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Assessment on Water Retention Function of Grassland Ecosystems in the Upper Yangtze River Basin

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Abstract: The upper Yangtze River basin, as an ecological protection screen for the whole Yangtze River, is a key ecological region in China. It is a substantial basis to assess the water conservation function of grassland ecosystem for sake of nature conservation, flood control and ecological regionalization. Through an integrated analysis on vegetation classification system and land-use changes, this study conducted a merger of various grasslands into eight assessment units. Interception (depth) under a single rain was formulated as the key indicator to evaluate water retention capacity of various grassland types. The results showed that the water-retention depth of grassland ecosystems within a single rainfall in the study area ranges from 17.25 mm to 40.65 mm, averaging 24.58 mm, among which the temperate-grass and *forb* meadow steppe had the highest capacity of water retention whereas the grass and *Kobresia forb* swamp meadow had the lowest capacity. A total amount of conserved water in the grassland ecosystems amounted to 45.67×10^8 m^3, pricing as \$$3.657 \times 10^8$. On spatial variances, the water-source area, which locates at eastern Qinghai-Tibetan Plateau, comes out to be the most important region whereas areas of Hengduan mountain region, northeastern Yunnan-Guizhou Plateau and eastern mountain ranges around Sichuan Basin co-form a generally important region.

Key words: The upper Yangtze River basin, grassland ecosystem, water conservation, function assessment.

Introduction

As an important component of terrestrial ecosystems on earth, grassland functions not only in providing animal products and vegetative resources, but also in maintaining the composition, integrity, function and process of natural ecosystems, especially in sustaining environment in arid and alpine areas (Xiao Guangdi, 2001; Cheng Zhongxin, 2001). Grassland in China covers an area of 3.92×10^8 ha, which rates a proportion of 13% of the world grassland coverage and is the second largest country, only next to Australia. The utilizable grassland coverage in China amounts to 3.10×10^8 ha and naturally distributes in a range between Daxinganling Mountains and Transection mountainous regions, mainly concentrating in Tibet, Xinjiang, Qinghai, Gansu, Guangxi, Yunnan and Heilongjiang. In the Yangtze River valley, the total area of grassland is 9059.82×10^4 ha, most of which grows in the alpine and prairie areas. Basically, grassland ecosystem in the upper Yangtze River basin plays an important role in water and soil conservation and even flood control, as is regarded the ecological protection screen for the whole Yangtze River valley (Li Bo, 1997).

Notwithstanding, few approaches have been conducted in assessing the water-retention capacity of grassland, and even less on a whole scale of a valley. The indicators used for assessment were mostly introduced from studies in forest ecosystems, and the capacity was bound to be roughly estimated by means of forest indicators (Guo Zhengguang, 2002; Ren Jizhou, 2002). Subsequently, further studies should be advocated both on optimum indicator system setting and on evaluating method unification.

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Study Area and Methodology

Study Area

The upper Yangtze River basin, having six municipalities or prefectures and 348 counties located in nine provinces (Qinghai, Xizang, Yunnan, Gansu, Sichuan, Shanxi, Chongqing, Hubei, and Guizhou), covers an area of 1.05 million km^2 and holds a population of 190 million people. It is the major inhabitation area for ethic minorities as Zang, Qiang, Li, Bai, Buyi and Tujia. It greatly varies in climate classifications and topography. The baseline climate there belongs to subtropical moist monsoon type, yet changes with elevations ranging from 250 m to 7700 m, and also differs in landforms of mountains, hills, valleys and even highlands. The upper reaches of the Yangtze River, originating from the roof of the world, characteristic of a massive area, diversified landform and unique eco-function, has been reputed for an area of affluent water resources; a key exploitation area of hydropower; a central place of biodiversity and nature conservation; and a major range rich in forests, grassland and wetland; a hotspot of rare and endangered species; and even a sensor of global changes. Thereinto, the grassland amounts to 9.06×10^8 ha. Water-retention capacity of grassland ecosystems there plays a key role in maintaining functions of the Yangtze River's water environment, contributing to water and soil conservation and regulate fluvial runoff. Hence, it is regarded as a shelter for keeping ecological balance of the whole Yangtze River valley.

