The Impact of the Three Gorges Hydroelectric Project on and the Preservation Strategies for the Biodiversity in the Affected Region

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(Received February 14, 1995)

ABSTRACT

The impact of the Three Gorges Hydroelectric Project on the plant diversity in the reservoir region was assessed based upon field surveys of the plant species and vegetation surrounding the reservoir area that will be influenced by this project. The reservoir area harbors known higher plants (except Bryophytes) of 190 families, 1012 genera, 3012 species (including 29 sub-species, 286 varieties and 16 forms). Of which, 37 endemic species can only be found in the reservoir region, 47 species, including 22 endangered species, 20 rare species and 5 threatened species, have been listed in the "Plant Red Data Book of China". Vegetation types in the reservoir area, except for those found in the cultivated land, have 89 formations. The coniferous forests are most widely distributed, while broadleaf evergreen forests are only scattered in the central parts of the mountain. The plants belonging to 120 families, 358 genera and 550 species that are at present distributed under the flooded line (185 m) in the reservoir will be affected by the project, based on their current distributional range from the established database. Moreover, 27 community types in the potentially flooded area will be eliminated from the area as well, since the original habitats of some species will be destroyed after the reservoir is filled with water. Flooding will directly lead to the extinction of species and community types in the reservoir region unless preservation strategies are to be taken. Even if it is assessed solely based on the loss of natural vegetation and the destruction of the habitats that are currently cultivated, the economic loss caused by flooding will be severe.

Key words biological diversity, Three Gorges Hydroelectric Project, preserving strategies, impact of the hydroelectric project

1 Introduction

On April 3, 1992, the People's Congress of China finally passed a bill on the construction of the Three Gorges Hydroelectric Project. This project was planned as part of economic and social development program to be implemented during the next 10-Year Plan. Therefore, the evaluation studies on building the Three Gorges dam was finally completed, and the biggest hydroelectric project in the history of China came to an operation stage. The Three Gorges dam project has won a world-wide attention since its initial stage. For instance, many international organizations and internationally-known experts were involved in the proposal preparation, site investigation and the final evaluation of this project. Various institutions and organizations carried out detailed studies

and gathered a certain amount of information (Jin et al, 1983; Jin et al, 1984; Chen, 1991). The Chinese Academy of Sciences (CAS), on behalf of the State Science and Technology Commission of China, coordinated a project entitled "Study on Impact of the Three Gorges Hydroelectric Project on Ecological Environment and the Possible Strategies for Action". This study lasted for 5 years. The first phase of this study was to answer whether the dam would benefit the environment. The second phase was to gather fundamental background information and to look for long-term strategies as regard to the sustainable development and conservation of the Yangtze River region and its environments. In terms of terrestrial plant conservation, the purpose of the study reported in this paper was designed to look for ways by which the natural and man-managed vegetation, species diversity and endangered plants could be conserved.

The Three Gorges region is rich in plant species diversity, since this area was merely affected by the Quaternary Glacier. Therefore, many relic plants are kept here, along with many endemic plant species and genera (Zheng, 1984; Ying et al., 1984). Since the early 1880s, this area has received wide attention of the Chinese and foreign botanists. Henry, A (1885~1888); Wilson E H (1900, 1907, 1909), Faber E (1887) and Silvestri R (1904~1907) and some famous Chinese botanists came here to collect plant specimens (Bretschneider, 1962).

This paper is to discuss the results of a detailed survey of the plant species diversity, community types along the Yangtze River, to identify the region's higher plant species, vegetation types, and to evaluate the impact of this project on species diversity and vegetation types.

2 The natural environmental conditions in the reservoir region

The reservoir region includes the 19 counties and cities that will be affected by the project. This region is located at the longitude of E 106°~111°50', latitude of N 29°16'~31°25', the eastern end is Yichang City of Hubei Province and the western end is Baixian of Sichuan Province (Figure 1).

