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PIONEER PLANTS FOR ECOSYSTEM RECOVERY IN DRAINAGE BASIN OF ERLONGSHAN RESERVOIR IN HEILONGJIANG PROVINCE, CHINA

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ABSTRACT: This article reveals the ecological features and the theories and methods of introducing pioneer plants in the process of eco-restoring in different degenerative ecosystems in the drainage basin of Erlongshan Reservoir in Heilongjiang Province by systemically studying the deteriorative ecosystems and using recovery theory. The study shows that with the rise in degenerative degrees of the ecosystems, bio-species and bio-diversity sharply decrease in the study area and microclimate becomes warmer and drier in natural ecosystem. Therefore, we must attach importance to the construction of plants and biodiversity. In the study, different pioneer plants are selected for different degenerative ecosystems to restore and maintain the service functions of the ecosystems.
KEY WORD: degenerative ecosystem; pioneer plants; biodiversity

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1 INTRODUCTION

The kernel study of sustainable development in the controlled basins of reservoirs focuses on recovery and reconstruction of degenerative ecosystems. In view of frequent and great fluctuation and function decline of degenerative ecosystems, it is indispensable to recover the structure and function of the ecosystems. In the courses of recovery and reconstruction of degenerative ecosystems, the primary stage of recovery succession is to construct initiative ecosystems. The success of establishing ecological landscape depends on the selection and disposition of pioneer plants. The research on recovery and reconstruction of degenerative ecosystem becomes more and more universal. However, we have not deeply studied pioneer recovering plants, especially in Heilongjiang Province, which have placed emphasis on cutting the forest other than breeding in forest management in a long period so that the environment degenerated in a serious way. What′s more, it taked blind eyes on tree planting and afforestation, as a result, the survival rate of nursery stock is usually low. To provide theoretical foundation for the recovery and reconstruction of degenerative ecosystem in Heilongjiang Province, this article picks out pioneer recovering plants as a studying target.

2 STUDY AREA

The drainage basin of Erlongshan Reservoir, with an area of 275.5km^2, was selected as the study area, which is located in Binxian County of Heilongjiang Province, and is 56km away from the east of Harbin City. The region is located in the south margin of the east mountainous region in Northeast China, filled with hill and mountain land. The natural vegetation is made up of the temperate needle-broad-leaved mixed forest, and the soils are mainly the dark brown soil, black soil and meadow soil. Generally speaking, the region belongs to the temperate continental monsoon climate.

The basin possesses the functions of flood control, water supply and tourism and plays non-displaceable and special role in the development of economy and society of Binxian County. In the recent years, however, under the pressure of population increase, irrational utilization of resources, environment degeneration, and the decline of the carrying capacity of environment, the sustainable development of study area has confronted

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the challenges of reservoir sedimentation, decrease of water-holding capacity, water pollution, intensification of eutrophication, and exacerbation of ecological environment, etc. Forest coverage in drainage basin of Erlongshan Reservoir has dropped from 78% in the 1950s to 31% at present, certainly resulting in long and profound negative effect (HUA *et al*., 2002).

3 DEGENERATIVE ECOSYSTEMS OF DRAINAGE BASIN OF ERLONGSHAN RESERVOIR

3.1 Types of Degenerative Ecosystems

On the basis of vegetation map, soil, age of stand and vegetation coverage, as well as characteristics of natural environment and with the combination of qualitative and quantitative method, the drainage basin of Erlonshan Reservoir can be divided into four degenerative ecosystems (Table 1, Fig. 1).

(1) Light degenerative region (LDR) refer to the natural stands in sub-mature or over-mature phases with high coverage, being mainly distributed in faraway mountain and nearby watershed, and accounting for 23.3% of the whole basin area.

(2) Moderate degenerative region (MDR) refer to natural secondary forest that lies in mid-faraway mountain and tourist regions with larger man-made influence than LDR, which are mostly mid-mature forest and occupy 39.7% of the whole basin area.

(3) Severe degenerative region (SDR) mainly refer to the regions near dwelling center, nearby mountains, as well as lessive tableland with severe man-made damage, low vegetation coverage, serious loss of soil and water, low natural productivity of plant, and worse ecosystem stability, which take 5.2% of the whole basin area.

(4) Recovering degenerative region (RDR) mainly refer to the spacious plantations mostly in sapling phase. Though the sapling plantations have played some roles in improving water and soil and ameliorating environment, it is lower in biodiversity and feebler in ecosystem functions than natural forests for its much simpler configuration (horizontal and vertical). However, it can become a special region as supplement of the studies on natural ecosystems and it constitutes 8.1% of the whole basin area.

