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RESEARCH ARTICLE

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Management pattern of ecological public welfare forests in South China

Abstract The characteristics and actualities of ecological public welfare forests in South China are studied in this paper, including common and special management patterns. The restoration and reconstruction pattern of subtropical evergreen broad-leaved forests, zonal vegetation in the key eco-zone, and the transformation pattern of coniferous and broad-leaved mixed forests in the general eco-zone with multi-forms are discussed in detail. The authors also point out, based on ecological transformation and utilization, that ecological public welfare forests should be oriented to multiple benefit utilization to maintain sustainable management.

Keywords South China, ecological public welfare forest, transformation, management pattern

1 Introduction

The ecological public welfare forest construction system is a complex system of many interacting factors. The complication results from the diversities of constituents, such as forest species, function, management measures and forest types. The management pattern is different for the same forest type because of different management objects or different management periods. In recent years, some provinces in South China, such as Zhejiang Province, have begun to establish criteria to property rights, land types, forest species, gradation of conservation, chief management measures and specific technique rules for different types of ecological public welfare forests (Leading Group of Forestry Classification Management Office in Zhejiang Province, 2002; The Monitoring Centre of Forest Resource, 2002). It is known that the structure of forest types is often improper, the equality of forests is poor and the share of protective forests is too big in proportion to the ecological public welfare forests in South China (Cai, 1999; Ning, 1999; Chen, 2006). In addition, the main function of forests varies in different regions. Based on these, the paper discusses the management pattern of ecological public welfare forests in South China.

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2 Common pattern

The ecological function of a forest ecosystem can be greatly realized by the creation of ecological public welfare forests. Chief management objectives would include restoration and conservation of the forest ecological function, the creation and maintenance of forest ecological landscapes, the development and utilities of forest recreation, the management and conservation of some forests with special functions and the comprehensive utility of forest multifunction. Different management approaches should be adapted for different objectives, and different technical systems should be applied to different forest types.

2.1 Community succession pattern

In its narrow definition, succession means that one forest community is substituted by another due to the development of interior contradiction of the forest communities in every site (Li, 1994). The theories of ecological community succession show that the interaction in one community, between different communities, or between communities and the abiological environment promotes the succession. As a result, a climax community emerges which fits the local climate, sites and habitats very well. At the stage of climax community, the forest structures rarely change, the forest ecosystem is correspondingly stable and it has better ecological effects.

In South China, the monsoon climate is typical and has a highly good fit for plant growth. The collectively-owned forests are mostly located at the place where the southeast monsoon is active. The principle of succession is useful to protect and restore the forest ecosystem naturally.

2.2 Close to nature pattern

The close to nature pattern is used to manage forests naturally by setting up technical measures which are close to the natural ecosystem based on research on virgin forests, including material circulation, energy flux and information exchange. This approach improves the integrated productivity of all kinds of forest ecosystems (Li and Guan, 1999). For example, to manage forests by natural measures would mean avoiding disturbing forests frequently and advocating natural regeneration. Other measures are to maintain the integrity of the forest landscape and protect biodiversity against destruction; to grow broad-leaved tree species in coniferous forests to grow mixed forests, and change the regular and even-aged forests into multi-layered and uneven-aged forests to enrich the diversity of tree species so that the ecosystem can remain stable and safe. To keep forest land from being covered continuously, wood harvesting must be carefully done to protect the forest. To maintain sustainable productivity and harmony of the forest ecosystem, chemicals should be avoided, the forest floor and litter over mature forests should be preserved, and endangered wildlife should be conserved.

Close to nature pattern and community succession pattern are analogous, as both are based on the fundamental theories of natural succession. The distinction between the two is not only in terms of utilizing the whole/entire forest resource, but also in developing natural succession as the management objective. It is a basic principle for all kinds of management measures which should be abided by, and it also is the prerequisite for ecological public welfare forests to have sustainable development.