The Yangtze River rises in rugged mountains on the northern border of Tibet. It flows 6300 kilometers eastward to enter the Pacific Ocean in Shanghai. Situated on about two-thirds of the way to Shanghai is a spectacular stretch, 200 kilometers long, called the Three Gorges. There the river bisects three mountain ranges. The south of the reservoir is Wushan mountain and Qiyaoshan mountain with an altitude of 1000~1500m. The north of the reservoir is Daba mountain. The central reservoir is paralleled terraces and forms paralleled valleys of eastern Sichuan. Wold, hill terrace and plain cover 67.7%, 29.5% and 0.9%, respectively, of the total reservoir area (Chen, G, 1991). The climate of reservoir area is characterized by warm winter and dry spring, hot and dry summer, abundant precipitation in autumn, high humidity and foggy weather, which is typical of the humid subtropical monsoon type. The annual mean temperature is 15~19°C, and the annual precipitation ranges from 1000~1200mm. The rainfall from April to October occupies over 80% of the annual precipitation, and hot summer occurs from July to August.

Main soil types of the reservoir region are yellow soil, red loam, yellow brown soil, brown rendzima, black rendzima, rice soil and alluvial soil. Some brown soil, dark

Fig. 1 The map of the Three Gorges Reservoir region.

brown and mountain soil types exist at higher elevation of the mountains.

The region lies in the northern part of the sub-tropical zone, and has mild climate and abundant rainfall. All the climatic features are suitable for many plants to grow. Since the Quaternary Glacier had a little impact on the flora of the Three Gorges region, this area became a refuge for plants in the Tertiary period, keeping many relic plants and endemic species (Zheng, 1984; Ying et al., 1984). Therefore, the Three Gorges region is one of the key areas for biodiversity conservation (Chen, L., 1993).

The long history of human activities and natural disaster has a significant influence on the region, especially the rapid expansion of population. The natural vegetation has been severely damaged and serious soil erosion has taken place. At present, the forest coverage is only 19.5% (closed canopy forest 14.9%) in the reservoir, therefore, the Three Gorges region is also an area with severely degraded ecosystems.

3 *Methods of study*

From 1984~1990, Institute of Botany, Wuhan Institute of Botany, Chendu Institute of Biology of the CAS undertook a series of studies on plant species and community diversity in the reservoir region. The research contributed greatly to the basic understanding of the plant communities, plant species, rare and endemic species, and to the evaluation of the impact of the project on the local flora.

The database of plants in the reservoir region was established based on field investigations. The Three Gorges plant database includes the species' Chinese name, Latin name, family, distribution, geographic distribution, elevation, geographic component, habitat, utilization purpose and reference. Index analysis was carried out by different aims. By screening plants distributed below 200m elevation, species that would suffer from flooding could be identified. The field work data were used for the analysis of the

response of the vegetation to the dam construction. Seventeen transects were laid out along the river side from western end, Baxian to eastern end, Yichang. The width of each transect was 10m, vertical to river flow direction up to 200m. 10×10m quadrat was used as a unit for measuring height, DBH and canopy relative coverage of plant species.

4 Results

4.1 Species diversity

Established plant species database provides a full account of 190 families, 1012 genera, 3021 species (29 sub-species, 286 varieties and 16 forms) of known higher plants (except mosses) available in the reservoir region. The total number of the species is 10.28% of the entire plant species, or 9.85% of the seed plants in China (Table 1).

Table 1 Flora of the Three Gorges Reservoir region.

	Family	Genus	Species	Subspecies	Variety	Form
Pteridophyta	26	51	115		5	2
Gymnospermae	9	25	42		6	
Angiospermae						
Dicotyledoneae	138	767	2081	25	249	14
Monocotyledoneae	17	169	443	4	26	
Total	190	1012	2681	29	286	16

