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Conservation for the landscape ecological diversity in Wulingyuan scenic area of China

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Abstract: Wulingyuan is located at the mountainous area of the middle reach of the Yangtze River, it is one of the three nature heritages in China which ranks in the "List of World's Heritage" by UNESCO. It is characterized by quartz sandstone peaks landform with several landform components(pattern, corridor) and rich in landscape ecological diversity and biodiversity. The main patterns(ecosystem) include mid-height mountain peaks, rift-valley and streams among peaks, peaks and gullies on slopes, square mountain-platforms and peaks among blind valleys and so on. The corridor system consists of natural corridors and artificial corridors among which the stream corridors account for a major part. The fracturing of habitat is unfavorable for the biodiversity conservation, but meanwhile the habitat diversity leads to an increase in biodiversity. Therefore, it is still rich in landscape ecological diversity in Wulingyuan. The biodiversity at the level of landscape component(ecosystem) and the function of the Wulingyuan complex ecosystem, and the measures for the biodiversity conservation in Wulingyuan ecotourism area are discussed in this paper.

Keywords: Wulingyuan; quartz sandstone peaks; landscape ecological diversity

1 General introduction to the formation of the quartz sandstone peaks and diversity of species

By the end of the year of 2001, 28 culture and nature heritages in China have ranked in the "List of World's Heritage" by UNESCO. Among them, Taishan Mount, Huangshan Mount, Wuyi Mount, Emei Mount—Leshan Buddha are natural and cultural heritage, Lushan Mount belongs to culture landscape, while Wulingyuan, Jiuzhaigou and Huanglong belong to nature heritage. Among the latter type, Wulingyuan occupies an important part for its unique and rare large areas of quartz sandstone peaks landforms and its rich biodiversity which gives unique aesthetics and biological resources storage value to this area. At a time when tourism is flourishing in China, how to protect these valuable and precious nature heritage and cultural and natural heritage has become an important question for discussion. The key to the protection of nature heritage is conservation of natural landforms ecology and biodiversity.

Wulingyuan lies at latitude 29°16'25"—29°24'25" and is located in Zhangjiajie City, northwest of Hunan Province, covering an area of 264 km². Its core area covers from Suoxi hydroelectric power station to Zhangjiajie Mozi ravine which is the source of Suoxi Stream with a length of 19.2 km and a small watershed of 92.2 km² in which quartz sandstone peaks occupies 82.8 km². This area is situated in the north-central part of the subtropical area and belongs to inland mid-low height mountain area monsoon humid climate with an average annual temperature of 10—16°C and annual rainfall of 1400—1700 mm.

The main scenic area is a disk-shape basin, 800 meters above sea level, surrounding by peaks and hills about 1200 meters. The highest point above in this area is 1344 a.s.l. while the lowest point is only 339 meters. There are more than 3100 quartz sandstone peaks of different sizes in this area among which there are more than a thousand peaks with a relative altitude of more than 200 meters. The history of such kind of peculiar landform can be traced back to Paleozoic era(PzD) of more than 300000000 years ago. At that time this area belonged to beach area. Due to the repeated rising and sinking of the earth's crust, it kept depositing with clastic rocks which later formed quartz sandstone layer(quartz account for 90%—95%) of more than 500m which constituted the quartz sandstone base of the nowadays Wulingyuan natural scenic area. From Paleozoic era(PzP), this area has been in a swelling state and during the period between Mesozoic era(MzJ) and Mesozoic era(MzK) about 100000000 years ago when the intense Yanshanian Movement, which involved the whole mainland China, occurred, pediments of different levels have formed due to the crust folding and twisting. And owing to the ravages of wind and rain and gravitational erosion later on, the landforms of nowadays have been gradually come into being meanwhile rich landscape ecological heterogeneity and biodiversity in the scenic area have also been formed. Nowadays, 37 families and 239 species in pteridophyte, 6 families and 9 genera and 12 species in gymnosperm, 89 families and 245 genera and 471 species in angiosperm are found in this area. In xylophyta families cover more than 16 species include Lauraceae, Fagaceae, Theaceae, Caprifoliaceae, Rosaceae and Papilionaceae. Tropic genera account for 47.2% of the total while temperate genera account for 47.6% and the components of vegetation have distinctive marginal and transitional characteristics(Qi, 1992). Ancient genus and family of plant cover a comparatively larger part in this area. Some have been included in List of Plants for Conservation in China(1999) among which there are 7 species in grade one: *Davidia involucreta*, *Davidia involucreta* var. *vilmoriniana*, *Bretschneidera sinensis*, *Metasequoia glyptostroboides*, *Taxus chinensis*, *Ginkgo biloba*, *Cycas* spp.; 33 species in grade two: *Emmenopteryx henryi*, *Liriodendron chinense*, *Pseudotaxus chienii*, *Dipteronia dyerana*, *Cephalotaxus oliveri*, *Cercidiphyllum japonicum*, *Tetracentron sinensis*, *Eurycorymbus cavalerier*, *Pseudolarix amabilis*, *Pseudotsuga* spp., *Torreya* spp., *Taiwania cryptomerioides*, *Acidosasa chinensis*, *Sorghum propinquum*, *Zoysia sinica*, *Cinnamomum camphora*, *Cinnamomum longepaniculatum*, *Machilus nanmu*, *Phoebe bournei*, *Phoebe zhennan*, *Ormosia henryi*, *Ormosia hosiei*,