2.3 Landscaping pattern

The characteristics of forest landscapes come into being through the interaction among soil, water, vegetation and structure. The effects of forest management measures are influential not only in ecology but also in forest landscapes. The landscaping pattern is used to improve diversity, features and aesthetic sense, and keep the nature ecosystem balance and stability by some specific management measures, according to the theories of aesthetics. These measures can be applied to natural forests, planted forests and the whole process of afforestation, including silvicultural regionalization and design, cutting and landscape planning of afforestation, tending and reforestation (Zhong et al., 1999).

This kind of management pattern is mostly used to improve the recreation function and breed the potential ornamental value of forests. The management measures are varied at different stages.

2.4 Intensive management pattern

The intensive management pattern is mainly adapted for the protection of forests. This approach aims to get the best reward and benefit from farmland protection forests, windbreak and sand-fixing forests, road protection forests, bank protection forests and specific utility forests such as institutional forests and reserve-seed tree forests. Taking farmland protection forests as an example, we should select the proper tree species and clarify afforestation density, mixed proportion and structure types of forest belts and networks for different protection objectives. Second, they should be tended chronically, such as cutting the weak and replanting to promote the maturity of the forest belt and network and make full-play of the desired effect. Third, based on the protection maturity period and quantity and craft of the forest belt (Jiang, 1994), we must make it clear when the forest should be harvested and regenerated. Lastly, we should choose the best methods such as half belt regeneration, belt interval regeneration and overall regeneration to regenerate the forest belt or network. The whole process is highly intensive (Table 1).

3 Restoration and reconstruction of an evergreen broad-leaved forest in the important ecological region

The evergreen broad-leaved forest is mostly distributed over subtropical areas where the climate is very humid, hence it is also called subtropical evergreen broad-leaved forest. It consists of evergreen broad-leaved tree species which often belong to the vegetation classes of Fagaceae, Lauraceae, Theaceae, Magnoliaceae, Hamamelidaceae (Zhong, 1988). This forest type is the zonal vegetation in the collectively-owned forest regions of South China, the special ecosystem of the subtropics and the most important type in the Gene Banks. Its structure is complex and possesses various tree species. It is significant to us on water and soil conservation, stable forest ecosystem balance, and microclimate improvement. It is obvious that the ecological effect of an evergreen broad-leaved forest is better than the coniferous forest and bamboo forest (Li, 1994; Wen and Liu, 1995; Liu et al., 1996; Peng, 1996; Feng et al., 1999; Wu et al., 2002; Xing et al., 2003; Yao et al., 2003; Li et al., 2004).

However, the proportion of evergreen broad-leaved forests is still very low in the collectively-owned forest

Table 1 Management measures of ecological public welfare forest measure

management measures	management objective
Artificial regeneration	Wasteland, shrubbery, farmland near to forest, open forest failing in natural regeneration, and some mature or over mature forest
Stand improvement by replanting	Forest being destroyed, dwarf forest, low-effective forest, etc
Enclosure for vegetation protection	Ecological public welfare forest being protected specially
Closing the land for reforestation	Ecological public welfare forest whose forest canopy density is from 0.3–0.5 situated in the important ordinary area
Closing the land for forest protection	Ecological public welfare forest whose forest canopy density is over 0.5 situated in the important ordinary area
Ecological thinning (forest thinning for improving ecosystem)	Ecological public welfare forest which is too dense or the important ecological public welfare forest which is at young-middle age needing sanitation cutting and thinning
Ecological selection cutting (forest selection cutting for improving ecosystem)	Ecological public welfare forest whose canopy density is over 0.8 and is over mature
Ecological and economical forest	Ecological public welfare forest which consists of bamboo or is used for economic objective

regions of South China, although the project of growing natural broad-leaved forests has been initiated. Majority of the broad-leaved forests measuring 77.03×10^4 hm^2 in Zhejiang Province are evergreen broad-leaved forests. The minority are deciduous broad-leaved forests mostly distributed over the Montane Altitudinal Belts where the altitude is from 700 to 1400 m but whose quantities are usually small (Ding and Song, 2003). The area of a broad-leaved forest is 45.26×10^4 hm^2, and the proportion is 22.9% compared with the total area of an ecological public welfare forest, while the others are coniferous forests and coniferous and broad-leaved mixed forests. Compared to its protection effect, the area proportion of a broad-leaved forest is too small. The natural succession from *Pinus massoniana* Lamb forest to evergreen broad-leaved forest will take 80 years or 100 years.