Methodology

Integrating Grassland Categories into Assessment Unit

Reports on assessment of grassland functions were basically based on grassland classifications or grassland regions. Grassland classification was pioneered by Wang Dong in 1955. Thereafter, great achievements had been made in setting up various classifying systems, such as habitat-based classification system (Jia Shengxiu, 1955), multi-scale sequential classification system (Xu Peng, 1965) and management-based comprehensive classification system (Xu peng, 1985). Out of the integrated analysis and under the guidance of principles of being sensitive, representative, and maneuverable, assessment units in this study were determined into eight groups (Table 1), formulated from China's vegetation classification system and reassured by land use types interpreted from satellite images in 2000, so as to compare different ecosystems in eco-functions.

Table 1: Assessment unit group of grassland water-retention capacity

Unit No.	*Assessment unit group*	*Group composition*
1	Temperate-grass and forb meadow steppe (TGFS)	*Festuca ovina* and *herbarum variarum* meadow steppe, *Gramineae* and *herbarum variarum* meadow steppe
2	Temperate bunch grass steppe (TBGS)	*Stipa bungeana* grassland, *Stipa capillata* grassland
3	Grass and *Carex* spp. alpine grassland (GCAG)	*Carex Linngrassl* and *Gramineae* grassland
4	Temperate tussock grassland (TTUG)	*Themeda triandra* var. *japonica tussock* grassland, *Miscanthus sinensis tussock* grassland, *Arundinella hirta tussock* grassland, *Heteropogon contortus tussock* grassland, *Imperata cylindrica* var. *major tussock* grassland
5	Grass and forb meadow (GAFM)	*Calamagrostis epigejos* and *Gramineae* meadow, *Cynodon dactylon* meadow, *Imperata cylindrica* var. *major* meadow, *Festuca ovina* and *herbarum variarum* meadow *(Carex Linn* and *herbarum variarum* meadow*)*, *Blysmus sinocompressus* and *herbarum variarum* meadow
6	Grass and *Kobresia* forb swamp meadow (GKSM)	*Kobresia* spp. and *carex* spp. meadow, *Poa* spp. meadow
7	Grass and forb salina meadow (GFSM)	*Karelinia caspica* meadow
8	*Kobresia* spp. forb alpine meadow (KFAM)	*Kobresia capillifolia* meadow, *Kobresia setchwanensis* meadow, *Carex yunnanensis* and *herbarum variarum* meadow, *Kobresia* spp. and *carex* spp. meadow

Table 2: Parameter acquisition for different assessment units

Assessment unit	*Plant biomass (kg/ha)*	*Herb-layer water storage capacity (mm)*	*Litter-layer water storage capacity (mm)*	*Total of interception in a single rain (mm)*	*Soil noncapillary porosity (%)*
TGFS	20,240	0.60	0.04	0.64	5.97
TBGS	10,290	0.33	0.03	0.36	10.46
GCAG	18,890	0.44	0.04	0.48	13.39
TTUG	16,110	0.37	0.06	0.43	6.87
GAFM	10,040	0.31	0.03	0.34	6.38
GKSM	8440	0.29	0.04	0.32	6.62
GFSM	14,890	0.39	0.07	0.45	5.6
KFAM	12,240	0.31	0.03	0.33	9.14

Index Parameter Investigation

Indexes parameters were obtained through typical sampling surveys from August, 2006 to August, 2007, which were conducted in various grassland types in Hongyuan County and Ruoergai County, Sichuan and Jielong Township, Yushu County, Qinghai within an elevation range of 3420-3940 m. During the field survey, 40 sample plots, five plots for each assessment unit, were selected to harvesting the herbaceous biomass and the litter amount by quadrates of 1 m×1 m within a 10 m×10 m basic plot, which was chosen by differentiation in topography, grassland community, coverage, and elevation. Biomass of fresh samples were determined in fields, and those of laboratory samples were dried to be constant in weight in an oven under a temperature of 80ºC in about 24 hours, then water content and interception (storage) capacity (converted to Depth) were calculated. Meanwhile, a soil pit in each plot was digged to sample for determining its non-capillary porosity proportion by alcohol-burning method.

