Urgent Problems of Grassland Management in Temperate China and Practicable Solutions

System Discordance and Coupling

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1. Abstract

Due to the intensified pressure of population growth, harsh natural conditions and errors made in system management, problems of grassland management in temperate China have prompted an ecological crisis which is apparent from the obvious discordance between existing agricultural systems. A possible and practicable solution to these problems is to rationalize through coupling potentially compatible production systems. System coupling would gradually eliminate the incompatibility between the existing crop and livestock production systems, pasture production and grazing systems, and agricultural production and marketing activities.

There may exist three ways for system coupling in the management of grasslands in north China: a) between mountain, oasis and desert systems; b) between crop and livestock production systems; and 3) between grassland agricultural systems and urban areas. Through system coupling the production potentials in different farming systems, would be taped out for a higher total productivity and the maintaining of overall ecological conditions - the goal of an improved management scheme for grasslands in north China.

Key words: grasslands in north China, system discordance, system coupling, grazing system, grassland agricultural system

2. The background of grassland formation in China

The formation of grasslands is generally influenced by the three group factors, i.e., social, biological and non-biological factors. The relationships between grassland and above factors can be written as:

$$R = s(k, p, l). o(z, d, w) . f(q, t, d)$$

Where R denotes grassland resource; s denotes social factors; k is scientific and technological levels; p is production level; l is living level, o is biological factors; z is vegetation; d is animals; w is microorganisms; f is non-biological factors; q is climate, t is soil and d is location.

The grassland resource is basically influenced by biological and non-biological factors. However, the grassland has a resource attribute only after its economic value has been acknowledged by the society. Therefore social factors are necessary resource attributes of the grassland resource information.

However, the biological and non-biological aspects of grasslands in China are largely ignored and the grassland resources are almost synonymous with the fragile ecosystems, whereas the social factors, exacerbate the process of grassland degradation.

The grassland is comparatively tolerant to the harsh climate and soil conditions. Due to the inadequacy of moisture supply (e.g., desert and arid areas) and temperatures (e.g., mountain and high latitude areas) the grassland belongs to the marginal land in the agricultural systems.

However, the grassland is more capable to resist adverse conditions than cropping systems and forestry. In most cases, the areas where the grassland occurs are not suited to farming or forestry but good for animal husbandry. Because of its ecological fragility, misuse of grassland can lead to irreversible damage of the ecosystem.

Because of the strong population pressure and historic reasons, the grassland has been gradually encroached the cropland and resources have shifted (the grassland with better ecological conditions are used for farming). In a society of self-sufficiency, the population supported by arable cropping is 10 - 20 times more than that supported by forestry or grassland.

On the Loess Plateau, for instance, the divisions between cropping and animal husbandry took shape through eleven stages, which lasted almost 3000 years, until cropping was finally the dominant agricultural system (Ren Jizhou 1997). As a result, soil erosion became one of the long-standing problems that perplexed the regional development for a long term.

Part of the grasslands occur in the ecotone of diverse ecological types, that is, the ecological diversity leads to biological diversity and provides the places where cropping, animal husbandry and forestry supplement each other. Because of their ecological fragility, these areas tend to be excessively exploited and finally become victim of an ecological crisis. Excessive land reclamation, undue emphasis on cropping and incomplete cropping systems are examples of the misuse of resources.

3. Successions in grasslands in China

Based on the structure of the grassland resources and the specific conditions in China, a succession of grassland can be distinguished in China as illustrated in Figure 1.

In the first stage of grassland degeneration, the yield of plants decreases; in the second stage of grassland degeneration, the botanical composition changes, low production animals replace higher production animals; in the third stage of grassland degeneration, the topography is affected.