The important ecological region means the ecosystem is very significant or the ecosystem is easily interfered. Thus, the restoration pattern of a broad-leaved forest is different for different types and stages of succession (Yu, 2004).

3.1 The secondary bare area

Usually, because of constant destruction, the evergreen broad-leaved forest has disappeared, soil erosion is serious, and the propagule is scarce. As a result, it is difficult to regenerate naturally.

The reconstruction models of evergreen broad-leaved forests are chosen to seeding with pioneer tree species and closing the land for reforestation. The shrubs grow three to five years after seeding and closing the land for reforestation. We then replant local tree species and dominant species which are 2–3 years old, and later continue the management measures of closing the land for reforestation.

3.2 The secondary shrubs

The secondary shrubs are young-aged forests which often grow in the cutting forestlands or burned forestlands. It regenerates naturally and the propagules come from forest soil seed banks. At the beginning of natural regeneration, the dominant species are usually *P. massoniana* and a great many broad-leaved tree species. These types of community structure are very complex and there is no obvious layer. The height of these communities is often below 5 m, mostly 3–4 m. Coverage rate is often over 90%, therefore it is very dense.

There are three ways to reconstruct an evergreen broad-leaved forest. Firstly, the young trees of *P. massoniana* are the dominant species in these communities. The young-aged forest needs intermediate-cutting, so we should cut the weak young trees of *P. massoniana* and just keep the valuable ones according to the constitution of tree species. This allows us to bypass the stage of pure forest of *P. massoniana*. At the same time, we can replant rare broad-leaved tree species intentionally and reasonably, and then use them at maturity in the future. Secondly, bamboos are the dominant species in these communities. We should conserve the young broad-leaved bamboos, replant some when necessary, reduce management intensity and stop taking advantage of the bamboos especially in those regions where the ecosystem is significant or unstable. Thirdly, young broad-leaved trees are the dominant species in these communities. Some of them need cutting and replanting with valuable evergreen broad-leaved tree species, if it is necessary and possible. Most of them need management when closing the land for reforestation and to avoid destroying the original structure and ecological function.

3.3 The secondary forest

The chief forest species of secondary forests in South China are the coniferous forest and coniferous broad-leaved mixed forest, and also ecological public welfare forest. Of these, the pure forest of *P. massoniana* and the *P. massoniana* broad-leaved mixed forest are the main species. We should transform these forest species into

broad-leaved ones, because their functions are better than secondary bare area shrubs, but their ecological functions are worse compared with evergreen broad-leaved forests.

The communities are primarily composed of the pure forest of *P. massoniana*. It is generally accepted that the stage of the pure forest of *P. massoniana* is an important stage to succession, and it will be replaced by evergreen broad-leaved forests in the end. The *P. massoniana* responds well to light, can endure drought and tolerates barrenness. At the beginning of succession, the environment is fit for *P. massoniana*, helping it grow and become the dominant species rapidly, and the forest first grows and becomes a pure forest of *P. massoniana* quickly. Broad-leaved trees will then gradually replace them and be dominant in these communities for the long term, with the evergreen broad-leaved forest eventually emerging. It is the climax of succession in South China. It is necessary to manage pure forest of *P. massoniana* intensively during the process of transformation to accelerate the restoration of evergreen broad-leaved forest and to keep the stand relatively stable. The measures usually decide how to do select cutting properly, including the period, selection wood and intensity (the maximum is usually 30%), to replant the right broad-leaved forest dominant species at different stages, and to create the poly-layered and uneven-aged forest. In a word, the principle of close to nature should be complied with during the whole process.