Results

Water-retention Capacity of Different Grassland Ecosystems

Admittedly, grassland ecosystems differ both in structure and function for various classifications and far-going distributions. There are also significant differences from forest ecosystems. It is believed that forest can effectively intercept rainfalls and control flood, yet such a function of grassland ecosystems has been less studied (Li Qi, 1999; Wangshiping, 2003). Substantially, grassland in the upper Yangtze River basin rates a great proportion in coverage and mostly locates in the water source areas, so that its water-retention capacity should not have been neglected. In order to compare water-retention capacity of different grassland ecosystems, saturated interception depth within a single rain was formulated as a common indicator (criterion), which can theoretically screen the spatial and structural variances of different grassland classifications. The saturated interception within a single rain was determined by totalling herb-layer water storage, litter-layer water storage and soil-layer water storage.

Calculated results showed that the water-retention depth of grassland ecosystem within a single rainfall in the study area ranges from 17.25 mm to 40.65 mm, averaging 24.58 mm (Table 3), among which that of the temperate- grass and *forb* meadow steppe was the highest, and contrarily that of the grass and *Kobresia forb* swamp meadow was the lowest.

Water-retention Quantity of Grassland Ecosystems

In order to calculate the total amount of water-retention by grassland ecosystems in the upper Yangtze River basin, those of three functional dimensions (herb-layer, litter-layer and soil-layer) of the ecosystems were separately determined by means of different formula:

$$W_g = \sum_{i=1}^{k} B_i D_i A_i \quad (1)$$

$$W_l = \sum_{i=1}^{k} L_i d_i A_i \quad (2)$$

$$W_s = \sum_{i=1}^{k} P_i T_i A_i \quad (3)$$

$$W_t = \sum_{j=1}^{n} W_g + W_l + W_s \quad (4)$$

Thereinto, W_t is the total amount of water-retention by grasslands in the upper Yangtze River basin (m^3); W_g, W_l, and W_s are water storage within herb layer (m^3), litter

Table 3: Water-retention capacity of different grassland ecosystems

Assessment unit	*Conserved water depth within herb layer (mm)*	*Conserved water depth of within soil layer (mm)*	*Total in an ecosystem (mm)*
TGFS	0.64	17.91	18.55
TBGS	0.36	31.38	31.74
GCAG	0.48	40.17	40.65
TTUG	0.43	20.61	21.04
GAFM	0.34	19.14	19.48
GKSM	0.32	19.86	20.18
GFSM	0.45	16.8	17.25
KFAM	0.33	27.42	27.75

layer (m^3); and soil layer. A_i (ha) is the area of the grassland classification. B_i and L_i (m^3/ha) are the biomass of herb layer and litter layer, respectively. D_i and d_i (cm) are interception depth of the herb layer and litter layer. P_i is the soil non-capillary porosity rate (%); and T_i is the thickness (cm) of soil permeability formation (regarded as 30 cm in common).

Out of an integrated analysis on water-retention capacity of grassland ecosystems in various areas, it was shown that the total quantity of water-retention by grasslands in the upper Yangtze River basin amounted to 45.67×10^8 m^3 for a coverage of 2465.56×10^4 km^2 (Table 4). Different grassland ecosystems varied in contributions, which were revealed by that *Kobresia* spp. *forb* alpine meadow, for their largest distribution area, dominates in water-retention and that grass and *Kobresia forb* swamp meadow shares the smallest proportion, rating only two million m^3 of water storage.

Table 4: Water-retention quantity of grasslands in the upper Yangtze river basin

Grassland ecosystem	*Area ($\times10^4$ km^2)*	*Water retention ($\times10^8$ m^3)*	*Water-retention per ha (m^3/ha)*
TGFS	4.67	0.08	170
TBGS	139.82	4.33	310
GCAG	66.88	2.68	400
TTUG	480.21	9.60	200
GAFM	136.94	2.60	190
GKSM	1.31	0.02	190
GFSM	15.91	0.43	270
KFAM	1619.83	25.92	160
Total	2465.56	45.67	185.22

Spatial Differentiation in Water-retention Capacity of Grassland Ecosystems

Through applying GIS technique and Visual Foxpro database, a Grid image (300 m×300 m) was produced for integrating the water-retention capacity of different grassland ecosystems in the upper Yangtze River basin (Figure 2). And then, an assessment scale was determined by interception depth ranging from 17.25 mm to 40.65 mm, among which three levels were formulated as: while the interception depth>31 mm, defined as Level 1; while it goes between 20-30 mm, defined as Level 2; while the interception depth<20 mm, defined as Level 3. Such definitions were applied to dividing the key regions of water-retention capacity of grassland ecosystems. As is shown, the water-source area, which is located at eastern Qinghai-Tibetan Plateau, comes out to be the most important region whereas areas of Hengduan mountain region, northeastern Yunnan-Guizhou Plateau and eastern mountain ranges around Sichuan Basin co-form a generally important region. Other areas including Sichuan Basin, the Wujiang river valley and the Jinshajiang River valley belong to the less important region. Hence, a reference may be drawn from the regionalization for grassland ecosystem protection and establishment in management practice.