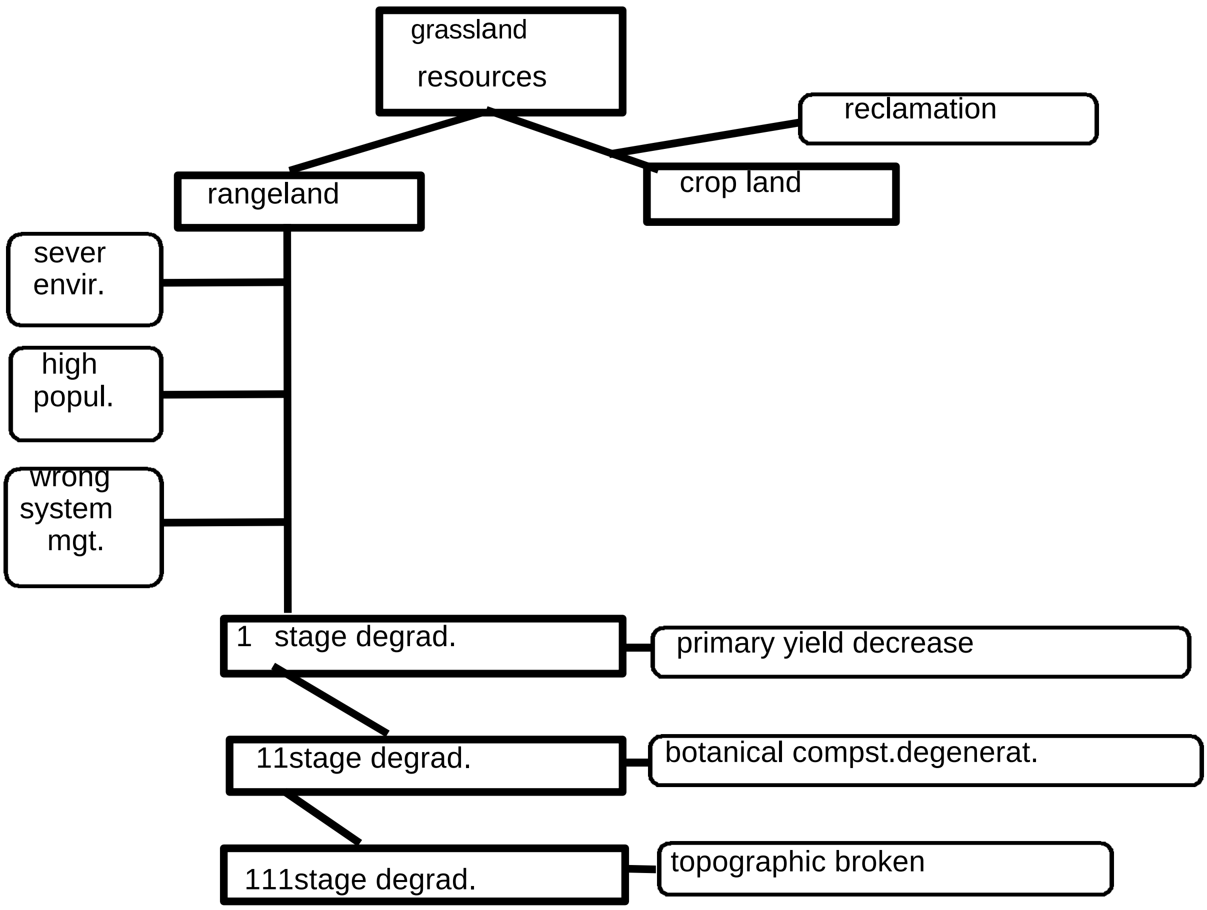
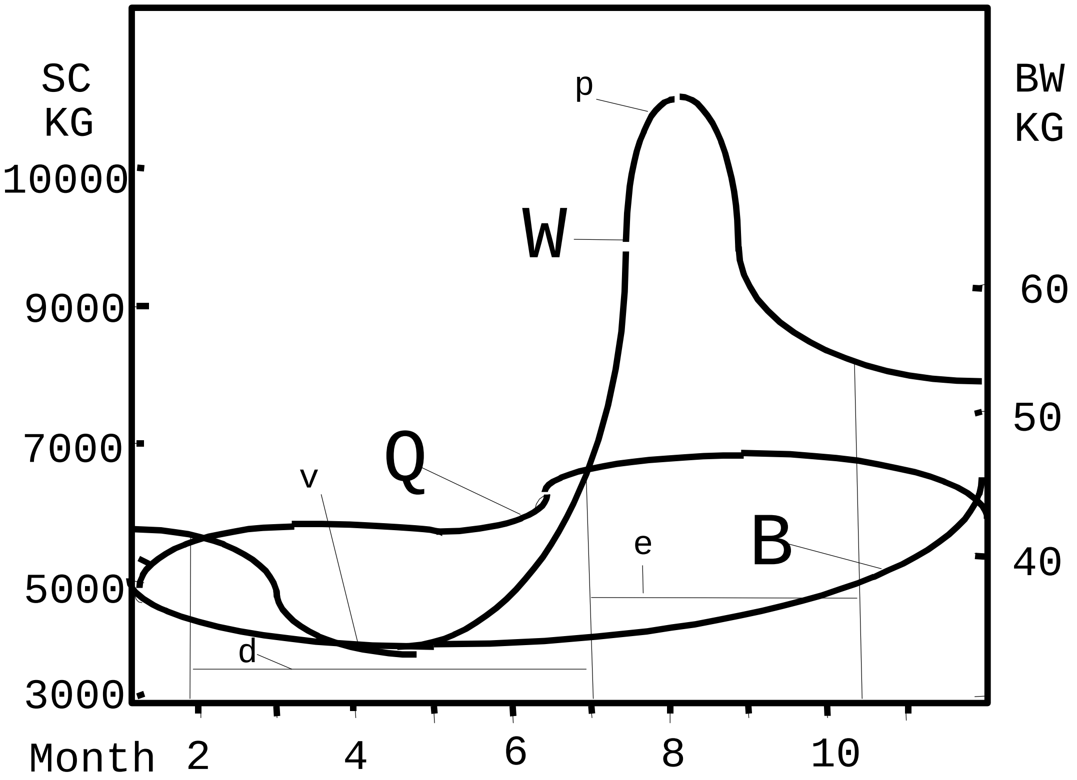