Secondly, the communities are *P. massoniana* broad-leaved mixed forests. These communities have been invaded by the broad-leaved as a dominant species. By allowing this, the individuals of *P. massoniana* will die off and the communities will reach the stage of climax communities naturally. At this stage, some mature or close to mature individuals of *P. massoniana* should be cut off to enlarge nutrition space for broad-leaved trees and to increase the speed of restoration of the broad-leaved forest. In addition, we also can benefit from tending cutting.

4 Transformation of coniferous broad-leaved mixed forest in the unimportant ecological region

A coniferous broad-leaved mixed forest offers more value than a pure coniferous forest for its higher productivity, higher fertility, better stability and protective effect. Furthermore, based on selection cutting, we can harvest the view value and economic benefit by managing the coniferous broad-leaved mixed forest (Wang, 1992; Zheng, 2001). Consequently, it is necessary to transform and create coniferous broad-leaved mixed forests (most of them are *P. massoniana* broad-leaved mixed forests) in the unimportant ecological regions. This management measure is fit for the ecological public welfare forest and forestry ecological construction in South China.

An unimportant ecological region means that the ecosystem is not very significant, excluding those ecological public welfare forest lands which need to be specially protected. There are two types.

4.1 The secondary shrubs

Secondary shrubs have three types; young broad-leaved forests, young coniferous broad-leaved mixed forests and young coniferous forests. These all benefited from the management measure of closing the land for reforestation in recent years, and they are large in proportion to the public welfare forest.

Being disturbed frequently or due to bad natural conditions, the pioneer tree species of *P. massoniana* fails to invade young broad-leaved forests. The evergreen broad-leaved tree species and deciduous broad-leaved tree species coexist at the beginning of succession. The upper-layer coverage of stand is large that there is shortness of light under the forest, some trees with strong sprouts often grow in a cluster, herb growth is bad, the structure of communities does not form and the ecological function of stands is not so good and unstable. So we should improve the condition of growth for young trees of *P. massoniana* by spot tending and replanting. The tending cutting intensity must be proper and the targets of cutting are the bad and weak ones; some need thinning. Finally, we also should make a plan to tending young trees of *P. massoniana* periodically.

We can easily finish our task for young coniferous broad-leaved mixed forests by the managing measure of closing the land for reforestation. But if the coniferous trees are less than 50% in proportion to the total, we should replant the young coniferous trees and keep the proportion from 50% to 70%.

For young *P. massoniana* forests, we just need to cut weak young trees of *P. massoniana* and replant some indigenous broad-leaved tree species to put the proportion between coniferous trees and broad-leaved trees under control.

4.2 The secondary forest

The chief types of ecological public welfare forests according to the constitution of dominant tree species include the secondary pure forest of *P. massoniana*, *Pinus* broad-leaved mixed forest and evergreen broad-leaved forest. They represent three different stages of succession respectively, with the stage of evergreen broad-leaved forest as the last one. Research shows that *P. massoniana* die off and are replaced by evergreen broad-leaved forest from the community of succession in the end due to shortness of light and narrow ecological amplitude,

affecting their material metabolism. If we want to make *P. massoniana* regenerate naturally, we should thin the community to keep low stand density and forest canopy density or produce some proper forest gap. To maintain the stage of *Pinus* broad-leaved mixed forest, we should regulate the density of both *P. massoniana* and broad-leaved trees and ensure that the tree species of *P. massoniana* is not sheltered by the broad-leaved trees and growing healthy. In addition, some research shows that being short of disturbance and approximate primary bare area are other reasons why the tree species of *P. massoniana* and the young tree of *P. massoniana* cannot regenerate naturally in the understory. Furthermore, the measure system for sustainable management of coniferous and board-leaved mixed forests has been proven based on scientific selection cutting (Ding and Song, 1998; Liu, 1998; Ding and Song, 2003). Consequently, if we want transform the secondary forest into a coniferous and broad-leaved mixed forest and keep the last stage stable, we therefore should disturb the forest persistently besides using the indispensable management measure of transformation to promote the natural regeneration ability of *P. massoniana*.