Kmeria septentrionalis, *magno lia officinalis*, *Magnolia officinalis subsp. biloba*, *Toona ciliata*, *Toona ciliata var. pubescens*, *Campiotheca avuminata*, *Phellodendron chinense*, *Changiosytrax dolichocarpa*, *Tilia amurensis*, *Zelkova schneideriana* and *Tricholoma matsutake*. And large quantity of lichen, bryophyte and fungus are found in this area. As for animals, there are 153 species of vertebrates among which there are 45 species of beasts, including 8 orders 21 families; 74 species of birds, including 11 orders and 28 families; 13 species of amphibians, including 2 orders and 6 families (Zhou, 1992). There are 18 species of animals for conservation in grade two, such as *Macaca mulatta*, *Moschus berezouskii*, *Tragopan temminckii*, *Andrias davidianus* and so on. In addition, about ten thousand kinds of insect specimen have been collected among which 20 orders, 133 genera and 583 species have been identified (Wang, 1992).

2 Ecological heterogeneity of patterns (ecosystem) insides the scenic area

Various landscape components (patterns, corridor) are found on the quartz sandstone base inside the scenic area, which gives comparatively, rich landscape heterogeneity to this area and various ecosystems are formed on this base. The main factor which leads to the difference in ecosystem lies in varied landforms under the influence of which various ecosystems composed of small habitat and multiple-biome are formed. Meanwhile the degree of human's conservation of landscape components and its development and utilization are also important factors, which lead to the difference in ecosystems. Each pattern forms one type of ecosystem with respective habitat and biome characteristics.

2.1 Mid-height mountain - isolated peaks pattern (ecosystem)

Quartz sandstone peaks are the most commonly seen landscape inside the scenic area, which mainly concentrate in Shadaogou and Tianzishan Mountain scenic area. The height of the stone pillars range from 100 meters to more than 200 meters, even as high as 300 meters. It is relatively flat on the top of the peaks. Various plants indomitably grow despite the thin and barren soil. Wuling pine constitutes the main groups of tree species. They are generally distributed over areas, which are more than 800 meters a. s. l. Among these pines, old trees of more than 100 years old and with more than 30 cm in chest diameter are not rarely seen. There are other superior tree species such as *Cyclobalanopsis multinervis* and *Carpinus fargesii*, and so on. On the top of the peaks, trees are distinctively undersized and the temperature on the top is 2—4°C lower than that of the bottom of the peaks. The top of the peaks has common cloud and mist, sufficient rainfall, high humidity, strong wind from all sides and abundant sunlight. This kind of peculiar eco-environment cultivates special biome which constitutes mid-height mountain-isolated peaks ecosystem. On the cliffs of the peak waist only grows lichen while on the platforms with thin and barren soil grows Wuling pine (more than 800 meters a. s. l.) and *Rhododendron Stamineum* and so on. The vegetation on the top and waist of the peaks are basically untouched original secondary vegetation, which forms landscape with unique appreciation value in perfect harmony with the peaks.