Figure 1. The dynamics of grassland degeneration.

System errors in the land and production planning are easily understood, such as the inappropriate policy of land reclamation. Another implication is the system discordance caused by subsystem coupling in a farming system. A common system discordance is the discordance in the distribution of grassland and animals in quantity and area alongside the discordance in biological species and community in their habitats, and temporal discordance, The last one is dominant (see Figure 2.). The temporal discordance tend to intensify the spatial and species discordance.

SE is where yields of grassland; BW-body weight of animals(kg), M is month , W is the dynamic line of standing crop of grassland, B is the dynamic line of animals average body weight, Q is feeds requirement for sheep, D is forage deficient period, C is forage surplus period, V is the valley period of plant growth, P is the peak period of plant growth.

Many factors influence grassland degradation. The general form of grassland degradation is desertification. Desertification in north China has intensified in the form of desertification and salinization and develops at a rate of 2100km /year. Within half a century, the rate of desertification has become three times faster than it was one hundred years ago.



SC: yields of grassland forages; BW: body weight of animals(kg); W: the dynamic line of standing crop of grassland pastures; B: the dynamic line of animals' average body weight; Q: feed requirement of sheep; D: forage deficient period; C: forage more-than-need period; V: the valley period of plant growth; P: the peak period of plant growth

Figure 2. Annual dynamics of the nutrition of alpine meadow versus sheep requirements at Mountain, northwestern China.

