

Review of the Studies on Vegetation Restoration of Degraded *Pinus Massoniana* Woodlands in China

Gang Li

Department of Environment Engineering, Zhejiang Guangchuan Engineering Consulting Co., Ltd., Hangzhou, 310020, China
Email: happylglove@126.com

Abstract

Pinus massoniana resources in Southern China are abundant which play extremely important role in forest resources. However, most of *Pinus massoniana* woodlands have occurred different degrees of degradation and these woodlands are difficult to play forest ecosystem functions. Therefore, how to restore the ecological functions of the degraded woodland is a serious problem. This paper summarizes the vegetation restoration ways, restoration patterns and their benefits in order to provide references for further management of degraded woodland in different areas. Meanwhile, the study prospects of degraded *Pinus massoniana* woodland were proposed, which enrich the study contents of ecological restoration of degraded woodland.

Keywords: *Pinus Massoniana*; Ecosystem Degradation; Vegetation Restoration; Soil Erosion

1 INTRODUCTION

Pinus massoniana is one of the timber forest species and protection forest species. And the World Bank Loan “National Afforestation” Projects designated which is one of the fast-growing and high-yield afforestation tree species (Qin et al. 1999). Because of its strong adaptability, easy propagation, rapid growth and extensive usage, it is widely distributed in 16 provinces of China (Huang 2009). In some of the major areas of China, such as Sichuan Basin, the area of *Pinus massoniana* forest accounts for 14% of the forest area. Moreover, in Fujian, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Guizhou, Guangdong, Guangxi and other provinces, the area of *Pinus massoniana* forest accounts for more than 40% of the timber forest area, the highest in Zhejiang accounts for 62.5%. Therefore, in Southern China, it becomes the main timber tree species (Zhou 2001; Mo et al. 2002; Yang and Li 1992). Because the soil suitability of *Pinus massoniana* is very strong and in the restoration of forest ecological system can play a leading role, thus it becomes the pioneer species of afforestation in soil erosion area. However, because of the special physiology feature, adding to the effects of artificial or natural factors, single vegetation structure, near surface vegetation difficult to grow, low biological productivity, poor soil properties, most of *Pinus massoniana* woodlands were unable to play an effective role in soil conservation (She et al. 2002). This phenomenon is called the “Floating Green” that is far seen green hill, near seen soil erosion (Liang et al. 2008).

In some *Pinus massoniana* woodlands of serious soil erosion, the species was single, vegetation sparse and uneven distribution, stand quality low. For example, in degraded woodland, the *Pinus massoniana* of 20 years old were only small aged trees which the density of 925 plants/hm², the average tree height of 0.8 m, the average ground diameter of 3.1 cm, due to serious soil erosion, part of the roots exposed. Other vegetation was a small amount of *Dicranopteris dichotoma* and *Arundinella anomala* (Lin and Xie 2003). Relevant studies have shown that in degraded coniferous forest, the vegetation composition was single, shrub and grass vegetation sparse, surface soil washed by runoff, nutrients loss serious, organic matter content low, soil porosity poor and sand content high (Zha et al. 2003). While the study about artificial simplex *Pinus massoniana* woodland concluded that soil compacted, soil ventilation poor, organic matter content and the main nutrient content low (He et al. 2010).

Natural factors, tree themselves characteristics and human activities influence the environment of *Pinus massoniana*

woodland, in which, natural factors and biological characteristics of *Pinus massoniana* itself are the internal factors. Most of *Pinus massoniana* woodland distributed in tropical and subtropical humid climate zones where mean rainfall was more than 1200 mm, obvious region difference, and concentrated distribution, large rainfall erosion kinetic energy (zhao 2002). On soil properties, soil erodibilities of each region are different. The higher erodibility in red soil region of Southern China is one of the main internal factor caused soil erosion of woodland (zhang et al. 1999). In addition, *Pinus massoniana* roots secreted acid substances, intensified soil acidification, which was an important reason for inhibiting the growth of other plants especially the near surface vegetation (zhang and wang 2010). Besides the above factors, human activity is another most important reason for causing the soil erosion of *Pinus massoniana* woodland. Long term since, the negative effect ways of human activities on coniferous forest include felling, deforestation for farming, burning mountain, etc. In addition, population growth leads to increasing of fuel demand, fuel demand cannot be solved, the masses have to cut wood and shovel grass to solve the firewood problem. This caused vegetation serious damage, soil erosion was doubled increasing every year (fang et al. 1999). Due to serious human disturbance, near a quarter of *Pinus massoniana* communities in Southern China appeared different degree of degradation. *Pinus massoniana* poor growth has become small aged trees (guo 2000).

Forest destruction leads serious soil erosion, which in turn exacerbates the forest community degradation and both of which form a vicious spiral. In degraded *Pinus massoniana* woodland, soil barren, hydrological effect poor, soil erosion serious, additionally, large area of vegetation restoration, these factors cause the forest vegetation restoration is difficult. Therefore, according to different conditions of degraded woodland, how to taking scientific comprehensive control and management to increase biodiversity, improve soil fertility, enhance the benefit of soil and water conservation, currently, is still a major problem. Visibly, it is an important scientific and practical significance to carry out species selection, diversity restoration, soil properties improvement, and soil and water conservation.