2.2 Rift-valleys and streams among peaks pattern (ecosystem)

Valleys, ravines and streams among peaks constitute a criss-cross network, which is rarely seen, even in the world with such big density and depth of cutting. The average water network density of valleys and streams is about 2 km/km² and the cutting depth ranges from 120—180m to 300—500m. It is rather humid and cool among valleys and streams with only 4—8 hours sunshine time a day, 2°C lower comparing to the area exposed to the sun of the same height a. s. l. Under such eco-environment, it is favorable for those humidity-inclined trees such as *Sloanea hemsleyana*, *Machilus Pingii* and *Tapiscia sinensis* etc. and some shade herbs and bryophyte and some peculiar animals like fish, reptiles and amphibians and so on. Ravines and streams are the main tourist passageway, which have already had standard walkway and many man-made buildings, which have attracted millions of tourists. Along the path, natural secondary vegetation is most commonly seen. The most famous and one of the best scenic area—Golden Whip Stream which is 6 km in length is attracting tourists with its fresh air and favorable climate.

2.3 Peaks and gullies on slopes pattern (ecosystem)

Stone peaks and castles spread over ravines and valleys on slopes with gradient of more than 30—60°. Despite the folded quartz stones which collapsed within ravines and the thin and barren soil, plants like *Castanopsis eyrei*, *Engelhardtia roxburghiana*, *Schima argentea*, *Cyclobalanopsis gracilis*, *Cornus controversa*, *Dendro banthamia japonica* and *Liquidambar acalycina* etc. in the form of secondary vegetation still flourish due to their indomitable vitality and the favorable humid micro-climate. On some slopes with comparatively better conditions, man-made mason pine forest. China fir forest, bamboo forest and cypress forest have been planted since the end of 1960s under which high shrubs like *Aralia chinensis*, short shrubs like *Rhododendrom*, herbs, bryophyte and lichen have already grown up. This area is the major living place for those macaques.

2.4 Square mountain—platforms pattern (ecosystem)

Square mountain-platforms are more than 800 meters a. s. l., about 300 meters in relative altitude. On the top of the platforms it is covered with near-horizontal rock layers and above which covered with red soil of about 3—5 meters in depth. Around the square mountain-platforms are cliffs consisted of rock walls and castles. The most famous square mountain in Wulingyuan is Huangshizhai, 1050 meters a. s. l. The connecting area on the top is less than 1 km² with core platform of about 0.2 km². There are also some other square mountains like Yaozizhai, Heicongnao, Yangzhai, Shuangzhai, Biantongzhai and Qingsizhai and so on. On the top of the square mountains, it belongs to the mid-mountain cold and humid climate and the earth layer is relatively thick but poor. The superior tropic tree species are mainly Wuling pine and some other trees like *Quercus phillyraeoides*, *Rhododendron Latoucheae*, *Schima argentea*, *Platycarya strobilacea* and *Rhododendron Stamineum* and so on. Artificial introduced fine varieties (1980) of trees on the top include *Cryptomeria*, *Daphniphyllum laucescens*, *Pterostyroxpsilophyll* and tea etc. grow in a favorable climate. The height of the plant community on the top is distinctively lower than that of the foot of the mountain. Moreover, there are more species of bushes, phanerophytes and herbs compared to the species of hemicyptophytes. As to those barrenness-resistant tree species with strong anti-adversity ability, they have played a very important part in conserving the bio-environment within the scenic area although their economic value

still needs to be explored. Among all the square mountains, most are untraversed while some mountains like Huangshizhai are important scenic areas.

2.5 Peaks among blind valleys pattern(ecosystem)

Embraced within the rock walls and cliffs, numerous peaks stand in the valley like forests. This kind of pattern has not been explored yet of which the most typical ones are the Xihai and Shentangwan. Nobody knows what grow at the bottom of the humid and secluded valley. At the foot of the rock columns and cliffs, there are some special species such as *Magnolia lotungensis* and *Michelia foveolata*, etc. which are humidity-barrenness resistant and belong to Magnolia family. This kind of ecosystem has special value whether from sightseeing angle or from the angle of scientific investigations.