According to research, evidence of human activities has been traced back to 1000 BC in the Hexi Corridor. Owing to its geographic location and contacts with the oriental-western trade, many nations migrated and colonized in this area and created economic and cultural systems with distinctive international features. After the Hanwudi Dynasti (156-87 BC), the silk road used to link two world centres of civilization, China and the Roman Empire. It was an 'ancient opening area' that held the lead in technology, culture, agriculture, politics and military affairs. This area has borne a heavy burden of human development for several thousand years and made a great contribution to the country and its nations but paid dearly. According to archaeological investigations, 22 sites of prehistoric ruins have been found in the Hexi Corridor and countless ruins of ancient towns and cities were buried by sand and (gobi) desert in the grassland area of north China. The well-known Juyan oasis in the Hexi Corridor, for instance, used to be a 'green great wall' in northwest China, which was irrigated by the Heihe river, originating from the Qilian Mountain in the Hexi Corridor. Weilu-Heicheng was one of the important cities in this area. Since the Han dynasty, it has been a famous historically city. Thousands of bamboo slips, a kind of official documents, excavated by the archaeologists from the ruins of the city, testify of the prosperity at that time. The Weilu-Ju Yanhai Lake composed of an east lake, west lake and north lake, had a water area of 800 km^2. During the transition period from the Yuan to the Ming Dynasty, the north lake dried up (400 years ago). The west lake dried up in the 1960's due to the large scale land reclamation and poor water replenishment from the upper reaches of the Heihe river. The east lake dried up in 1990s,.Now it is the origin of many sand storms. The catastrophic sand storms in the United States in the 1930s, in the former Soviet Union in the 1960s and in the 1990s originated in China.

Salinization is prominent in the grasslands of the arid area, furthered by the expansion of irrigation systems and poor management (saline areas accounted for 30% of total irrigation area in the Yellow River irrigation system). It mainly occurred in the edges of the oasis and led to the degeneration of the grassland with high productivity.

3.1 Three models of temperate grasslands in China

3.1.1 Production potentials of the mountain-oasis-desert ecosystem in the North-West Inland Area.

The grassland in north-west China is greatly influenced by gigantic mountains, such as the Qilian Mountains in the south of the Hexi Corridor, Tianshan Mountain, Kunglun Mountain, and Aretai Mountain in Xinjing province, which surround basins and form huge desert and semi-desert areas, The revers originating from the mountains irrigate many oases. Therefore, the mountain, desert and oasis make up the basic structure of the inland ecological systems in China. (Figure 3).

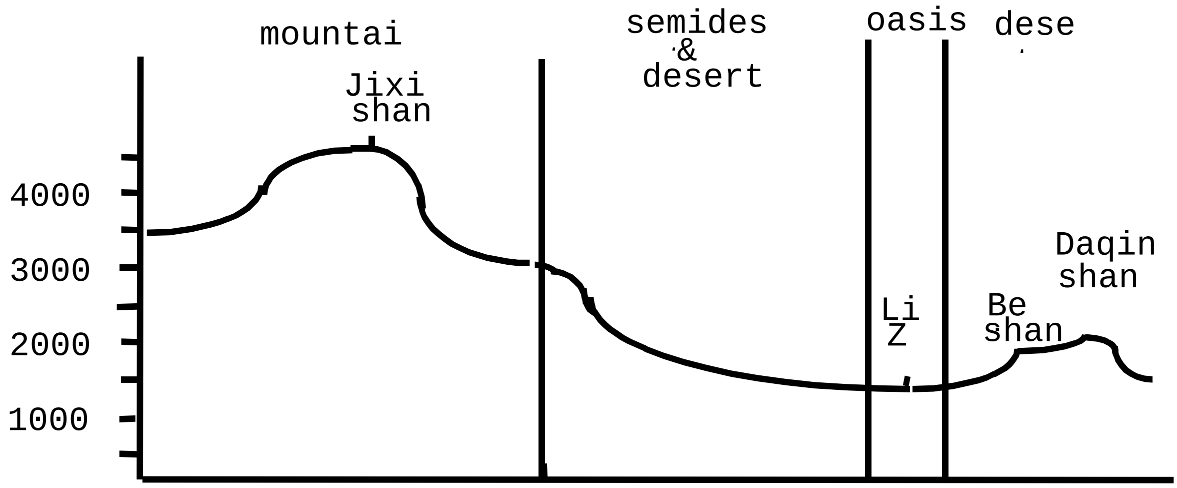
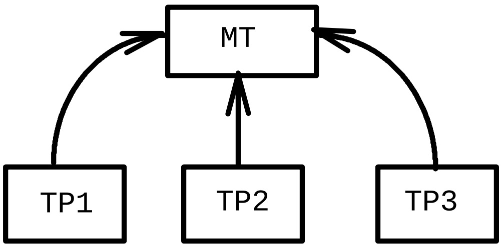