2 VEGETATION RESTORATION

Vegetation restoration is repairing or reconstruction damaged or destroyed forests and other natural ecosystems in order to restore its biodiversity and ecosystem function, through the protection of existing vegetation, forest closing, artificial reforestation (Song 2001; Yu and Pen 1996; Peng 1996). Vegetation restoration, vegetation reconstruction, biodiversity restoration, biotechnology control engineering are basically the same meanings which are not only a control technique, also is the process of control and ultimate goal (Cheng et al. 2006). In order to achieve the purpose of vegetation restoration in soil erosion areas, the problems of soil water shortage, soil nutrient poor, drought resistance plants breeding, must be firstly solved (Yang 1998). *Pinus massoniana* planted in hilly regions where soil barren and soil water shortage, was poor growth, in addition to man-made destruction, the biotope of vegetation further be destroyed.

For maintaining and transforming of the woodland productivity, protection and development biodiversity, ensuring the stability of forest ecosystem, the mixed forest of different species should be energetically advocated and developed. Stable and sustainable forest ecological system not only contains a wide variety of trees, but also contains multiple vegetation structures. Understory is an important part of forest ecosystem diversity, which plays an important role in promoting soil nutrient cycling and holding soil fertility. Therefore, floristics of understory and quantity are important ecological indicators to measure the effects of different species on ecological environment. Shrubs and grasses can increase forest biodiversity, at the same time, also weaken the raindrop kinetic energy, prevent the raindrop splash erosion, intercept runoff, promote nutrient cycling and improving soil structure. According to the survey, the mean maximum water holding rate of some shrub species was about 40%, and that of some grasses was about 57% (Zeng et al. 2006). In order to improve the benefit of soil and water conservation, the restoration of species diversity and ecological function must be carried out in degraded *Pinus massoniana* woodland. In recent decades, in order to realize the vegetation restoration of degraded *Pinus massoniana* woodland, the governments have been implementing a lot of projects, and many scholars have been carrying out a large number of researches, all of these provide basis for further improving the ecological function of *Pinus massoniana* woodland.

3 MEASURES OF VEGETATION RESTORATION

There are two mainly ways to restore the forest vegetation diversity, one is to rely on natural itself repair capacity and the other is the artificial ecology restoration. The former is mainly closed forest to facilitate afforestation so that the forest vegetation are not man-made destroyed. And this way is suitable for remote mountainous areas where economic backwardness. The latter is applied to severely degraded woodlands which cannot restore by itself in short-term and the dense woodlands which need to develop understory vegetation. In these forests, appropriate artificial tending can accelerate vegetation restoration rate and increase the forest biodiversity.

3.1 Closed Forest to Facilitate Afforestation

Closed forest to facilitate afforestation is the way of forbidding artificial cutting firewood and grazing activities within a certain period, by this way, strong resistance species make full use of the advantages of hydrothermal condition in the area to rapid reproduction and achieve ecological restoration (Guo 2000). The way is an effective ecological restoration measure for degraded *Pinus massoniana* woodland. By taken this way, degraded woodland can restore multilayer structures (contained tree layer, shrub layer, grass layer and moss layer) to play a good function of soil and water conservation (Lin et al. 1995). But through closed forest, the natural restoration abilities of different degraded *Pinus massoniana* woodlands were different. The survey found that the degraded *Pinus massoniana* community, which vegetation cover is more than 30% and organic matter is more than 0.5%, can be restored through closed forest. Nevertheless, vegetation cover is less than 30% or general degraded *Pinus massoniana* community can be restored through closed forest, fertilizing and tending management measures. But severely degraded *Pinus massoniana* community must take dibbling, fertilization and planting trees to restore the ecological communities (Guo 2000). Different degraded *Pinus massoniana* woodlands through closed forest for six years, the tree canopy density and the coverage of shrub and grass can increase 2-4 times (Qin et al. 1998). After a natural closed forest for fourteen years, the tree species in *Pinus massoniana* community of Dinghu Mountain increased from four types to seven types and biodiversity index increased with 2.6 times (Fang and Peng 1995). Closed forest measure low cost and its soil and water conservation benefit well, but it often conflicts with local sideline development. Thence, in accordance with specific conditions, different ways of closed forest can be taken.

3.2 Tending with Forest Thinning

The forest thinning is one of the measures of cultivating forest, also is one of the methods of getting woods. Thinning operation of dense stand is an important part of forest management. Because of weak illuminance, understory vegetation exiguous, after reasonable thinning, the illuminance in the forest enhance that is propitious to the vegetation restoration and development of forest system. Studies have shown that the forest thinning was multiple effects on the vegetation restoration of *Pinus massoniana* woodland. In artificial *Pinus massoniana* woodland, with increasing thinning intensity (10%-70% thinning intensity), the trees growth improved, understory vegetation restored, forest productivity increased gradually (Lin 2003; Tong et al. 2009). But the unreasonable thinning methods resulted in the destruction of forest system and serious soil erosion. But the unreasonable thinning methods result in the destruction of forest system, poor soil properties and serious soil erosion (Lin 2004). So, when taking thinning operation, there should be retained the appropriate proportion of trees in soil erosion-prone areas, especially the retention of broadleaf trees (Huang and Yang 2004). Arevalo et al. believed that the 50% thinning intensity was advantageous to the vegetation restoration of artificial coniferous forest (Arevalo and Fernandez-Palacios 2005). But how to determine a reasonable thinning intensity in the management of *Pinus massoniana* woodland should be studied further. Thinning intensity cannot be quantified based solely on cutting the number of trees. Besides it also should consider the initial planting density, site conditions, the number of thinning times, and other factors (Zhuang 1995; Lin 2004).