Features of species in the reservoir region are: (1) Plants of Compositae, Rosaceae, Gramineae and Liliaceae are dominant, occupying 21.48% of all plant species. (2) Many relic plants can be found. These relics include *Metasequoia glyptotroboides*, *Liriodendron chinense*, *Cathaya argyrophylla*, *Pseudolarix amabilis*, *Cercidiphyllum japonicum*, *Cyclocarya paliurus*, *Davidia involucrata*, and *Tetracentron sinensis*. (3) Components of flora are very complicate. The flora consist of 31.9% tropical, 26.97% temperate elements, 40.99% of species endemic to China, 0.97% of the species endemic to the Three Gorges region, and some Mediterranean, central Asia and cosmopolitan species. (4) Rich in endemic and endangered species. Three plant families—Bretchniidae, Davidiaceae and Eucommiaceae are endemic to China, which are widely distributed in the area. The Three Gorges reservoir region is one of the three centers for endemic plants in China, namely south-Sichuan and west-Hubei center (Ying, 1984). 47 species listed in the Red Data Book of China, including 22 vulnerable species, 20 endangered species and 5 rare species, are identified. The criterion for classification is set according to international standards and also based on individual situation of the listed species (Table 2). A total of 37 endemic species are only found in the reservoir region (Table 3). *Adiantum reniforme* var. *sinensis* is listed as an endangered species and an endemic to the reservoir. Great attention should be paid to the conservation of endangered endemic species with respect to the impact of the Three Gorges Project.

Table 2 Rare, endangered and vulnerable plant species distributed in the Three Gorges Reservoir region.

Species	Family	Distribution in Three Gorges Reservoir region	Status	Elevation (m)
1. <i>Ophioglossum thermale</i>	Ophioglossaceae	Chongqing, Changshou	V	600~1200
2. <i>Adiantum reniforme</i> var. <i>sinensis</i>	Adiantaceae	Wanxian, Shizhu	E	150~380
3. <i>Alsophila spinulosa</i>	Cyatheaceae	Chongqing	V	400~900
4. <i>Cephalotaxus oliveri</i>	Cephalotaxaceae	Yichang, Xingshan, Zigui	V	1000
5. <i>Abies chensiensis</i>	Pinaceae	Badong	V	1300~2100
6. <i>Cathaya argyrophylla</i>	Pinaceae	Wulong	R	900
7. <i>Picea brachytyla</i>	Pinaceae	Badong, Xingshan, Zigui, Wushan	V	1400~2000
8. <i>Picea neobeitchii</i>	Pinaceae	Badong, Xingshan	E	1500~2000
9. <i>Pseudolarix kaempferi</i>	Pinaceae	Wanxian	R	1000
10. <i>Pseudotsuga sinensis</i>	Pinaceae	Wanxian, Fengjie	V	900~1200
11. <i>Amentotaxus argotaenia</i>	Taxaceae	Xingshan, Wuxi, Shizhu	V	700~1200
12. <i>Metasequoia gluptostroboides</i>	Taxodiaceae	Shizhu	R	1000~1200
13. <i>Dipteronia sinensis</i>	Aceraceae	Badong, Yichang, Xingshan, Wushan, Wuxi	R	800~1900
14. <i>Dysosma versipellis</i>	Berberidaceae	Badong, Yichang, Xingshan, Wushan, Wuxi	V	500~2100
15. <i>Corylus chinensis</i>	Betulaceae	Zigui, Wulong Badong, Yichang, Xingshan, Wulong	V	900~2200
16. <i>Bretschneidera sinensis</i>	Bretschneideraceae	Chongqing	R	500~1000
17. <i>Heptacodium miconioides</i>	Caprifoliaceae	Xingshan	V	600~1000
18. <i>Cercidiphyllum japonicum</i>	Cercidiphyllaceae	Badong, Yichang, Xingshan, Wuxi	R	1000~1900
19. <i>Eucommia ulmoides</i>	Eucommiaceae	eastern Sichuan, western Hubei	R	700~1400
20. <i>Juglans regia</i>	Juglandaceae	Badong, Yichang, Wushan, Zigui	V	1400~1700
21. <i>Phoebe bournei</i>	Lauraceae	Xingshan	V	400~1000
22. <i>Phoebe zhenan</i>	Lauraceae	Yichang, Xingshan, Zigui	V	400~1000
23. <i>Glycine soja</i>	Leguminosae	Xingshan	V	300~1300
24. <i>Ormosia hosiei</i>	Leguminosae	Chongqing, Yichang	V	350~900
25. <i>Liriodendron chinense</i>	Magnoliaceae	Badong, Wanxian	R	650~1000
26. <i>Magnolia officinalis</i>	Magnoliaceae	Badong, Yichang, Xingshan, Zigui	E	300~1700
27. <i>Euryocrymbus cavaleriei</i>	Sapindaceae	Xingshan	R	800~1000
28. <i>Sinowilsonia henryi</i>	Hamamelidaceae	Fengdu, Wanxian, Shizhu	R	1100~1350
29. <i>Manglietia patungensis</i>	Magnoliaceae	Badong	E	700~1000
30. <i>Tetracentron sinensis</i>	Magnoliaceae	Badong, Yichang, Xingshan	R	1100~2000
31. <i>Davidia involucrata</i>	Nyssaceae	Badong, Xingshan, Wushan, Wuxi	R	1000~1600
32. <i>Davidia involucrata</i> var. <i>vilmoriniana</i>	Nyssaceae	Badong, Yichang, Xingshan, Wushan	R	1400~1900