Valuation of Water-retention within Grassland Ecosystems

There are many ecological, social and economic reasons for grassland assessment. In each case, assessment methods may be quite specific and are usually purpose driven. However, a general grassland assessment was recognized here to investigate and understand grassland ecosystem function of hydrologic mechanisms (for example, water source provision and flood control). In the past, water supply utilities typically met growing demand for water consumption by expanded supply infrastructures. Normally this was subsidized from the public purse. Environmental costs were rarely considered. An ever-expanding water supply has, however, become too expensive. New water supply dams face a shortage of suitable sites and escalating financial and

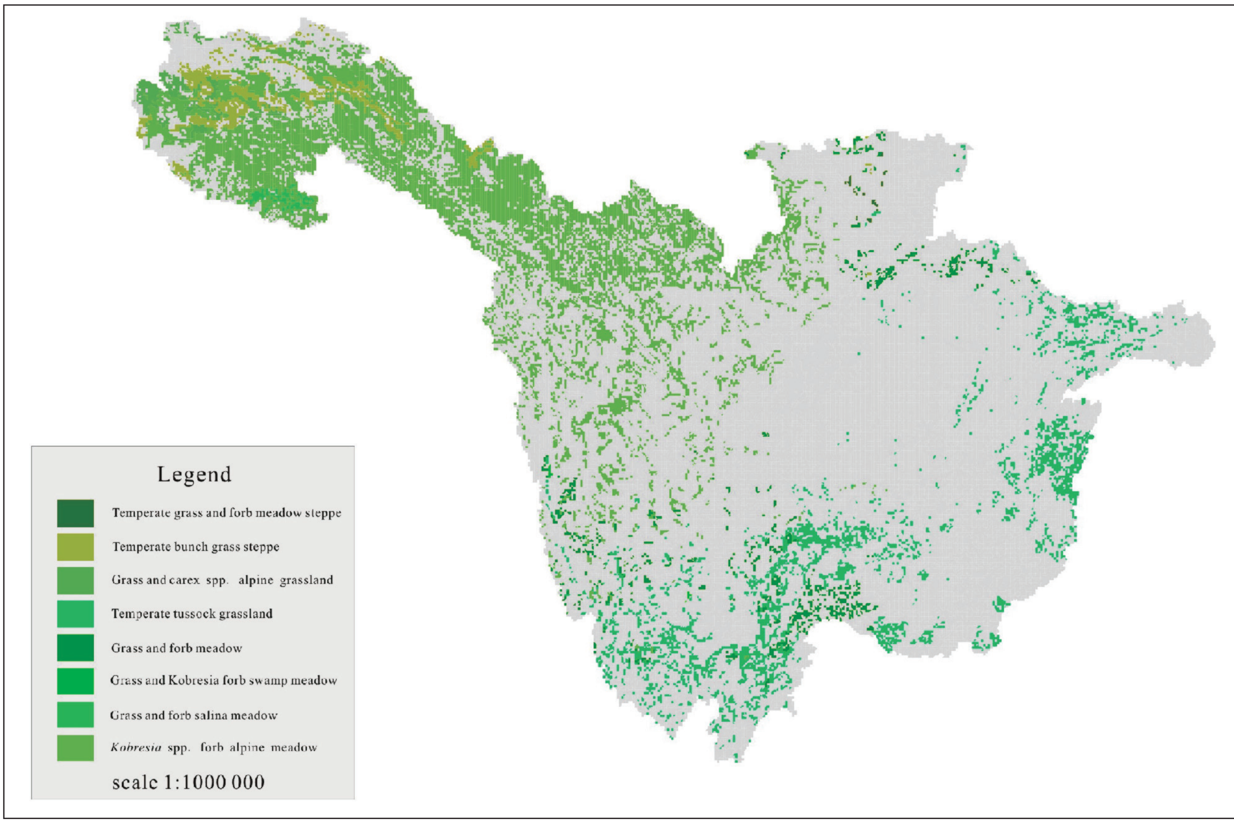

Figure 1: Distribution of grassland ecosystems in the Upper Yangtze River Basin.