4 VEGETATION RESTORATION PATTERNS

4.1 Adaptable Species Selection

The factors, including different growth conditions of *Pinus massoniana*, different natural conditions, soil developed

from different parent materials, determine the importance of species selection in vegetation restoration of degraded woodland. In particular, species selection should not only pay attention to the adaptability of the species to the soil, but also the roles of its improving soil properties and controlling soil erosion (ma and zha 2008). Different plants have different the ecological and biological characteristics and their requirements for growing conditions are various. Only well-grown plants can achieve vegetation restoration and played their soil and water conservation benefit. So, the success of vegetation restoration depends largely on the species selection (wang 2000). Experimental study (yao et al. 2005) in degraded *Pinus massoniana* woodland in Granite erosion regions had selected the shrubs (e.g., *Lespedeza bicolor*, *Lespedeza cuneata*, *Gardenia jasminoides*, *Castanea seguinii*, *Querceuls fabri*, *Vitex negundo*) and grasses (e.g., *Paspalum notatum*, *Eragrostis pilosa*, *Panicum bisulcatum*, *Sorghum sudanense*, *Paspalum dilatatum*, *Paspalum orbiculare*, *Hemerocallis citrina*, *Geissaspis stylosanthinae*, *Setaria glauca*, *Setaria palmifolia*). The fine grasses, *Paspalum notatum*, *Eragrostis pilosa*, *Lolium perenne*, *Cynodon dactylon*, *Eremochloa ophiuroides*, *Paspalum wettsteinii* and *Sorghum sudanense*, can be suitable for the vegetation restoration in the quaternary red soil area (wang et al. 2008). *Coriaria nepalensis*, *Verbena officinalis* and *Arundo donax* were the fine plants in Eastern hilly region of Hunan province (she et al. 2002). In low hilly red soil region, *Choerospondias axillaris*, *Schima superba* and *Liquidambar formosana* were suitable for interplant (yang et al. 2009). *Michelia macclurei* was the fine plant for interplant in coastal upland (zhang et al. 1993; chen 2004). And in eroded hilly lateric red soil area, *Castanopsis hystrix* was an excellent plant for interplant (liu et al. 1999). In addition, *Castanopsis lamontei* and *Castanopsis sclerophylla* were also can improve soil properties of *Pinus massoniana* pure woodland (Liu et al. 2004). However, China vast in terrene, natural conditions diverse and social environments varied, vegetation patterns of the forest ecological system must be different. When selection plants and collocation are in different regions, vegetation community structure and ecosystem succession should be first considered. Only reasonable vegetation selection and collocation can achieve good ecological environmental benefits.

4.2 Ground Vegetation to Controlling Soil Erosion

In the *Pinus massoniana* woodland serious soil erosion, ground vegetation restoration is the first task to control soil erosion. Due to ground vegetation can grow fast and cover the soil surface, in forest ecosystem reconstruction, it has been paid attention (Liang 2000). Ground vegetation restoration is a kind of biological measures. If it is used together with engineering measures and fertilization technology, the water and soil conservation benefits could be better. In Changting county of Fujian province, the fast method of ground vegetation restoration in degraded *Pinus massoniana* woodland was horizontal ditch tillage, using base fertilizer, sowing mixed grass seeds which were *Digitaria sanguinalis*, *Setaria glauca*, *Paspalum orbiculare*, *Magnolia multiflora*. After seedling emergence, fertilizer was used. In the second year, grasses covered all the ground (Zeng 2003). The mixed turf of *Vetiveria zizanioides* and *Paspalum notatum* were strip planted, then farm manure and compound fertilizer were used. In less than a year, grass coverage reached 85%. This method achieved the purpose of controlling soil erosion (Chen 2005). In sparse *Pinus massoniana* woodland of Southern Granite Region, the *Pinus elliotti*, *Schima superba*, *Liquidambar formosana*, *Lespedeza bicolor*, *Paspalum notatum*, were planted with alien earth and fertilized cake fertilizer, and dug horizontal ditch. In the same year, soil and water conservation benefit was very obvious (He et al. 2003).

4.3 Planting Grass to Promote the Tree Growth

Planting drought-barren resistant grass in the degraded *Pinus massoniana* woodland is an effective measure to promote other plants growth. The grass, more tillers and plexiform growth, can effectively disperse, postpone, weaken the runoff and reduce the soil erosion. Planting grass in degraded woodland can improve soil properties and microclimate conditions which provide favourable conditions for the tree growth. The grass more easily and fast covers ground than shrub and tree. And it is more important that planting grass accords with the succession theory of vegetation community (zhang and zhong 1991). In young or sparse woodland, planting grass, especially legume forage, can significantly promote tree growth and shorten the time of canopy closure, improve soil productivity (zhao and li 1996). So, planting grass in degraded woodland is very important to promote the growing of the Small Aged Trees. Studies have shown that planting grass for three years in degraded *Pinus massoniana* woodland can increase tree height with 1.9 times, 1.2 times crown diameter, and reduce soil erosion 91% (huang 2007). Through planting *Neyraudia reynaudiana*, the diversity of plant populations was greater than the similar woodland closed

forest for 15 years. This artificial interference vegetation succession time was only about 1/3 of the natural succession time (Liao 2005). It is thus clear that in pure woodland, ground no protection, serious soil erosion, soil properties poor, these factors must influence the vegetation growth. Grass woodland, not only high biodiversity, but also good soil properties, besides, the soil and water conservation benefit is obvious.