Besides the above key patterns(ecosystems), on the edge of the scenic area there are large areas of single-sided slopes and mountain ridges, which are covered with dense vegetation. On some areas with relatively better conditions, large areas of mason pine forest and China fir forest have grown up and there are also some small areas of tea field, bamboo field and farms. Surrounded by the three major scenic areas of Zhangjiajie, Yangjiajie and Tianzi Mountain, Yuanjiajie is a non-scenic area, more than 1000 meters a.s.l., which is the carbonate rock top on the quartz sandstone has been completely covered with natural secondary forests and artificial forests. The forests coverage rate within the whole scenic area has reached 85% while the core area has reached 97%. Although the non-scenic components are of less value, they contribute a lot to the formation and conservation of the ecosystem and biodiversity in the whole scenic area. Surround the scenic area, there are some other landforms like artificial lakes between quartz sandstone columns(Baofeng Lake, Suoxi Reservoir, etc.) and carbonate rock caves(Huanglong Cave, etc.).

3 Ecological heterogeneity and functions of corridor

In the scenic areas, various kinds of corridors combine different patterns into an integrated part. Corridors inside Wulingyuan Scenic area fall into two categories; natural corridors and artificial corridors. The natural corridors mainly include stream corridors, forests corridors along the streams or between slopes and valleys, etc. while the stream corridors can be subdivided into three types; corridors which dry up during dry season and flood during rainy season, spreading over slopes; flood and seasonal spring corridors in small numbers; stream corridors with abundant water during dry season and flood during rainy season are the main type of corridors for water flow in Wulingyuan, such as Golden Whip Stream and Suoxi Stream and so on. These three types of corridors have different hydrological, species features and ecological functions. The thread-belt type forests corridors along the streams are mainly composed of humidity-resistant trees and herbs. They are often scoured by the flood when the torrents rush down the mountains. The forests corridors between slopes and valleys are irregular belt-piece type corridors, which combine the slope-valley pattern under the peaks and cliffs into a whole part.

Different types of corridors provide spaces for cross-pattern activities of various kinds of animals like beasts, amphibians, fishes and snakes and so on. They have formed a corridor system by circulation and exchange of water, minerals and organic matters etc. among them. The activities of birds are less restricted by the conditions of the corridors compared to those large-sized animals. Due to the widespread cliffs, there often appears an absence of those large-sized animals in the vertical direction of corridors, which makes ecological distinction in species on the top of the three thousand peaks. This aspect still needs more study and exploration. As to the habitat and species conditions at the bottom of the peaks among blind valleys and the attached corridors still remains a riddle. The other category of corridors——artificial corridors include various foot paths, roads and two cableways inside the scenic areas which establish the main passageway for people and vehicles. As a key natural scenic area under world protection, the construction of the artificial corridors must benefit the conservation first, then tourism benefits.

4 Influences of landscape ecological heterogeneity to biodiversity

Wulingyuan consists of landscape on the base of the highly fractured quartz sandstones. This kind of fraction is unfavorable for the biodiversity conservation, but due to the diversified habitats brought by the fraction and the irregular edges lines between adjacent patterns or the increased transitional habitats leads to an increase in biodiversity. Because of the counteraction between these two aspects, the fractured scenic area still contains relatively rich biodiversity. The shattered and dispersed habitats(patterns, corridors) inside the scenic area and the irregular shapes have restricted the numbers of species groups. In different habitats, natural biocoenosis maintained more biospecies than the artificial single biocoenosis meanwhile preserved more rare and near extinction species. For example, the rare biome which featuring in yew as its dominating tree species in the deep ravine below the Platform Bridge in Yaozizhai scenic area also preserved many kinds of rare species scattered around. Moreover, distinctive differences exist in soil biocoenosis and microflora due to the differences in soil parent rocks, soil types (from bottom to top, vertically distribute mountain yellow-red soil, yellow soil, yellow-brown soil and calcareous soil, etc.), thickness in soil layers and natural fertility, and some other big differences in vegetation status and ecological conditions like light, heat, water, air, etc. in soil. Those distinctive differences generate important influences upon biodiversity to creatures on the ground.

5 Function features of complex landscape ecosystem in scenic areas

Inside the scenic area, different habitats constitute many kinds of ecosystems with their corresponding biotic populations. These ecosystems linked with each other to compose a large complex landscape ecosystem in Wulingyuan, which is basically a natural forest ecosystem with complex habitats.