Table1 Divide indices of different degenerative regions

	Coverage of forest (%)	Soil	Age of stand	Topographical type	Area percentage (%)
LDR	80–90	Dark brown forest soil	Mature	Mountain	23.3
MDR	70–80	Dark brown forest soil	Middle mature	Mountain	39.7
SDR	10–30	Lessive soil, litho soil	–	Mesa	5.2
RDR	70–80	Dark brown forest soil	Immature	Mountain	8.1
Farmland	–	Black soil, meadow soil	–	Plain	22.8
Reservoir	–		–	–	2.4

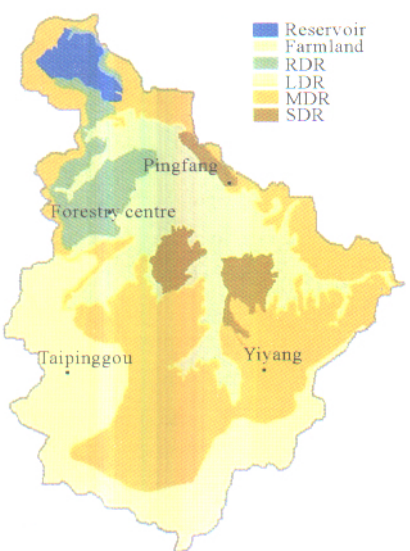

Fig. 1 Different degenerative regions of Erlongshan Reservoir

3.2 Plants and Microclimates in Different Ecosystems

Plants and microclimates were investigated in Taipinggou as a representative of LDR, Yiyang as a representative of MDR, Pingfang as a representative of SDR, and Erlongshan forestry centre as RDR. The results of investigation on plants are all averages of hilltop, hillside, piedmont and valley in each spot except plantation. The investigated areas are 20m×20m×1 for arbor, 10m×10m×1 for shrub, and 1m×1m×5 for herb in each habitat.

According to Table 2, the plant communities are obviously different in different degenerative ecosystems and the complexity of community and species and in general amount of arbor, shrub and herb all show as LDR>MDR>SDR, but the community of RDR, an artificial *Larix dahurica* community of 20 years old, is

special for its simple structure, high coverage equaling to that of MDR, no secondary shrub but 18 species of herbs, obviously higher than MDR.

Environmental function is different in different degenerative ecosystems. The function of plant community in different degenerative regions can be reflected by microclimate index that is average results investigated at 0.5m and 2m high from ground and 5 times a day in 5 days (Table 3). The results show it is obvious that relative humidity decreases, while temperature and wind speed increase, microclimate becomes warmer and drier, water-holding capacity of ecosystem goes down and intensity of soil erosion goes up gradually from LDR to MDR to SDR. Indices of environmental function are better in RDR community than in MDR community, while RDR is the highest in temperature and relative humidity among the four ecosystems, which may result from being close to reservoir.

4 ECOSYSTEM RECOVERY OF DRAINAGE BASIN OF ERLONGSHAN RESERVOIR

4.1 Principles of Degenerative Ecosystem Recovery

To recover degenerative ecosystem, a new ecosystem should be built by using a number of various plants according to the law of succession of natural vegetation and the genetic characteristics of ecosystem (ZHAO and PENG, 2001). The selection of pioneer plant species should depend upon the purpose of recovery. To protect and supervise endangered species, we should consider the long-term effect of incoming species on them, while, to recover functional mechanism of community, we should focus on recovery of ecological functions of community.

The selection of species for recovering communities should depend on the function types of the degenerative ecosystem. To recover windbreak function, the selected species should grow fast with plentiful fiber and strong physical resistance, and some proper under-layer shrub should be add too; to recover soil and water-holding function, herbages with tolerance to poor soil, strong nature to fix sand and soil should be selected first; to recover man-made vegetation with the effect of purifying environment, the species should have physiological ecology characteristics of anti-pollution; to recover high productive vegetation, heliophytes species with fast growth and strong renewal ability are preferred frequently; to recover natural landscape, selection of species and constructing modes of community will be complicated, the native species with different growth forms are often mixed and deployed. In brief, different ecology function types decide selection of species and reconstructing modes of different communities.