4.4 Combination of Tree-Shrub-Grass

A reasonable collocation of tree-shrub-grass is the basis of exerting the highest ecological function of plant community. Planting *Lespedeza bicolor*, *Quercus fabri* and *Paspalum notatum*, combined with suitable soil and water conservation engineering measures, are effective measures to control intensive erosion of *Pinus massoniana* woodland in red soil region (Guo et al. 1998). Some Studies had shown that in degraded sparse *Pinus massoniana* woodland, coverage less than 30%, taking combination of tree-shrub-grass measure, excavating horizontal ditch, fertilizing bio-organic fertilizer, in the same year, soil erosion amount can be reduced 2800 t/km², grass coverage is up to 85%, soiling grass yield 320 t/hm², sprouting growth 50 cm (Zeng and Yue 2004). In the ecological environment benefits, biomass and soil conservation benefit of tree-shrub-grass pattern are greatest in various combination patterns. Ecological benefit of various patterns are tree-shrub-grass pattern > shrub-grass pattern > tree-shrub pattern > tree-grass pattern > pure tree pattern. Compared with pure tree pattern, soil erosion amount of Combination patterns (tree-shrub-grass pattern, shrub-grass pattern, tree-shrub pattern and tree-grass pattern) were reduced 74.9%, 65.6%, 62.5% and 61.6% (Li et al. 2007; Dai et al. 1995). Therefore, the more complex ecological community structure, the more stable ecological function, the better soil and water conservation benefit.

5 THE ECOLOGICAL BENEFITS OF VEGETATION RESTORATION

5.1 Increasing Biodiversity by Controlling Stand Density

Biodiversity is an important indicator of measuring ecosystem stability, and also an effective indicator of reflecting community structure and function. So, woodland of single species should be taken biological and engineering measures to restore its biological diversity. But single vegetation density too high will inhibit the survival and development of other species, also lead to a decline of biodiversity. In the development of *Pinus massoniana* woodland, the stand density influences biological diversity. The study showed that with the increasing of stand density of *Pinus massoniana*, mean tree height, surface coverage and biomass decreasing, the viability of understory also declining (huang 2009). In *Pinus massoniana* woodland of middle density (1800 plants/hm²), abundant species of shrub layer, large biomass, complex structure, the soil properties better than that of dense or sparse woodland (kang et al. 2009). When the stand density is too sparse, biomass and nutrient accumulation of the whole system dropped, and species increasing rate reduced (li et al. 2009). Therefore, dense or sparse stand density is disadvantage to the development of understory biodiversity. A reasonable afforestation density can increase the diversity of forest vegetation, enhance the ability of resisting outside interference, and can play a good ecological environment benefit.

5.2 Improving Soil Properties

The relationship between soil and vegetation is closely related. Soil is an essential environment factor for forest plant growth, which provides the necessary moisture and nutrients for the growth and development of forest plants. On the contrary, the emergence and succession of forest vegetation also influence the soil development, such as improving soil properties. Consequently, one of the aims of vegetation restoration in degraded woodland is to improve soil properties. In degraded *Pinus massoniana* woodland, carrying out closed forest pattern, tree-shrub-grass pattern, mixed broadleaf-conifer pattern and planting grass pattern, the water stable aggregates content (>0.25 mm), soil dispersion rate, soil anti-erodibility had been improved to some extent. In the four patterns, the effect of closed forest pattern was most obvious (yang et al. 1996). The mixed patterns of *Pinus massoniana* and *Castanopsis kawakamii*, *Cyclobalanopsis myrsinaefolia*, *Michelia macclurei*, *Cunninghamia lanceolata*, respectively, the soil water retention and soil porosity of former two were better than that of later two. Soil organic matter, total nutrient content, available N and P content of former two were high (li 2010). *Castanopsis kawakamii* can improve the soil physical properties in 0-40cm of degraded *Pinus massoniana* woodland, and *Michelia macclurei* can improve the properties in 40-60cm

(Lin et al. 2004). Stand density also influenced on soil properties. Too dense stand density, the non-capillary porosity, capillary porosity, total porosity in 0-40cm soil layer increased. While, soil organic matter, total N, total P, hydrolysable N and available P decreased (Huang 2009). By 45% thinning intensity in too dense woodland, the organic matter, total N, total P, hydrolysable N, available P, available K increased by 14.5%, 41.30% and 74.14%, 11.55%, 33.37% and 16.19%, respectively. Soil water content and soil moisture storage increased by 13.61% and 10.50% (Lin 2003). In addition, traditional controlled burning for afforestation will lead to significantly reducing of soil organic matter, total N, available N and P, compared with zonal cutting vegetation for afforestation, the contents of these indicators were reduced by 102%, 157%, 81% and 57%. Meanwhile, water stability of soil aggregate deteriorated, soil structure more easily damaged, humus layer completely washed (Cai 1999).

5.3 Improving Water Conservation Capacity

Regulatory function on hydrological process, mainly reflects on the capacity of vegetation and soil on controlling rainfall, including vegetation interception, the water holding capacity of living mulch and litter, the soil permeability and the water-holding capacity of the soil. According to the study of *Pinus massoniana* woodland, the throughfall accounted for 76.70% of the total atmospheric precipitation, canopy interception 23.03% and stem-flow 0.27% (Cui et al. 2005). If no understory, all the throughfall will fall to ground. Contrarily, the throughfall is again intercepted by understory, finally litter absorption and interception, the throughfall will be greatly reduced. The species and amount of litter play an important role in the water conservation function. The maximum water holding capacity of litters in different woodlands is different. The maximum water holding capacity of undecomposed layer in *Pine-Oak* mixed woodland was 3104 g/kg, in *Quercus variabilis* pure woodland it was 2865 g/kg, in *Pinus massoniana* pure woodland it was 2211 g/kg. The maximum water holding capacity of the semi-decomposed layer was 2527 g/kg, 2492 g/kg, 2015 g/kg, respectively (Zhang et al. 2003). Therefore, in the immature timber, the water holding capacity of litter in mixed conifer and broadleaved woodland was greater than that of pure broadleaf or coniferous woodland. The amount of litter is one of the important indicators to reflect the water holding capacity. The annual amount of litter in *Pinus massoniana* pure woodland was 3.44 t/hm². But after interplant *Michelia macclurei*, *Castanopsis fissa*, *Castanopsis sclerophylla*, *Castanopsis kawakamii*, *Cyclobalanopsis myrsinaefolia*, *Castanopsis lamontei*, the annual amount of litter were increased to 7.14 t/hm², 6.74 t/hm², 8.04 t/hm², 7.15 t/hm², 7.53 t/hm² and 6.15 t/hm² (Sun 2005). Forest soil is a water storage device and regulator in forest ecosystem. After closed forest, total water holding capacity was 1717.872 t/hm², it was 219.112 t/hm² greater than the control. The water holding capacity of understory was 24.722 t/hm², it was 27.2 times of the control. The water holding capacity of 0-40 cm layer was 1693.15 t/hm², it was 196.21 t/hm² higher than the control (Lin and Xie 2003). Therefore, the woodland with complex vegetation structure has a strong hydrological regulatory function.

