestry production industry, improve forestry production efficiency, and maximize profits, forestry enterprises invest in the construction of production-related forestry infrastructure, which is usually private goods. There are also roads, forest fire facilities, and other quasipublic goods facilities.

5.4.3 Government Departments and Their Scope of Supply

If pure public goods are provided by the private sphere because there is no competition and exclusivity, the private sphere is not profitable, and the means are not enough to make ends meet, so private entities are generally unwilling to supply them alone. Therefore, pure public goods are generally provided by the government alone or in cooperation with prestigious communities in some countries such as China. Pure public goods forestry infrastructure, such as fire watch towers, monitoring equipment for key animal activities, and road patrols cannot be separated from government support and policy guidance.

5.4.4 Social Celebrities and Their Scope of Supply

In order to obtain higher social value such as reputation, some social celebrities donate to the forestry infrastructure of public goods with social significance. Therefore, these people can also be regarded as the main supply subjects of forestry infrastructure. However, compared with forest farmers and enterprises, and government departments, social celebrities only account for a small proportion of the total number of forestry infrastructure suppliers.

6 Discussion and Conclusion

Three main issues were studied in this paper: (1) Compared with the general infrastructure, what are the characteristics of forestry infrastructure? (2) What are the classifications of forestry infrastructure in existing studies? (3) New classification of forestry infrastructure. The following was found: (1) Although forestry infrastructure is a subsystem of infrastructure, it is different from general and rural infrastructure. Forestry infrastructure is characterized by small and scattered forestry production facilities, a focus on ecological facilities, the naturalness of facility construction, and insufficient willingness to construct facilities. (2) Existing classification of forestry infrastructure has various problems. For example, the classification method is only suitable for cities and not villages, and only production facilities are classified. (3) On the basis of the classical quartering method of goods, forestry infrastructure was divided into private goods, crowded public goods, club goods, and pure public goods forestry infrastructure. This classification method applies to both cities and villages. The types of facilities covered by this classification are relatively complete. Current classifications of forestry infrastructure are not widely applicable. This paper classified forestry infrastructure from the perspective of supply on the basis of the classical quartering method. This classification is helpful in clarifying the supply subject and scope of supply of different types of forestry infrastructure, and it can lay the foundation for studying the supply mechanism of forestry infrastructure. This new classification is conducive to solving problems such as the insufficient supply of forestry infrastructure and low quality. Therefore, it is of theoretical and practical significance to classify forestry infrastructure from the perspective of supply on the basis of classical quartering.

The types of forestry infrastructure were summarized and classified in detail by consulting the relevant literature and field investigations, and the new classification covers as much as possible all types of forestry infrastructure. However, due to the limited number of research units and the number of typical cases that were mastered, research results may not be accurate. The concept and categories of forestry infrastructure need to be further studied and supplemented.

Supplementary Materials:

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