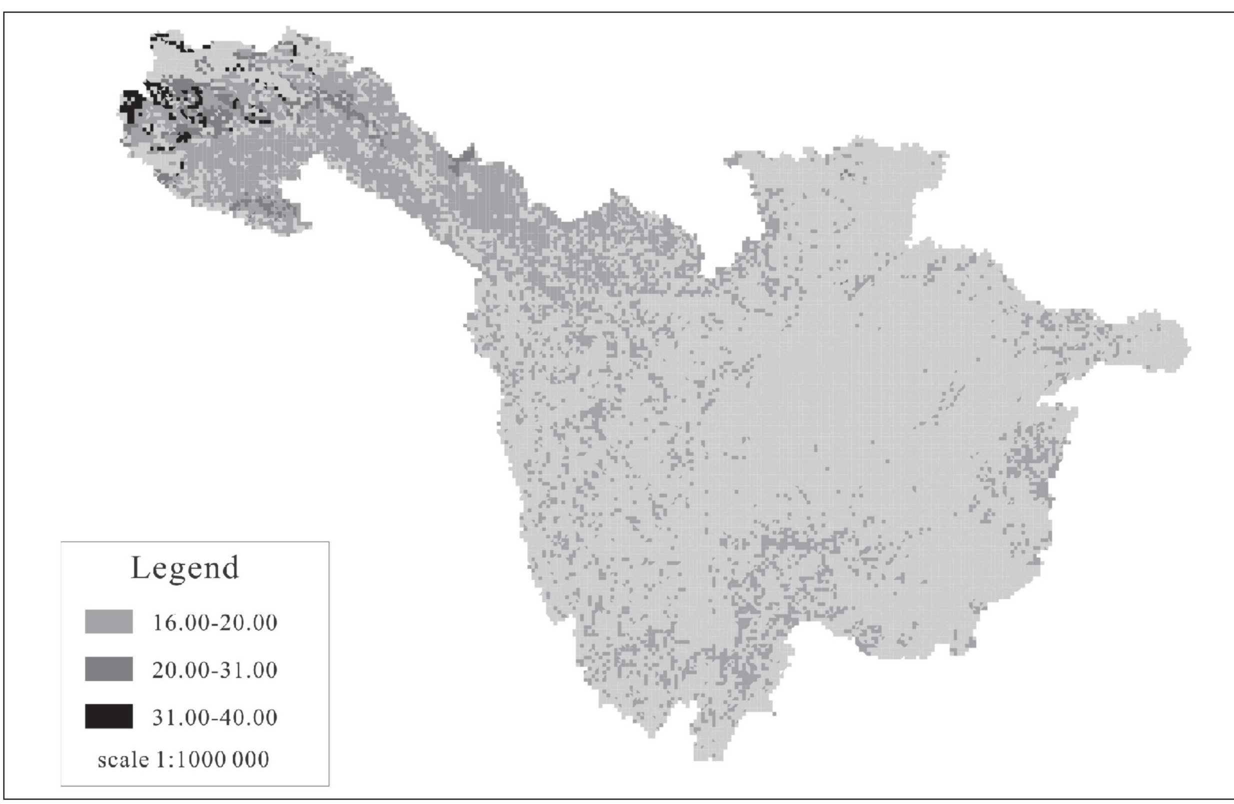

Figure 2: Water-retention capacity of grassland ecosystems in the Upper Yangtze River Basin.

environmental costs. In place of new dams, there is a range of policies that governments can use to encourage water conservation. In order to provide a decision criterion, hereby water-retention was priced by a method of Image-engineering Substitution (Liu Qi, 1999), which was based on a unit cost of \$0.08 per cubic metres of water reserved by a dam. Then, as a total amount of 4.567×10^9 m^3 of water-retention by grassland ecosystems in the upper Yangtze River basin, its total value can be priced as $\$3.657\times10^8$, equal to 2.93×10^9 RMB, functioning as three Gezhouba Reservoirs. Accordingly, grassland ecosystems in the study area should not be neglected in water supply and conservation.