5.4 Controlling Soil Erosion

Vegetation can intercept rainfall, regulate runoff, reinforce soil mass, improve soil properties, and play important roles in controlling soil erosion. But different vegetation structure has different effects on soil and water conservation. In the four patterns, tree-shrub-grass pattern, tree-shrub pattern, tree-grass pattern and pure tree pattern, the benefit of tree-shrub-grass pattern is the best. Its soil erosion amount was the 1/3 of tree-shrub pattern, the 1/5 of pure tree pattern, while, runoff was the 1/3-1/2 of tree-grass pattern, the 1/10 of barren hill (Yang et al. 2001; Li et al. 1995). Interplant *Pinus elliottii*, *Dalbergia balansae*, *Lepedeza bicolor*, *Digitaria sanguinalis*, the runoff was reduced by 50%-60%, soil erosion amount decreased 80%-90% (Feng 1990). After the improvement of degraded *Pinus massoniana* woodland through tree-shrub-grass, in the first four years soil loss amount decreased by 8%-19%, in fifth or sixth year decreased by 43.55%, in seventh year reduced by 99% (Peng et al. 2007). In vegetation restoration process, usually combined engineering measures in order to ensure the effectiveness of restoration and processes. However, the effects of different engineering measures on soil erosion are different. By fish-scale pits afforestation, compared with barren hill, whole reclamation and Banded reclamation afforestation, the mean soil loss amount was lower 15.2%, 76.2% and 46.7%, respectively (Liang et al. 1997). Thus it can be seen that in the management of degraded woodland, reasonable vegetation selection and engineering measures can effectively control soil erosion, promote vegetation growth and ensure the success of ecological restoration.

6 SUMMARIES AND PROSPECTS

Soil erosion is directly related to the ecological security of the country. Serious soil erosion, the focus of ecological deterioration, has become one of the most prominent problems in the ecological environment of our country. As one of the main measures to prevent and control soil erosion, vegetation plays an important role in ecological environment reconstruction. So the most serious problem in the soil erosion area of ecological environment reconstruction is the problem of vegetation restoration. In recent decades, many scholars studied ecological restoration of degraded *Pinus massoniana* woodland, proposed many ecological restoration theories, summarized a large number of practical experiences which provided a scientific basis and reference for the future studies. Through the review and analysis of the studies on degraded *Pinus massoniana* woodland, the vegetation restoration has been paid more and more attention. It is concluded that there are several contents must be further researched:

(1) The barrier factors of vegetation restoration in degraded woodland. Vegetation restoration of degraded woodland has been practiced for many years in the world, and its theories and methods have been greatly developed. However, vegetation restoration involved extensive contents, only in a comprehensive understanding of forest vegetation structure, function, dynamic change, and site environment, to explore the mechanism of the forest vegetation restoration can be possibility. In the vegetation restoration of degraded *Pinus massoniana* woodland, the various factors of influencing vegetation growth and development must be considered. Such as soil, interspecific competition, environmental change and stress, plant physiological characteristics, climate and human activities. In China, vast territory, regional difference obvious and complicated natural conditions, the barrier factors of vegetation restoration in different regions are different. To find out the barrier factors can direct the vegetation restoration of different regions. In addition, it is important to reveal the degraded mechanism of *Pinus massoniana* woodland.

(2) Integrated technology of vegetation restoration. Vegetation restoration of degraded *Pinus massoniana* woodland has been the focus of many scholars. They did a lot of studies on methods, patterns and ecological environment effect, also put forward the suitable patterns for vegetation restoration of degraded woodland in different regions. But less detail information about the ratio of vegetation composition, mixed way, density control, community structure configuration are recorded, there is no control measure system of degraded *Pinus massoniana* woodland in different site conditions. The promotion of restoration technology is also lack. Strengthening integration of ecosystem restoration technology will be beneficial to reliability and success of the vegetation restoration.

(3) Spatial-temporal monitoring of vegetation restoration. Most conventional vegetation restoration studies were based on a sample survey, which was limited by time and space, causing less information obtained. Secondly, the survey method and indicators by different researchers were not unified and the lack of systematic, which made it difficult to compare benefit of vegetation restoration in different regions. The development of 3S technology enables the development of study methods of vegetation restoration, expanding study scales in the time and spatial. Currently, canopy layer information is easily captured by remote sensing. It is mature and reliable method to estimate coverage of tree, shrub and grass in the planar scale. However, for the degraded *Pinus massoniana* pure woodland easy to form “Floating Green”, only the canopy layer information cannot fully reflect the actual situation of woodland. Integrated vegetation parameters of tree-shrub-grass in vertical scale can be used to evaluate the ecological environment of woodland. In recent years, the development of new sensors, such as laser radar, laser altimeter and multi angle strabismus optical sensor, can be used for the measurement of the vertical structure of vegetation, which provides new technical method for the vegetation studies.