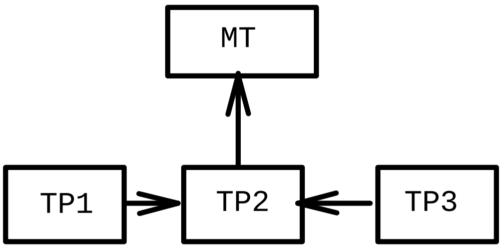
Figure 3. Mountain-oasis-desert agro-ecosystem chain (the north slope of Qilian Mountain) From the Resources Lab. Gansu Grassland Ecological Research Institute.

Despite 7% oasis area in the desert, agriculture in oasis areas accounts for over 90% of total desert area. For instance, the oases lying at the foot of Qi'lian Mountain, e.g., Wu'wei Oasis, Zhang'ye Oasis and Ju'quan Oasis, are local centres of economy and culture. At present, however, these oases, are isolated can not fully plays their core functions due to serious system discordance and ecological collapse. If the oasis is taken as a development nucleus and coupled with Mountain and desert to form an optimized system, 'mountain-oasis-desert', overall development will be enhanced. According to preliminary studies, the productivity of the coupled system in Hexi Corridor will increase six fold in comparison with the traditional system (Figure 4, 5).



TP1: energy output from the mountain sub-system; TP2: energy output from the oasis sub-system; TP3: energy output from the desert sub-system ; MT: total energy output to the market

Figure 4. The energy output from the three subsystems of the mountain -oasis-desert agro-ecosystem chain to the market *without* coupling.



TP1: energy output from the mountain sub-system; TP2: energy output from the oasis sub-system; TP3: energy output from the desert sub-system ; MT: total energy output to the market

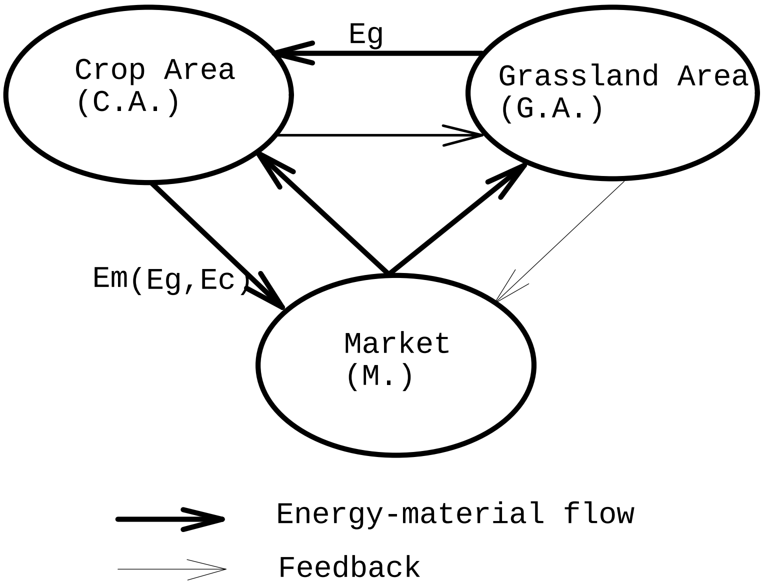
Figure 5. The energy output from the three subecosystems of the mountain-oasis-desert agro-ecosystem chain to the market *with* systems coupling.