The whole scenic area of Wulingyuan belongs to natural reserve. Although there are forestry centers inside the area, they only serve for the scenic area's construction and conservation and have very small output quantity of timber. The energy flow and material flow inside the scenic area are in a natural and relatively enclosed status because of the following factors: although there are millions tourists but the energy and material they bring in and out are limited; and the main channels to output water, minerals, soil and species are the Golden Whip Stream and Suoxi Stream which go through the core scenic area.

The distinctive differences in habitats and species of different kinds of landscape components surely lead to differences in ecological process. For example, the ecosystems on the top of the mid-height peaks are just like isolated islands with relatively simple species. Under the formidable habitat conditions, the vegetations are mainly rock-bearing plants. With the low rate of photosynthesis of the plants which leads to a small amount of biomass and with small number of animal species, the decomposition rate of the dead plant is comparatively slow which result in a distinctively slow rate in the ecological process; production-consumption-decomposition and result in a small intensity of energy and material flow. As for the ecosystem of streams and gullies among valleys and peaks, the habitats has relatively better conditions which lead to more plant species and larger amount of biomass, meanwhile the faster speed of decomposition makes it the most active part in the ecological process of the whole scenic area. This type has stronger intensity in energy and material flow. As for most streams and gullies on slopes, the poor site conditions decide the inactive ecological process. For the square mountain-platform ecosystem, there are larger areas of land with cold climate, but the thickness in soil and high fertility makes richer plant species and larger biomass than that of on the top of the rock pillars, but still less than that of stream and gullies on slopes and in valleys. The better site conditions of the carbonatite cover over mountain ridges around the scenic area and the center of Yuanjiajie, despite the elevation of more than 1000 meters, leads to dense forests, which provide good ecological protection for the scenic spots in the middle of the mountain or at the bottom.

The surface water flow system is one of the most significant factors, which influence the landscape changes. This system is composed of precipitation, slope runoff and stream flow, which unite the other eco-systems as a whole, and give an universal influence upon the whole complex landscape ecosystem. Water flow is still the main impetus and channel of species dissemination of plants, fish and amphibians, and it also serves as main medium of soil nutrients flow. Water flow has distinctive seasonal features, which has the most precipitation from April to July with relatively rich quantity of heat when the plants grows fastest and the soil has its biggest drenching and dissolving quantity. However, the loss of nutrients caused by soil drenching and dissolving must be supplemented from the continuous decomposition of the dead plants and decay of the sandstones. Such loss and supplement has formed a low-level balance under natural conditions which leads to a slow increase in plant biomass. So the current relatively small biomass was accumulated through decades and hundreds of years. Moreover, the ecosystem formed under such relatively poor site conditions is rather fragile which would be hard to restore if damaged, therefore, it must be put under strict protection.

6 Conserve biodiversity from angle of protecting the landscape heterogeneity (ecosystem diversity) in the scenic area

Concerning protection of biodiversity, measures could be taken from. These four aspects: genes, species, ecosystem and landscape ecology of which the protection of the former two are the base. Species can be conserved on site or transferred on other site while ecosystem made up of habitat and biocenosis cannot be transferred and protected. For the conservation of the complex landscape ecosystem composed of many ecosystems, it is only feasible to be protected on site. And to global and universal sense, its protection is of greatest significance. It is the highest-leveled macroscopic protection in real natural conservation work.

The natural landscape and its heterogeneity are always in changes due to natural and human factors. Among natural factors, the most important one is that the landforms of the quartz sandstone peaks have been changed due to continuous slow decay, abrasion and gravity-collapse which can be proved from large quantities of drift bed rocks on slopes and in streams. The scenic area would finally be turned into straths and mounds due to the gradual shrink of rock pillars, dikes and square mountains after billions of years. This is a natural law that human being has no power to prevent. The current Wulingyuan basin has been cut into countless mountains and ravines by water flow during billions of years. So the cutting process of the water flow is usually very slow. However, it would occasionally occur severely in a day or a couple of days. Take the extraordinary rain storm occurred in July 23, 1993 as an example, flood which came from the catchments area of Tianzi Mountain and Yuanjiajie quickly affluxes into the 40 to 80 meters wide stream in the Shilihualong with a proximate flow of 200 m³/s. After the sweep of the fierce flood of all the paths and plants, only a white rock channel remained. Beside the hazards of flood, frost appeared in winter on mountains of more than 700 meters a. s. l. also damaged the vegetations to different extents. For instance, several hundred-year-old pines were broken off by the frost in Suoxiyu, and samplings of China fir forest with broken treetops had reached 90% in 1982. Also in the same year, fire alarms happened several times which luckily had not brought destructive fire due to timely rescue. Some other insect hazards also happened occasionally. Besides disasters, the slow interior source successions of vegetation are also important factors in nature landscape changes.