(4) Quantitative study on soil erosion of woodland. Because of the special environment, long term lopping in some regions led to the thin canopy layer. Additionally, lack of understory, it is easy to form a “Green Umbrella” effect, and occur serious soil erosion in the woodland. In 2005, during the comprehensive scientific investigation of soil erosion and ecological safety in China, the “Soil Erosion in Woodland” also is put forward. For example, in Southern China, the mean coverage of 8 provinces was 52.9%, some even more than 70%, but there were still serious soil erosion in woodland. Therefore, besides vegetation restoration, but also to strengthen the quantitative studies of soil erosion in woodland. In various soil erosion assessment models, the canopy coverage is selected as vegetation parameter, which not considered the structure of tree-shrub-grass. The “Green Umbrella” effect in degraded *Pinus massoniana* woodland makes it difficult to exactly assess erosion. The quantitative studies on the effect of different

vegetation structural layers on soil erosion can provide the necessary correction parameters to assess soil erosion.

ACKNOWLEDGMENT

The study work was supported by the Zhejiang Provincial Natural Science Foundation under Grant No. Y14E090019 and Provincial Specialized Program for the Institutes of Zhejiang Province under Grant No. 2014F50015.

REFERENCES

- [1] Arevalo JR and Fernandez-Palacios JM. 2005. From *Pinus* plantations to natural stands. Ecological restoration of a *Pinus canariensis* Sweet, *Ex Spreng* forest. Plant Ecology. 181: 217-226
- [2] Cai MS. 1999. Effect of soil and water conservation of different afforestation methods. Fujian Soil and Water Conservation. 12(3):43-44 (in Chinese)
- [3] Chen KL. 2004. Selection and cultivation system for mixed forests of *Pinus massoniana* Lamb and *Michelia macclurei* Dandy. Forestry Prospect and Design. (2):9-11 (in Chinese)
- [4] Chen ZB. 2005. Rehabilitation of eroded granite mountainous region and its eco-environmental effects. Fuzhou. Fujian Normal University (in Chinese)
- [5] Cheng DB, Cai CF and Sun YY. 2006. The review of vegetation restoration researches. Subtropical Soil and Water Conservation. 18(2):24-26 (in Chinese)
- [6] Cui HX, Zhang ZW, Chen YS, Zhang ZY and Wen XS. 2005. The hydrological and ecological effect of the *Masson's Pine* in Lianxiahe Watershed of Three Gorges Reservoir Area. Journal of Central South Forestry University. 25(2):46-49 (in Chinese)
- [7] Dai YX, Xu PG, Zou ZH, Liu X and Huang JL. 1995. Study on vegetation restoration technology in purple hilly eroded area. Journal of Central South Forestry University. 15(2):184-189 (in Chinese)
- [8] Fang W and Peng SL. 1995. Changes of tree species in the succession process of *Pinus massoniana* community in Dinghushan, Guangdong, P.R. China. Journal of Tropical and Subtropical Botany. 3(4):30-37 (in Chinese)
- [9] Fang XR, Zhou LS and Huang JS. 1999. Soil erosion and its countermeasures in the hilly granite area of southwest Fujian: a case study of Hetian Township in Changting County. Soil. 31(4):175-178 (in Chinese)
- [10] Feng WT. 1990. Experiment of soil erosion control used mixed vegetation pattern. Jiangxi Forestry Science and Technology. (1):21-22 (in Chinese)
- [11] Guo XM, Niu DK, Lin YQ and Huang XH. 1998. Restoring technique of vegetation on eroded red soil in Jiangxi and benefits from its comprehensive harnessing. Research of Soil and Water Conservation. 5(2):108-112 (in Chinese)
- [12] Guo ZM. 2000. Study on the ways of recover and restoration for degraded community of *Pinus massoniana*. Forestry Science & Technology. 25(6):1-3 (in Chinese)
- [13] He GQ, Huang CB, Cao JZ, Ma CB, Huang XR and Li BP. 2010. Study on soil physical and chemical characteristics of *Pinus massoniana* plantations in dry-hot valley of the northwest Guangxi. Journal of Anhui Agriculture Science. 38(3):1610-1613 (in Chinese)
- [14] He JY, Huang YL and Zhen QM. 2003. The rapid vegetation cover technology of the weathered granite erosion land in the southward. Jiangxi Hydraulic Science & Technology. 29(4):195-196 (in Chinese)
- [15] Huang DY. 2009. Undergrowth vegetation and soil properties of *Pinus massoniana* with different densities. Protection Forest Science and Technology. (2):21-23 (in Chinese)
- [16] Huang JH and Yang LL. 2004. Study on effect of cutting model of *Masson Pine* and *Schima Superba* mixed forest on soil fertility. Protection Forest Science and Technology. (2):7-8 (in Chinese)
- [17] Huang QH. 2007. The management and utilization of the grass planted in forest land returned from farmland. Guizhou Animal Science and Veterinary Medicine. 31(4):49-50 (in Chinese)
- [18] Kang B, Liu SR, Cai DX and Lu LH. 2009. Effects of *Pinus massoniana* plantation stand density on understory vegetation and soil properties. Chinese Journal of Applied Ecology. 20(10):2323-2331 (in Chinese)
- [19] Li GL, Liu Y, Lu RH, Yu HQ and Li RS. 2009. Responses of understory vegetation development to regulation of tree density in *Larix principis-rupprechtii* plantations. Journal of Beijing Forestry University. 31(1):19-24 (in Chinese)
- [20] Li LH. 2010. Soil Water retention & soil fertility of mixed forest of *Pinus massoniana*. Protection Forest Science and Technology. (4):36-38 (in Chinese)
- [21] Li SC, Liu XL, Liu XQ and Shi YH. 1995. Study on biomass and hydrological effect of *Pinus massoniana* forest. Central South