The total output of energy increases: MT=E(TP1e +TP2e +TP3e), TP1--energy output of mountain sub ecosystem, TP2--energy output of oasis sub ecosystem, TP3-energy output of desert ecosystem, MT-total energy output of the three sub ecosystems. e ,e ,e --the magnifying coefficient of systems coupling of every subsystem.

Most grasslands in the north-west inland in China can be analyzed using this model.

3.1.2 The production potential of the transition Area with a cropping-grazing system

Traditionally, there is a demarcation line between arable farming and grazing in China, i.e., from the north-east to the south-west of China, starting at Muo'he county in Heilongjiang province, along the Greater Xing'an Mountains to the south, parallel along the Great Wall to the Ten'geli Desert and east end of the Ba'dan Ji'lin Desert, then passing through the Loess Plateau and the east border of the Qin'hai-Tibet Plateau and then passing along the west of Sichuan province and finally entering into Yunnan province at Tengchong county. The region north-west of this demarcation line was traditionally grazing area, whereas farming extended in the opposite direction. Along both sides of the transition area are some 'tea and horse' markets, which were directed at trade activities between the farming and grazing areas. Many cities along the line used to be well-known for their prosperity relying on farming-grazing systems coupling and became the legendary paradises of 'gold-rushers' at that time. These coupling systems formed naturally but were not perfect and needed to be optimized. They accelerated economic development at both sides of the line and showed their immortal merits to history. The modern market economy gradually developed coupling systems but need energetic support to make their functions supportive to economic development (Figure 6.).



Eg : energy output from G.A.; E_C : energy output from C.A.; E_m : total energy flow to M

Figure 6. The energy output from the crop sub ecosystem and the grassland animal production sub ecosystem with system coupling.

3.1.3 The Production Potential of the Grassland-Urban System

The Grassland-Urban System has close links with urban areas and large-scale production has been the general trend. Traditionally, the big and middle cities in north China are, more or less, linked with the grazing areas. A good example could be the cattle feedlot in San'he county in Beijing city linking an urban environment with grassland animal husbandry in Inner Mongolia, and forming an Inner Mongolian grassland-Beijing coupling system.. The urban cattle fattening industry by using the feeder calves from the grassland has not only satisfied the urban market demand, but promoted the development of grassland areas as well. The enormous social and economic benefits from system coupling have generated great interest (Figure 7).

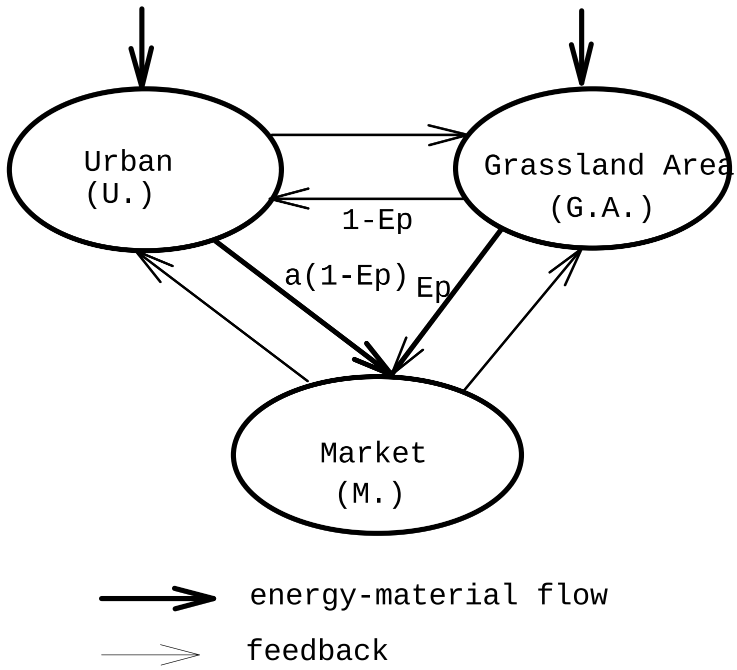


Figure 7. The energy from the urban-grassland sub-ecosystem and the grassland animal subecosystem with system coupling. Ep is the output energy from G.A.