The chief man-made sabotage to the forest occurred in the early 1960s because of cutting forests without plan. Therefore, besides forests on the stone pillar top, some square mountains top and trees inside blind valleys which are virgin secondary forests, the rest existing forests are man-made forests or secondary forests which have been recovered through thirty years of time. For example, among forestry area of Zhangjiajie Forestry Park, the area of man-made forests accounts for 41.2% while natural forests 58.8%. Nowadays, a lot of areas especially peripheral areas of the main scenic areas are being afforested. Another factor of man-made sabotage is the fast growing of tourism. In 2001, tourists in the core scenic areas reached about 1.2 million who bring pollution to the air and water. Some key scenic spots also faced partial damage because of construction of roads, cableways and tunnels inside these areas. Moreover, with the development of tourism, disturbance of human activities have been intensified which bring about great influence upon species of animals. Large-sized animals such as fox, jackal, musk-deer, antelope have escaped away and rarely seen, only left a certain number of animal species like macaque, wild boar and so on. However, generally speaking, the current conservation of landscape and biodiversity inside the scenic area is in a comparatively good condition.

Therefore, with the development of eco-tourism, measures should be taken to maintain the diversity of the landscape

ecosystem and scenic area ecosystem. The main measure are as follows: (1) The most important measure in the whole scenic area is to strengthen the protection of forests and vegetation by planting forests persistently and dealing with the relationship between conservation, tourism and forestry production properly. Forests planting must adapted to local place and suitable tree species, taking amenity forests as the main type of forests and its protection as the main task. Cutting of trees is prohibited inside the scenic area. Meanwhile lengthen the cutting cycle of the fir trees inside the non-scenic areas to more than 30 years and limit the cutting amount of over-ripe man-made forests to ensure that the consumption amount of man-made forest resource be at least 50% lower than the increment. (2) Setting out core area for unconditional conservation. Such areas like stone peaks tops, blind valleys (Shengtangwan, Xihai), and some square mountains (Heichongnao) which contain special ecosystems are prohibited for opening and touring must be put under absolute protection. Set out buffering areas around the core areas for sightseeing, but generally, passage is prohibited. And travel and sight seeing must be limited to a certain areas on tourist paths, observatory platforms and some square mountains. Tourism in Wulingyuan should take "Return to nature" as its theme. (3) Enhance the construction of botanical breeding gardens and wild zoological gardens. Focus on protection and research of important and rare species inside the area. Some wild animals, like macaque, tragopan, golden pheasant and giant salamander, etc. can be released back to nature after artificial propagation in order to increase the number of wild groups species. (4) Construct two-circuited firebreak belt by planting arbors, which have blocking functions to canopy fires. Construct observation towers and radio communication in accordance with the belt to prevent forest fires. (5) Manually control and disperse directions of surface water flow of large-scaled catchments area through water conservancy facilities construction to prevent damage to ecosystem in streams and valleys caused by mountain torrents. (6) Start from radical cure of pollution source, control water and air pollution and protect hydrological ecosystem and air inside the scenic area. (7) The ultimate measure is to reinforce education and improve people, especially decision makers' ecological consciousness about development of forestry tourism. Properly handle the relationship between natural conservation and tourism exploitation, stick to the policy of conservation first, exploitation second. Properly specify the maximum tourist intake capacity in key scenic spots and the scenic area as a whole to prevent excess load of tourists. At the same time, intensify propagation and strictly carry out different related laws and regulations about conservation of scenic area, nature, environment and species and so on.

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