Forest Inventory and Planning. (3)26-29 (in Chinese)

- [22] Li XX, Zuo CQ, Yao YC and Fan MH. 1997. Research on the optimization of vegetation stratum structure in the granite soil eroded region. *Research of Soil and Water Conservation*. 4(1):202-207 (in Chinese)
- [23] Liang HW, Huang CB, Su Y and He SZ. 1997. Preliminary study on the effect of soil and water conservation of *Pinus massoniana* forest in engineering measures. *Journal of Plant Resources and Environment*. 6(1):29-34 (in Chinese)
- [24] Liang X. 2000. Discussion on approaches to the quick eco-environment construction of degenerated land in south China. *Research of Soil and Water Conservation*. 7(3):142-144 (in Chinese)
- [25] Liang Y, Yang X, Pan XZ, Zhang B and Shi DM. 2008. Characteristics of soil erosion in hilly red soil region of Southern China and its prevention countermeasures. *Soil and Water Conservation in China*. (12):50-53 (in Chinese)
- [26] Liao BS. 2005. Analysis on the forest bio-diversity of after plantation of *Neyraudia reynediana* in the strong serious soil erosion area. *Subtropical Soil and Water Conservation*. 17(3):30-32 (in Chinese)
- [27] Lin DX, Fan HB, Su BQ, Liu CH, Jiang ZK and Shen BG. 2004. Effect of interplantation of broad-leaved trees in *Pinus massoniana* forest on physical and chemical properties of the soil. *Acta Pedologica Sinica*. 41(4):655-659 (in Chinese)
- [28] Lin HZ. 2004. Effect of harvesting systems on vegetation and soil fertility of *Pinus massoniana*. *Protection Forest Science and Technology*. (1):8-9 (in Chinese)
- [29] Lin KM, Luo FP, Zheng YS, Wu ZX and Zhang SL. 1995. Study on conservation capacity of water in Masson Pine community among closed forest. *Journal of Fujian College of Forestry*. 15(3):262-266 (in Chinese)
- [30] Lin WL and Xie JS. 2003. Study on rehabilitation of water conservation function of *Masson Pinus* growing on severe eroded red soil and managed through grazing ban. *Soil and Water Conservation in China*. (11):27-29 (in Chinese)
- [31] Lin XL. 2004. Study on tending and thinning intensity of *Pinus massoniana*. *Journal of Fujian Forestry Science and Technology*. 34(Z1):22-23 (in Chinese)
- [32] Lin YL. 2003. Effects of thinning degree on the growth and soil fertility of *Pinus massoniana* plantation. *Protection Forest Science and Technology*. (3):16-17 (in Chinese)
- [33] Liu SZ, Ao HX, Xia HP, He DQ, Jiang LS and Dai WH. 1999. Eco-benefits from improving the pure *Pinus massoniana* forest in an eroded hilly laterite red soil area. *Tropical Geography*. 19(3):118-212 (in Chinese)
- [34] Ma ZY and Zha X. 2008. Research on ecological recovering of erosive degraded *Pinus massonian* woodland in red soil region of Southern China. *Research of Soil and Water Conservation*. 15(3):188-193 (in Chinese)
- [35] Mo JM, Sandra B, Peng SL, Kong GH, Zhang DQ and Zhang YC. 2002. Role of understory plants on nutrient cycling of a restoring degraded pine forests in a MAB reserve of subtropical China. *Acta Ecologica Sinica*. 22(9):1407-1413 (in Chinese)
- [36] Peng SL. 1996. Restoration ecology and vegetation reconstruction. *Ecologic Science*. 15(2):26-31 (in Chinese)
- [37] Peng ZH, Yuan ZK, Kuang JJ, Yuan SB, Fan SP and Wu WW. 2007. The influence of vegetation resume process on erosive volume of red soil in the hill. *Research of Soil and Water Conservation*. 14(5):356-358 (in Chinese)
- [38] Qin GF, Rong WC, Jin GQ and Hong W. 1999. A study on soil erosion in Masson Pine young stand. *Scientia Silvae Sinicae*. 35(Sp.1):29-33 (in Chinese)
- [39] Qin TA, Gao DJ, Long YM, Ma DW and Nong YF. 1998. Study on Masson Pine of closed forest in Heng County. *Guangxi Forestry Science*. 27(3): 122-128 (in Chinese)
- [40] She JY, Zeng SQ and Cai H. 2002. Study on the recovery of the ecological function and the vegetation under the forests of the low-effect water and soil conservation forests of Masson Pine I. The optimized management patters of the recovery techniques. *Central South Forest Inventory and Planting*. 21(2):1-3 (in Chinese)
- [41] She JY, Zeng SQ, Li ZH, Lv Y and Chen LM. 2002. The transform and management model of low-quality low-effect *Pinus massoniana* secondary forest in the hills in the east of Hunan province. *Hunan Forestry Science & Technology*. 29(1):6-9 (in Chinese)
- [42] Song YC, eds. 2001. *Vegetation ecology*. Shanghai. East China Normal University Press (in Chinese)
- [43] Sun X. 2005. Effects of planting hardwood species under the canopy of Masson's Pine stand on the forest litter and soils. Fuzhou. *Fujian Agriculture and Forestry University* (in Chinese)
- [44] Tong LL, Xu XG, Guan QW and Tang GG. 2009. Effects of thinning on the community structure of *Pinus massoniana* plantation in Wuxiang Temple Forest Park, Lishui County. *Journal of Jinling Institute of Technology*. 25(1):70-73 (in Chinese)
- [45] Wang WM. 2000. Study on approaches to vegetation restoration on sloping field in southeast parts of Fujian province. *Research of Soil and Water Conservation*. 7(3):138-141 (in Chinese)
- [46] Wang ZY, Zuo CQ, Yang J, Yu RG and Li XQ. 2008. Study on the selection and evaluation of grasses for soil and water