Table 2 Biodiversity of ecosystems in different degenerative regions

	Arbor		Shrub		Herb		Renewal layer		Total
	Species	SDI	Species	SDI	Species	SDI	Species	SDI	species
LDR	15	4.79	8	5.03	39	8.13	12	6.98	62
MDR	6	5.86	4	3.39	14	5.08	2	3.71	24
SDR	1	1.00	5	3.22	9	3.10	1	1.00	15
RDR	1	1.00	0	0.00	18	6.14	0	0.00	19

Note: SDI represents Simpson Diversity Index

Table 3 Microclimate indices in different degenerative regions

	Temperature		Relative humidity		Wind speed	
	2m	0.5m	2m	0.5m	2m	0.5m
LDR	5.14	4.98	64.6	66.7	3.46	3.27
MDR	5.60	5.50	57.8	63.8	3.63	3.58
SDR	5.84	5.76	55.1	59.5	4.32	3.66
RDR	6.10	6.32	75.7	77.6	3.95	2.88

4.2 Selection of Pioneer Plants for Different Degenerative Ecosystems

Research on recovery ecology has found that the recovery velocity of ecosystem is significantly influenced by pioneer species in initial phase of succession. For example, Fabaceous plants are often taken as pioneer species in the recovery of degenerative ecosystem in the south of China (LIU and HE, 1993) for its higher net photosynthesis velocity and biological characteristic of root nodule′s fixing nitrogen which are able to accelerate the input of energy and substance to the system and make a favorable primary phase of syngenesis, further, distinctly improve microenvironment in shorter time and create conditions for invasion of subsequent species, consequently, accelerate the course of syngenesis. Therefore selecting proper pioneer species is a key link of ecologi-

cal recovery course. From comparative studies on plant communities and two ecological demonstration areas in the east bank of Erlongshan Reservoir and Lishugou, different pioneer plants have been selected for different degenerative regions in the basin.

4.2.1 Light degenerative regions

These regions present good phase of natural secondary forest and favorable environmental conditions to meet the need of development of native *Pinus koraiensis* and broad-leaved mixed forest, but valuable species such as *Pinus koraiensis* and other broad-leaved species have already disappeared due to successive cutting. Recovery of LDRs is relatively easy, and two methods are often adopted. The easy and economical one is to enclose the whole mountain. After five to ten years of natural recovery of standing seed sources, diversity of plant species will increase markedly. The investigation on the regions such as Dazhujuan enclosed for 5 years and Taipinggou enclosed for 10 years shows that the enclosure promotes the recovery of ecological function of plants, but spontaneous recovery of economic plants and high quality trees is slower. For example, there are 13 plant species with 10cm to 3m in height in renewal layer in Taipinggou such as *Acer mono*, *Acer tegmentosum*, *Quercus mongolica* etc., so it can be seen that there is a strong recovery mechanism in LDRs. However, conifer species such as *Pinus koraiensis* with superior economic value and hard-broad-leaved species (such as *Phellodendron amurense*, *Fraxinus mandsdurica*, *Juglans mandshurica*) are less, *Pinus koraiensis* appeared only 2 times and 3 individuals in the investigation. The other is to spread seeds of high quality species or transplant saplings of the superior species, such as *Pinus koraiensis*, and so on, to make them renew, and to plant *Picea koyamai*, *Abies nephrolepis*, *Larix dahurica* etc. in valley for reducing bad influence of cold lake on vegetation (LI, 1991). Thus, the earlier investment, the earlier income, moreover, both ecological and economic benefit can be got.

4.2.2 Moderate degenerative regions

As a result of long-term human interference, the species and amount of plants distinctly reduce in the MDRs. Then hierarchical structure of community is simplified, coverage reduces and ecological function degrades evidently (productivity, water-holding capacity, ability to regulate climate and environmental carrying capacity, etc. all decline obviously). Investigation on plants in tourism regions shows that arbor is apparently lower and species or amounts of plants are less than that of near-ripe woods. Due to low vegetation coverage, weak water-holding capacity, and decreasing ground cover, selection of pioneer plants in the MDRs should be as follows: the species enduring drought and barrenness as *Quercus mongolica*, *Ulmus macrocarpa*, *Armeniaca sibirica*, etc., should be selected for the relatively dry top of mountain, *Ulmus propinqua*, *Tilia mandshurica*, *Maackia amurensis*, and *Acer mono* for hillside, *Acer mono*, *Tilia mandshurica*, *Fraxinus mandshurica*, *Juglans mandshurica*, *Tilia amurefsis*, etc. for piedmont, and conifer species as *Picea koyamai*, *Abies nephrolepis*, *and Larix dahurica* for valley.

4.2.3 Severe degenerative regions

As a result of frequent and violent human interference, natural vegetation has been damaged severely in the SDRs. Thus, selection of pioneer plants should be different according to the types of SDRs.

In the rocky mountainous area around Pingfang, the drought- and barrenness-enduring species, usually living in warmer and drier regions, would be suitable for its thin dark brown soil layer, of which organic matter and moisture content are very low. The pioneer shrub species should be *Hippophae rhamnoides*, *Lespedeza bicolor*, *Sorbaria sorbfolia*, *Crataegus pinnatfida*, etc. While the pioneer arbor species should be *Quercus mongolica*, *Ulmus macrocarpa*, *Maackia amurensis*, etc. The enclosure is also important for vegetation recovery in these regions. The investigation shows that many herbs as *Artemisia scoparia* and *Artemisia sacrorum* formed herbage covering layer quickly after returning farmland to forestland or grassland in infertile mountainous area, which makes favorable conditions for lessening erosion by water and wind and accumulating organic substance.