(Continued)				
33. <i>Coptis chinensis</i>	Ranunculaceae	eastern Sichuan. Western Hubei	R	1000~2000
34. <i>Berchemiella wilsonii</i>	Rhamnaceae	Xingshan	E	900~1200
35. <i>Emmenopterys henryi</i>	Rubiaceae	Badong, Yichang, Xing- shan, Wushan, Wanxian	R	600~1400
36. <i>Tapiscia sinensis</i>	Staphyleaceae	Badong, Yichang, Xingshan, Fengjie, Wanxian, Shizhu	R	600~1400
37. <i>Pterostyrax psilophylla</i>	Styraceae	Badong, Yichang, Xingshan	V	1000~1800
38. <i>Camellia grijsii</i>	Theaceae	Yichang	V	150~500
39. <i>Stewartia sinensis</i>	Theaceae	Badong, Yichang, Xingshan, Wushan	V	900~1900
40. <i>Euptelea pleiospermum</i>	Trochodendraceae	Badong, Yichang, Xingshan, Wanxian, Fengjie, Wushan	R	700~1800
41. <i>Pteroceltis tatarinowii</i>	Ulmaceae	Badong, Xingshan, Zhigui	R	500~800
42. <i>Trillium tschonoskii</i>	Liliaceae	Badong, Wushan, Wuxi, Wanxian	V	800~2200
43. <i>Changnienia amoena</i>	Orchidaceae	Wushan, Wanxian, Zhongxian, Shizhu	R	740~1300
44. <i>Gastrodia elata</i>	Orchidaceae	eastern Sichuan, Western Hubei	V	1200~2150
45. <i>Ginkgo biloba</i>	Ginkgoaceae	Cultivated	R	300~1100
46. <i>Dimocarpus longan</i>	Sapindaceae	Cultivated	V	70~900
47. <i>Litchi chinensis</i>	Sapindaceae	Cultivated	V	70~800

Table 3 Plant species endemic to the Three Gorges Reservoir region.