The development of system coupling in China was not well organized and directed in the past. However, the practice has proved that appropriate system coupling, which needs less input and can rapidly become effective, can achieve enormous benefits and should be encouraged and developed vigorously.

4. Principles of Grassland Management Adapted in China

In order to maintain and develop the above characteristics of the grassland resources, several basic principles should be observed.

4.1 Principle of Sustainable Production and Ecological Productivity.

The principle of sustainable production is derived from the principle of sustainable subsistence. It suggests that stable outputs are achieved in combination with long term existence and healthy operation of the ecosystem. The key point is the principle of ecological productivity: production should carry on while the ecosystem maintains its healthy state .

4.2 Principle of keeping plants and animals in an immature state

Since the ecosystem is always changing, its productivity fluctuates. In essence, this fluctuation depends on the dynamics of energy. The system will be in an unbalanced state as its total energy increases and entropy decreases, while free energy accumulates. The free energy becomes an unstable potential energy when it accumulates to a critical point. It needs to find an outlet, so we should take products from the ecosystem. Otherwise the ecosystem gets information feedback to reduce the accumulation of the free energy in the ecosystem. So the ecosystem reduces its activities, and production decreases. Of course this is not valid in an agricultural ecosystem.

Based on the principle of ecological productivity, the means of production, labour and environmental factors that influence the production need to be optimized to promote the rational operation of an ecosystem. The accumulation of free energy and outputs by the ecosystem are to be realized while maintaining healthy operation of the system.

Maintaining the pre-summit state of grassland ecosystems is an effective measure to keep an ecosystem in a healthy state and raise productivity. It includes the following aspects:

(a) Maintaining the immature stage of the ecosystem to get more productivity of the ecosystem. As a life system, the ecosystem has stronger viability before reaching the mature stage. On the contrary, in the summit stage, the viability of ecosystem decreases rapidly. An ecosystem in an immature state has an unsaturated potential and possesses more bonding energy among its components (subsystems) and hence is a more open system. As a result, the ecosystem is more vigorous and productive (more free energy and products). With regard to the measures to raise system productivity, system optimization is a common method to keep the ecosystem in an immature stage and therefore the ecosystem been strengthened. The dependence of herbivorous animals on plant products is widely used to keep the vegetation in an immature state.

(b) Maintaining the immature state of some components in an ecosystem. Living beings have an inherent motivation to become mature. They have stronger viability in the immature stage that can be utilized to strengthen the system functions. The performance of herbs is a good example. Imposing proper measurements, such as cutting and grazing on the herbs, can raise the herb yield and be conducive to the stability and health of the plant community. It is also suited to renew shrub and forest lands as well. In plant production, except for the purpose of seed collection, all crops should be maintained in an immature state. Only herbivores animals fully use immature vegetation. It can therefore be concluded that herbivores are not only important to maintain the immature state of an ecosystem, but they enhance the ecological productivity of an ecosystem as well.

4.3 The principle of system coupling

Two or more ecosystems which are affined in nature have a tendency to combine with each other. When the conditions are given, they can integrate into a new system with a stronger structure and better functions. This is so-called system coupling. In grassland ecosystems, there are great potentials for system coupling between different production systems and regions. The productivity of a coupling system can be raised by ten or even a hundred times. In addition, if the pre-plant production system and the external biological production system are coupled, the productivity can be further increased. Of course, system discordance should be avoided.