For the slope farmlands being cultivated, which cannot forever, or cannot recently return to forest or grassland, shrubbery network paralleling with contour line should be constructed in the convex slope. The pioneer species should be *Lespedeza bicolor*, *Hippophae rhamnoides*, *Rose davurica*, etc. with high economic value. These species are shorter and would not shade peripheral crops, but can greatly promote the fixation of soil and windbreak. The study shows that loss of soil and water has declined after the deployment of vegetation for protecting slope by combining arbor (*Populus Simonii*, *P. nigra*), shrub (*Lespedeza bicolor*, *Rose davurica*) with herb (*Medicago falcata*) in ecological demonstration area in the east to reservoir. The research on recovering plants of erosion gully shows that shrub barrier should be formed in all regions around erosion gully, while planting of *Larix dahurica* in erosion gully will assist soil and water conservation, then, original erosion gully will be blockaded and riveted by plants

gradually unless there is deep erosion of cloudburst in one or two years after transplanting. The research on Xiaoyushugou proved that the method is effective.

In the farmlands of lessive tableland, with low fertility and bad structure of soil, crop output is low due to extensive cultivation, and soil erosion is severe as a result of tableland terrain. Because there exists a hard lessive layer in lessive soil, it is difficult for most plants to penetrate into the layer by roots. Therefore, straight-rooted and deep-rooted *Pinus sylvestris* and all kinds of barrenness-eduring shrub species should be planted in this region after returning the farmlands to forestlands.

4.2.4 Recovering degenerative regions

RDRs mainly occupy hills and mountains. The simple forest phase reduces heterogeneity in community and internal environment capacity of community (space and style of niche). Monotonous landscape incurs hidden calamities of fire or insect and community instability. Therefore, the selection of pioneer species in the RDRs should focus on increase of heterogeneity of community structure and function. The countermeasures are as follows: first, plantation in cutover lands should be dominated by high economic value conifer matched by heliophilous pioneer species as poplar, birch and so on. The research on soil animals shows that species and amount of soil animals in temperate artificial larch forest are obviously less than those of mixed broadleaf-conifer forest. And the amount of soil animals influences circulation of materials of forest ecosystem directly (ZHANG, 2001). Second, inseminating or planting valuable shrubs in existing pure forest after thinning trees, for instance, developing *Acanphopanax senticosus* below larch forest can not only obtain visible economic benefit and biggish ecological effect but also enhance resources utilization efficiency greatly (ZHU, 1996).

During recovery succession of degenerative ecosystems, many uncertain disturbing factors often appear as species invasion and habitation, etc. Allowing for ecology recovery is a dynamic course with the changes of pioneer plants being concordant with the development of system succession, supervisors should take proper species into community at the right moment to accelerate development of system by the way of direct succession. Consummation of system structure will certainly enhance its function, and actualize the purpose of ecology recovery gradually.

REFERENCES

HUA De-zun, LI Chun-yan, ZHAO Mei-wei, 2002. The eco-environment present status and construction of Erlongshan reservoir watershed [J]. *Research of Environmental Sciences*, 15(3): 11–12. (in Chinese)

LI Jun-qing, 1991. The effect of mountainous temperature inversion on the vertical distribution and growth of the forests [A]. *Long-term Located Research on Forest Ecosystems* [C]. Harbin: Northeast Forestry University Press. 504–511. (in Chinese)

LIU Hong-jie, HE Yi-geng, 1993. Field planting experiment on the amelioration of erosion soils with tropical pioneer plants [A]. In: *Utilization and Protection of the Biological and Soil Resources* [C]. Beijing: Science Press. 186–191. (in Chinese)

ZHANG Xue-ping, 2001. Soil animal guilds and their ecological distribution in the northeast of China [J]. *Chinese Journal of Applied and Environmental Biology*, 7(4): 370–374. (in Chinese)

ZHAO Ping, PENG Shao-lin, 2001. Species and species diversity in relation with restoration and persistence of degraded ecosystem function [J]. *Chinese Journal of Applied Ecology*, 12(1): 132–136. (in Chinese)

ZHU Ning, 1996. The heterogeneous habitat influence on the seed germination of *Acanthopanax senticosus* and its seed pool dynamic [J]. *Acta Ecologica Sinica*, 16(4): 408–413. (in Chinese)