Species	Family	Distribution	Elevation (m)
1. <i>Adiantum remiforme</i> var. <i>sinense</i>	Adiantaceae	Wanxian, Shizhu	80~430
2. <i>Plagiogyria caudifolia</i>	Plagiogyriaceae	Chongqing	800
3. <i>Tsuga chinense</i> var. <i>robusta</i>	Pinaceae	Badong	1800
4. <i>Salix michiotricha</i>	Salicaceae	Xingshan	900~1700
5. <i>Salix polyclona</i>	Salicaceae	Xingshan, Badong	2100~2600
6. <i>Pilea rubriflora</i>	Urticaceae	Yichang	1210
7. <i>Stellaria henryi</i>	Caryophyllaceae	Badong	1020
8. <i>Berberis julianae</i> var. <i>batungensis</i>	Berberidaceae	Badong	1200~1800
9. <i>Mahonia confusa</i> var. <i>bournei</i>	Berberidaceae	Yichang	
10. <i>Neolitsea aurata</i> var. <i>glauca</i>	Lauraceae	Fengjie	800~850
11. <i>Sedum wilsonii</i>	Crassulaceae	Xingshan	
12. <i>Potentilla fulgens</i> var. <i>acutiserrata</i>	Rosaceae	Fengjie	
13. <i>Potentilla pendula</i>	Rosaceae	Fengjie	2600
14. <i>Padus brachypoda</i> var. <i>microdonta</i>	Rosaceae	Zhigui	840~2600
15. <i>Rubus wushanensis</i>	Rosaceae	Wushan	2000
16. <i>Stizolobium brunnescens</i>	Leguminosae	Badong	
17. <i>Flueggea leucopyrus</i>	Euphorbiaceae	Badong	2000
18. <i>Leptopus chinensis</i> var. <i>pubescens</i>	Euphorbiaceae	Yichang, Xingshan	300~900
19. <i>Securinega wuxiensis</i>	Euphorbiaceae	Wushan, Wuxi	60~250
20. <i>Myricaria laxiflora</i>	Aquifoliaceae	Badong, Zhigui, Wushan	70~150
21. <i>Ilex jinyunensis</i>	Aquifoliaceae	Chongqing	750

(Continued)

22. <i>Celastrus orbiculatus</i> var. <i>cunneatus</i>	Celastraceae	Yichang	600
23. <i>Meliosma subverticillaris</i>	Sabiaceae	Wuxi	1000
24. <i>Buxus sinica</i> var. <i>pumila</i>	Buxaceae	Badong	2100
25. <i>Acer oblongum</i> var. <i>trilobum</i>	Aceraceae	Yichang	750~1200
26. <i>Rhamnus tzechweiensis</i>	Rhamnaceae	Zhigui	700~1500
27. <i>Actinidia tetramera</i> var. <i>badongensis</i>	Actinidiaceae	Badong, Wuxi	2300~2400
28. <i>Ligusticum wuxiense</i>	Umbelliferae	Wuxi	1000~1300
29. <i>Hydrocotyle dielsiana</i>	Umbelliferae	Badong	1200
30. <i>Orthocarpus chinensis</i>	Scrophulariaceae	Xingshan	
31. <i>Pedicularis conifora</i>	Scrophulariaceae	Badong	
32. <i>Chirita fangii</i>	Gesneriaceae	Kaixian	370~1000
33. <i>Deinocheilos sichuanense</i>	Gesneriaceae	Wuxi	900
34. <i>Isometrum villosum</i>	Gesneriaceae	Shizhu	600~1600
35. <i>Lonicera mucronata</i>	Caprifoliaceae	Badong, Xingshan, Wushan	800~1500
36. <i>Neyraudia wushanica</i>	Gramineae	Wushan	185
37. <i>Smilax riparia</i> var. <i>pubescens</i>	Liliaceae	Badong	950~1600

4.2 Vegetation diversity

The reservoir lies in the North of mid-subtropical zone. The evergreen forests dominated by *Castanopsis* and *Phoebe* are zonal vegetation (Wu, 1980). The percent of forest coverage has been reduced to only 19.5% because of severe impact of human activities. Forests that have been rarely disturbed by human activities are only found at the upper parts of the mountains and only account for 30% of the total forested area. Man-made or semi-natural forests such as *Pinus massoniana* and *Cupressus funebris* types are widely distributed in the region, possessing about 60% of total forested area (40% scattered young forests). Small remnant patches of the original vegetation are only seen in the northeastern and southeastern wolds. In lowland, evergreen forests cover 0.01% of total reservoir area.