5. The principle of matching landscape with grassland development

The grassland resource is composed of landscape patches, which are separated by boundaries. The diversity of a landscape patch can be explained by:

- specific long-standing geomorphologic processes,
- specific biological gregarious models, and
- specific dynamics of the ecosystem in a certain period.

It is these patches with diverse features that make up the heterogeneity of the overall landscape. According to the viewpoints of landscape ecology, there are inseparably inherent relations among patch, boundary, and heterogeneity. The patch can be small or big, but it includes all connotations of grassland resources: Soil and landform are key elements of land management; the plant is the essential factor of primary production; and the animal is the key factor of secondary production. The different patches are integrated by energy flows (or dissimulated organism and products), which spread naturally or flow artificially across the boundaries of different patches. The relations of matter (energy or its dissimulated organism) and patches can be written as:

$$p(X1, X2)\ at = (vj, hj)+(ri, pai, di, si, pri)$$

where p(X1, X2) denotes the probability of matter movement form X1 to X2 within time t; vj and hj denote the heterogeneity of animals in the landscape patch j; ri is movement rate of animal i; pai is movement route; di is the density of individual animal; si denotes the social intervention; and pri is environmental adaptability of an animal.

This formula can be used to describe the energy exchange among the different patches by making some slight changes:

$$p(x1, x2)at = (vj, hj)+(ri, pai, di, si, pri, ei)$$

where ei is the energy carrying by each organism. It is this kind of energy exchange that forms the essence of grassland production and is essential to the subsistence of herbivorous animals. Each animal requires a fundamental niche and most herbivorous animals require more than one ecological element to satisfy their subsistence. According to the principle of optimum foraging and cost-benefit ratio, animals obtain food and habitats at different times and places in the most economic way. The diversity of the landscape patches is very suited to meet the diverse requirements from the animals. In fact, there are series of matching relations between landscape and animals. These matching relations provide effective measures to overcome system discordance and improve the system as well.

However, the principle of landscape heterogeneity is poorly understood and ignoring the matching principle of landscape and grassland resources has led to long-term system discordance and economic losses due to misdirection of grassland and production planning.

6. Conclusion

- China has large areas of grassland and rich animal and plant resources. The grassland area is over 393.097 million ha, which accounts for 41% of the total territory and is 3.7 times the size of the arable land.
- Due to the harsh natural conditions, population pressure, and misdirection of management policies, the grasslands in China are generally in a ecological crisis. The major problems in land use planning can be attributed to system discordance between plant production systems and animal production systems.
- The grassland degradation is being intensified, which is illustrated by desertification and salinization in north China and rocking and baring processes in the south. The fundamental way out for it is developing the grassland agricultural system in these areas.
- For the above reasons, several principles should be followed, i.e., the principle of sustainable production and ecological productivity; integration of summit community with pre-summit community; the principle of system coupling; and the matching of landscape and grassland resources.

7. References

Ren, Jizhou, Zhang, Zihe, Hu Zizhi, Hou Fujiang, Chen quangong: The strategy for Chinese grassland resources development, Acta Praculture (in publishing).

China National Committee for the implementation of the United Nations convention to combat desertification (CCICCD): China Country Paper to Combat Desertification, 1997

Li Jiandong, Zheng Huiying: The management of salinized land and its biology mechanism, 1996

Agricultural Bureau of Guizhou Province, Soil Research Institute of Academe Scinia: The Soil of Guizhou Province, 1980, Preface ii

Ren Jizhou, Wan Changhui: System coupling and mountain-oasis-desert Ecosystem, Acta Prataculture, 1994, [3], 1; 8

Ren Jizhou, Zhu Xingyun: The main pattern of agro-grassland system Hex Corridor and its system discordance, Act Prataculture, 1995 [1] 69;80

Ren Jizhou: The eco-productivity of agriculture, Acta Prataculture, 1995 [2] 1;5