- conservation in the red soil area. *Pratacultural Science*. 25(5):87-91 (in Chinese)
- [47] Yang H, Liu GZ, Yue JW, Zhu H, Zhang HY, Long W and Luo YC. 2009. Tree species selection for forests form transformation of the deteriorated *Pinus massoniana* forests in red soil low hilly area. *Jiangxi Forestry Science and Technology*. (6):1-6 (in Chinese)
- [48] Yang YP and Li CB, eds. 1992. *Forest in Sichuan*. China Forestry Publishing House (in Chinese)
- [49] Yang YS, He ZM and Ling Y. 1996. Effect of different control model on antierodibility of seriously deteriorated red soil. *Journal of soil erosion and soil and water conservation*. 2(2):32-37 (in Chinese)
- [50] Yang YS. 1998. Study on restoration of biodiversity in eroded quaternary red clay region (ii). Key technology and sustainable development. *Research of Water and Soil Conservation*. 5(2):82-86 (in Chinese)
- [51] Yang ZJ, Xu DP, Liu YL, Pen YQ and Wang WM. 2001. Effects of planting models on soil and water control. *Soil and Environmental Sciences*. 10(4): 293-296 (in Chinese)
- [52] Yao YC, Li XX and Zuo CQ. 1997. Study on suitable plants in granite erosion area. *Soil and Water Conservation in China*. (11):16-20 (in Chinese)
- [53] Yu ZY and Pen SL, eds. 1996. *Study on vegetation restoration ecology in tropical and subtropical degraded ecosystem*. Guangdong Science and Technology Press (in Chinese)
- [54] Zeng HS and Yue H. 2004. Main model of vegetation recovery in granite severe soil erosion area centering the Hetian Township of Changting County. *Fujian Soil and Water Conservation*. 16(4):16-18 (in Chinese)
- [55] Zeng HS. 2003. Influence of planting grasses on vegetation diversity of Masson Pine trees area. *Soil and Water Conservation in China*. (1):26-27 (in Chinese)
- [56] Zeng SQ, She JY, Xiao YT, Lv Y, Deng XW and Tang DS. 1996. Quantitative study of Hydrologic functions of *Pinus massoniana* forest I. Canopy interception and soil water storage capacity. *Journal of Central-South Forestry University*. 16(3):1-8 (in Chinese)
- [57] Zha X, Huang SY and Lin JT. 2003. Effect of conifer problem on soil microbial characteristics. *Journal of Soil and Water Conservation*. 17(4):18-21 (in Chinese)
- [58] Zhang HJ, Chen JH, Shi YH, Qi SL, Chen Y, Pan L and He F. 2003. Reserves and water capacity characteristics of three kinds of litter of Three Gorges Area. *Journal of Soil and Water Conservation*. 17(3):55-58 (in Chinese)
- [59] Zhang JW, Liao LP, Li JF and Su Y. 1993. Litter dynamics of *Pinus massoniana* and *Michelia macclurei* mixed forest and its effect on soil nutrients. *Chinese Journal of Applied Ecology*. 4(4):359-363 (in Chinese)
- [60] Zhang SG and Zhong CZ. 1991. Conserving soil and water with grasses in the lead and in combination of trees with shrubs. *Bulletin of Soil and Water Conservation*. 11(2):8-12 (in Chinese)
- [61] Zhang TL, Shi XZ and Zhang Q, eds. 1999. *Cause, process and mechanism of soil erosion and degradation*. Beijing. China Agriculture Press (in Chinese)
- [62] Zhang WM and Wang XX. 2010. Characteristics of soil acidification and primary study of biological mechanism of typical forest plantation in subtropical China. *Soil*. 44(6):1021-1028 (in Chinese)
- [63] Zhao FX and Li GQ. 1996. Current advance of tree-grass complex system researches. *Journal of Northwest Forestry College*. 11(4):81-86 (in Chinese)
- [64] Zhao QG, eds. 2002. *Temporal-spatial variation, mechanism, regulation of soil degradation in red soil region of Eastern China*. Beijing. Science Press (in Chinese)
- [65] Zhou ZX, eds. 2001. *Pinus massoniana in China*. Beijing. China Forestry Publishing House (in Chinese)
- [66] Zhuang CH. 1995. Study on quantitative thinning of *Pinus massoniana*. *Forest Science and Technology*. (6):20-22 (in Chinese)

AUTHORS



Mr. Li Gang, Born in 1985, graduated from the Institute of Soil Science, Chinese Academy of Sciences in 2012. His major is soil and water conservation and desertification control, major interests are soil erosion and its environmental effects, watershed comprehensive management and its benefit evaluation, soil erosion monitoring technology.

He is serving in the Institute of Soil and Water Conservation, Zhejiang Institute of Hydraulics & Estuary, and the Department of Environment Engineering, Zhejiang Guangchuan Engineering Consulting Co., Ltd. Email:happyglove@126.com