The main vegetation types, except for original agriculture fields, form 89 formations. The coniferous forest area is the biggest. *Pinus massoniana* and *Cupressus funebris* forests, which are mostly artificially planted, are widely distributed in the terrace areas that are under 1000m elevation, and are composed of acid and calcareous soil. *Pinus henryi* and *P. armandii* forests are distributed on the middle and upper parts of the mountains. *Picea neoveitchii* and *Abies fargesii* forests can be found on the submountain or upper-mid mountain. There are some distributions of *Cunninghamia lanceolata* forest. Moreover, some patchy areas of *Keteleeria davidiana*, *Metasequoia glyptostroboides* and *Cathaya argyrophylla* forests are present. The remained types of evergreen broad-leaved forest are mainly composed of *Castanopsis*, *Cyclobalanopsis glauca* and *Quercus engleriana*. *Machilus* and *Phoebe* forests are distributed in some areas. The *Castanopsis* forests mainly include *Castanopsis fargesii*, *C. eyrei*, *C. sclerophylla* types. Forests of *Quercus spinosa*, *Q. spathulata* are present in the middle part of the mountain. The dominant species of broad-leaved deciduous forests mainly include *Quercus*, *Castanea*, *Betula*, *Populus* generas. The main types are of *Quercus serrata* var. *brevipetiolata*, *Q. aliena* var. *acuteserrata*, *Q. actutissima*, *Q. variabilis*, *Castanea sepiunii*, *C. henryii*, *Betula utilis*, *B. albosinensis*, *B. luminifera*; *Populus davidiana* forests. There are some

forests of *Alnus cremastogyne*, *Platycarya strobilacea*, *Fagus* as well. The understories of deciduous broad-leaved forests sometimes own saplings of evergreen trees or evergreen shrubs.

Conifer and broad-leaved mixed forests mainly are *Pinus massoniana* and *Quercus variabilis*; *Cupressus funebris* and *Quercus variabilis* etc. There are some distribution of bamboo forests in the reservoir region, mainly *Phyllostachys pubescences*, *Ph. nigra* var. *hennis*, *Sinocalamus affinis* and shrub types of *Phyllostachy congesta* and *Sinarnnd-inaria nitida* etc.

Shrubland is an important type of vegetation, and covers 20% of the total reservoir region. The main types of shrubland are *Distylium chinense*, *Buxus sinica* var. *pumila* and *Rhododendron simsii*, *Sageretia thea*, *Myrsine africana*, *Pyracantha fortuneana*, *Cotinus coggygria*, *Loropetalum chinense*, *Vitex negunda*, *Rosa cymosa* shrub.

Grassland covers 15% of the total reservoir area. Main grass types are *Pogonatherum crinitum*, *Heteropogon comtortus*, *Imperata cylindrica* var. *major*, *Eulaliopsis binata*, *Arthraxon hispidus*, *Arundinella hirta* communities.

Vertical distribution of the vegetation in the reservoir region is not distinct due to serious impact by human activities. The analysis of remained natural vegetation demonstrates that belts of broadleaf evergreen forests, evergreen deciduous broad-leaved mixed forests, mountain conifer and broad-leaved forests and sub-mountain conifer forest are at the elevations under 1300m, 1300~2200m and above 2200m respectively. This vertical distribution is only well maintained on the southern slope of Shenglongjia mountain range in the northeastern part of the reservoir region.

4.3 Impact of Three Gorges Hydroelectric Project on plant biodiversity

4.3.1 Effect of flooding on plant species diversity

Based on results obtained by screening plants distributed under 200m elevation in the database, the flooding caused by the dam will have severe impact on the plants of 120 families, 358 genera and 550 species. In terms of the absolute quantity of the species, families of Gramineae, Compositae, Euphorbiaceae and Rosaceae will be the most affected. In terms of the severity of the impact, Sapindaceae, *Distylium* of Hamamelidaceae, *Hibiscus* of Malvaceae, *Myricaria* of Tamaricaceae, *Bauhinia* of Leguminosae, *Securinega* of Euphorbiaceae and *Neyraudia* of Gramineae will be most greatly affected. Plants distributed in the reservoir area and listed in "Red Data Book of China" are surveyed clearly for their distribution under 200m. The main distribution zone of *Adiantum reniforme* var. *sinensis* will be severely damaged and other species will not. Since the distribution of this species is not limited to the areas under 200m, therefore, if the original place above 200m is protected, flooding would not directly destroy this species totally. Off-site protection of *Adiantum reniforme* var. *sinensis* has been successfully done by the Wuhan Institute of Botany and also a successful bacteria-free cultivation has been completed by the Institute of Botany of CAS, all these have laid a good foundation for the germplasm resource conservation.