The first type of transformation is the secondary pure forest of *P. massoniana*. *P. massoniana* is the only population for the tree layer and the stand is often stratified; there are usually many young evergreen broad-leaved trees in the understory, so the forest types are diverse (Tong et al., 2004). To create this type, we should first select to cut some trees of *P. massoniana* to increase transparency, so that the young evergreen broad-leaved trees can grow well. Second, we should tend the understory to clear the non-objective and valueless tree species. In addition, we should replant some valuable broad-leaved tree species or objective tree species understory and some young trees of *P. massoniana* when the mixed proportion is out of balance.

The second type of transformation is the secondary coniferous broad-leaved mixed forest, which is the transitional type of progressive succession and is the objective stand of forest cultivation among the zonal succession series. At the beginning of this stage, trees of *P. massoniana* are dominant. At the end of the stage, broad-leaved trees are dominant. Finally, broad-leaved tree species replace the coniferous tree species. To manage the coniferous broad-leaved mixed forest ideally, we should select to cut some mature individuals of *P. massoniana* and some broad-leaved trees to keep a reasonable mixed proportion and create a forest gap by evergreen broad-leaved tree clear-cutting in patches to promote the natural regeneration of *P. massoniana* or replant young trees of *P. massoniana*. The intensity of clear-cutting in patches must be proper and should not do any harm to the ecosystem. The harvesting cycle of selection cutting, select to cut mature individuals of *P. massoniana* periodically, and regenerate and tend the stand must be in time to cultivate the poly-layered and uneven aged *Pinus* broad-leaved mixed forest.

The third type of transformation is the secondary evergreen broad-leaved forest. It is the zonal climax of communities; although its total area is small compared with others, its canopy is good. The individuals of *P. massoniana* have been unable to regenerate by themselves and some broad-leaved trees have been over maturity at this stage. To transform it, we should cut individuals of broad-leaved trees whose growth is weak or coverage is large, and clear the shrubs understory to increase forest transparency. We also can adapt the measures of spot sowing and tree planting on bare land under the forest gap to promote the regeneration of *P. massoniana* and tend them in time. Three or five years later, we should execute the second thinning to ensure enough nutrition space for *P. massoniana.*

5 Conclusions

The aim of research on the management pattern of ecological public welfare forests in South China is to conserve and utilize these forests reasonably. Therefore, we can practice these theories to manage these forests and take advantage of their multifunction. Under equal utility conditions, the forest ecological landscape utility is preferred. The process of utility is gradual and orderly. In the near future, the central task is to transform and conserve ecological public welfare forests and construct management planning, then reasonably utilize and continue conserving ecological public welfare forests in the middle phase. There are several problems which should be given attention in practice. Firstly, these common management patterns of ecological public welfare forests are not isolated. On the contrary, they can interact and be interdependent, including the multi-function property of ecological public welfare forest. All of them serve as the basis to establish and execute management measures. Secondly, the restoration of evergreen broad-leaved forests in the important ecological regions is a complex project. In practice, we should devise proper management planning based on different conditions of the stand, forest land, ecological region and other actualities. The primary management measure is closing the land for reforestation. In addition, the forest should be managed with definite objectives such as regeneration, tending and selection cutting. Thirdly, under the prerequisite of maximizing the protection effect of the ecological public welfare forest, the transformation of the coniferous broad-leaved mixed forest in the unimportant ecological region is a way to reasonably utilize the economic value of the forest. Significant change will mark the process of transformation to a coniferous broad-leaved mixed forest, especially for the orientated transformation of the

secondary coniferous pure forest and broad-leaved pure forest. Without this change, the forest ecological effect will be hampered and a new ecological problem may even arise. Consequently, the process of transformation should be scientifically demonstrated, strictly supervised and relate closely to local social economic development. In addition, farmers are the subjects tasked to construct the ecological public welfare forest; in management practice, we should achieve the transition from department-run forestry to society-run forestry, and the application of the management pattern of ecological public welfare forest in practice is a prerequisite.

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