Discussion

The upper Yangtze River basin is a key ecological area in China and a safeguard of eco-security for the whole Yangtze River basin. It is also an enrichment area and a supply area of water resources in China. Because of particularity of natural, social, economic demands and their multiplicity and longevity, water retention function becomes a substantial focus of ecosystem services, which is crucial to natural conservation and flood control in the Yangtze River basin (Wu Ning, 2004; Liu Yanguo, 2006). Due to its largeness in area, complexity in geography, ecosystems and variances in regions, and even lack of previous reference for approach, what was estimated in this study was just a preliminary value. In the process of data integration, even though informative data were of dissymmetry and disunity, and there were great space and time differences among assessment index parameters, yet statistic samples were investigated and applied for a database establishment by GIS techniques. While in the process of assessment of unit-scale transformation, we adopted multiple operation platforms such as ArcMap and Visual Foxpro and made use of grid data (300 m × 300 m) and of Visual Foxpro database for overlapped calculations to accomplish the quantitative evaluation for spatial differentiation of different units. However, due to the influence of grid density, some important information might have been lost or screened, which might have led to accuracy weakness in results. Consequently, regional quantitative value determined by evaluation could only embody and reflect infrastructure of water-retention contributions of grassland ecosystems in the upper Yangtze River basin. Still, many scientific problems in assessing water-retention function are worthwhile to be further studied, on basis of oriented observations and GIS implementations. And then, key important water conservation protection areas will be worked out for practice.

References

Ayling, R.D. and K. Kelly (1997). Dealing with conflict: Natural resources and dispute resolution. *Conservation Forestry Review.* **3:** 182-185.

Chen Zhongxin and Xinshi Zhang (2001). The benefit value of ecosystem of China. *Bulletin Sciences*, **45(1):** 17-24.

Costanza, R., Arge, R., R. Groot et al. (1997). The value of the world's ecosystem services and natural capital. *Nature,* **386:** 253-260.

Guo Zhenggang, Zhang Zihe and Fujiang Hou (2002). Degeneration and Artificially Controllable Factors and Classified Management Strategies of Hexi Corridor Grassland. *China grassland*, **24(3):** 53-58.

Guo, Z.G., Liang, T.G. and Z.H. Zhang (2003). Classification management for grassland resources in Gansu province, China. *New Zealand Journal of Agricultural Research*, **46:** 123-131.

Jin Yanping (2003). Sustainable land use in western China. *Acta Prataculturale Science*, **12(6):** 18-23.

Li Bo (1997). The present situation, problems and counter-measures of grassland resources in China. *Bulletin of the Chinese Academy of Sciences*, **13(1):** 49-51.

Liu Qi (1999). An Inquiry into the Ecological Economic Value of Grassland Resource in China. *Journal of Sichuan Grassland*. **21(4):** 1-4.

Liu Yanguo, Peng Peihao, Chen Wende and Yukuan Wang (2006). Assessment on water-retention capacity of vegetations in the upper Yangtze River Basin by GIS. *Journal of Anhui Agricultural Sciences*, **34(14):** 3323-3325.

Ren Jizhou (1995). Grassland Agroecology. Beijing. 14-18.

Ren Jizhou (2002). Establishment of an agro grassland systems for grain storage—A thought on restructure of agricultural framework in Western China. *Acta Prataculturale Science*, **11(2):** 1-3.

Sun Hongliang (2003). An approach to the development direction of farming and animal husbandry in north west area of China. *Acta Prataculturale Science*, **12(6):** 1-6.

Wang Shiping (2003). Vegetation degradation and protection strategy in the "Three rivers fountainhead" area in the Qinghai province. *Acta Prataculturale Science*, **12(6):** 1-9.

Wu Ning and Luo Peng (2004). Rethinking on the ecological theories related to the ecological construction and management of the high-frigid grasslands in the upper Yangtze River. *Chinese Journal of Applied and Environmental Biology*, **10(4):** 537-542.

Xie Gaodi, Zhang Yili and Chunxia Lu et al. (2001). Study on valuation of grassland ecosystem services of China. *Journal of Natural Resource*, **16(1):** 47-53.