Endangered and rare species like *Ginkgo biloba*, *Dimocarpus longan*, *Litchi chinensis* have been introduced to the reservoir region historically. Species of high economic values like *Dimocarpus longan* and *Litchi* will be endangered severely by flooding. Among the 37 species endemic to the reservoir region, *Neyrara washanica* and *Myricaria laxiflora* will be severely affected by flooding. They will disappear unless off-site protection

measures are taken.

4.3.2 Effect of flooding on community

There will be 27 plant communities to be affected by flooding according to the survey results of 17 transects laid out under 200m elevation (Fig. 2). *Buxus sinica* var. *pumila* shrub, *Securinega wuxiensis* shrub and *Myricaria laxiflora* shrub will be flooded totally, while other types will be found from similar habitats. Economic loss of vegetation by flooding will be inestimable.

Fig. 2 Plant community types under 200m elevation, which will be flooded when the reservoir region be filled with water.

1. *Pinus massoniana* forest; 2. *Cupressus funebris* forest; 3. *Robinia pseudoacacia* forest; 4. *Eucalyptus* forest; 5. *Citrus* forest; 6. *Sinocalamus affinis* forest; 7. *Bamboo* forest; 8. *bamboo* shrubs; 9. *Distylium chinensis* shrub; 10. *Vitex negunda* shrub; 11. *Vitex negunda*, *Cotinus coggygria* shrub; 12. *Cotinus coggygria* shrub; 13. *Coriaria nepalensis* shrub; 14. *Indigofera ichangensis* shrub; 15. *Ficus tikoua* shrub; 16. *Rosa cymosa* shrub; 17. *Quercus aliena* shrub; 18. *Cyperus rotundus* grassland; 19. *Imperata cylindrica* grassland; 20. *Heteropogon contortus* grassland; 21. *Arundinella hirta* grassland; 22. *Arthraxon hispidus* grassland; 23. *Phragmites australis* grassland; 24. *Miscanthus sacchariflorus* grassland; 25. *Miscanthus sinensis* grassland; 26. *Saccharum arundinaceum* grassland; 27. Agriculture field.

4.4 Strategies for protection of plant biodiversity in the reservoir region

The original habitats of some species will be flooded after the reservoir is filled with water. Flooding will have severe impact on rare and endangered plants, and will directly lead to the disappearance of 3 species and 3 community types unless protection strategies are to be taken. Cares must be taken for *Adiantum reniforme* var. *sinensis* conservation. Disappearance of forests, shrublands and grasslands by flooding will lead to economic and ecological losses. Therefore, in order to minimize these influences, it is imperative that the protective forest systems have to be strengthened during the exploitation migration, otherwise, new waves of migration will again damage species, vegetation and environment in the region. Strengthening nature reserve protections and the research on the restoration of degraded ecosystems and optimized artificial ecosystems will serve for economic development. Along with building the Three Gorges dam, botanical gardens to keep rare and endangered plant species will help the off-site protection of them.

ACKNOWLEDGMENTS

This research project was financially supported through grant of 75-16-06 of State Science and Technology Commission of China. We are much indebted to Professor Jin Yixing, Mr. Jiang Mingxi and Mr. Zhang Quanfa of Wuhan Institute of Botany, Chinese Academy of Sciences and Professor Hu Dong of Capital Normal University for taking part in the field expedition, to Dr. Han Xingguo for providing valuable criticism of the draft and checking the English text.

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