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Hierarchical Framework for Rangeland Management
-A Case Study in Inner Mongolia-

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Abstract: Compared with equilibrial theory, which attributes vegetation change to livestock grazing rate simply, non-equilibrial theory has paid much importance on the impact of abiotic factors on vegetation growth. In fact, both stocking rate and abiotic factors are key variables for vegetation growth. However, it is very difficult to choose proper paradigm for the management of an ecosystem because the definition of equilibrial or non-equilibrial ecosystem is always depending on scales. By analyzing NDVI data and collecting related data on rangeland management and water resources through herders' interviews, this article tries to establish a hierarchical framework for rangeland management in Xilingol Prefecture to combine equilibrial and non-equilibrial theories in order to provide reference for animal husbandry development and explore root reasons for rangeland degradation.

Keywords: Equilibrial ecosystem, Hierarchical framework, Inner Mongolia, Non-equilibrial ecosystem, Rangeland management,

1. Introduction

Since 1984, Livestock and Rangeland Double-Contract Responsibility System (LRDCRS) has been implemented in pastoral areas of Inner Mongolia. The rangeland was divided into small pieces and distributed to herders' households because it was perceived that a herder would protect his rangeland when he had property rights on rangeland. Therefore, the traditional nomadism was crumbled and herders' livestock are limited in herders' contracted rangeland. In fact, the LRDCRS cannot be implemented without two assumptions: invariable abiotic factors and stable and uniform vegetation growth. Based on these two assumptions, a stable stocking rate can be evaluated and carrying capacity management can be implemented on every herder's contracted rangeland. However, rangeland degradation has become more and more serious in Inner Mongolia. About 38.7 million ha natural rangeland, 44.4% of total rangeland of Inner Mongolia, degraded and desertified at moderate to heavy degree, and rangeland productivity decreased by 30-70% (Joint Research Team of rangeland Ecology, 2003). Meanwhile, many herders have fallen into poverty. Livestock population per capita in 24 pastoral counties decreased from 108 SSU in 1998 to 33 in 2004 (Dalintai, 2006). To explore root reasons for these problems, it is necessary to rethink production system of rangeland animal husbandry to test if the institutional arrangement can match rangeland ecosystem characters.

For the characters of rangeland ecosystem, the debate between equilibrium and non-equilibrium paradigms has developed to the requirement to combine these two theories because both of them are needed in management practices (Illius *et al*., 1999; Briske, 2003). Different from equilibrium paradigm, which has minimized the importance of climatic variability and episodic events on ecosystem behaviors (Ellis and Swift, 1988; Wu and Loucks, 1995), non-equilibrium paradigm has minimized ecosystem regulation and stability and placed greater emphasis on external disturbances as drivers of ecosystem behaviors (Briske, 2003). However, neither paradigm alone is comprehensive enough to explain ecosystem dynamics effectively. Vegetation dynamics is impacted by both grazing and climate variability (Fernandez-Gimenez and Allen-Diaz, 1999). In fact, the theoretical explanations of the equilibrium and non-equilibrium paradigms explicitly emphasize the importance of scale in their determination (Wiens, 1989; Levin, 1992; O'Neill, 2001). Stability at larger scales implies a 'stable equilibrium state' (Illius and O'Connor, 1999). The hierarchical patch dynamics paradigm may be seen as a way of unifying these two perspectives across multiple scales of space and time (Wu and Loucks,

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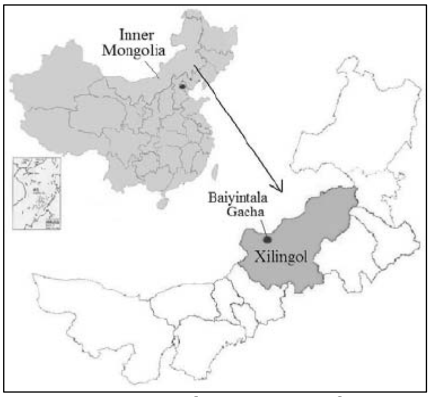

Fig. 1. Location of Xilingol Prefecture in Inner Mongolia.

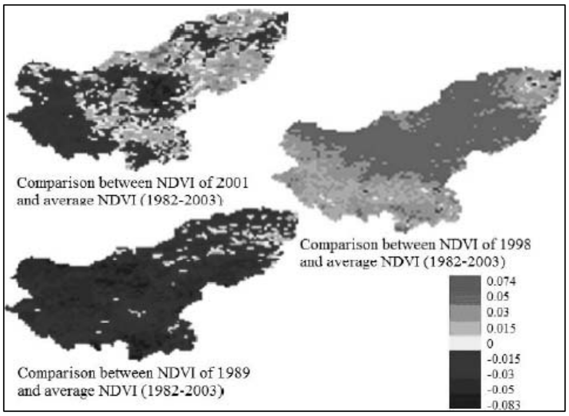

Fig. 2. Comparison between average NDVI of 2001/1989/1998 and the average NDVI of 22 years. Data source: Environmental and Ecological Science Data Center for West China.

1995). However, how to establish this hierarchical framework to provide guidance for practical management is still a problem.

2. Materials and Methods

Our case study is Xilingol Prefecture, which locates in the middle of Inner Mongolia (**Fig 1**). The area of Xilingol Prefecture is 203,000 km^2 and the population was 975,000 in 2004. The precipitation in most area of Xilingol Prefecture is 200 mm to 350 mm, and it is more than 400 mm in east point and less than 150mm in part of western region. Because water resource is the most important resource for dryland, the hierarchical framework is established based on water resource in three spatial scales. For large scale of whole prefecture, the relationship between vegetation growth and precipitation is tested by using NDVI (1982-2003) and precipitation data (1971-2005) collected by 13 weather stations in Xilingol Prefecture. For middle and small scales, the data collected from Herders' interviews in July of 2007, which was conducted in Baiyintala Gacha (Mongolian word for village) in northwest of Xilingol prefecture.

3. Results and Discussion

Water resource has different heterogeneity on different spatial and temporal scales. According to the requirement of animal husbandry management in Xilingol Prefecture, the hierarchical framework is composed of three levels: large scale, middle scale and small scale.

3.1 Large scale: the whole Xilingol Prefecture

On large scale of the whole prefecture, the precipitation exerted important impacts on vegetation growth. The precipitation of 1998 is much higher widely in Xilingol Prefecture. In some regions, the precipitation is 200 mm more than average level of 22 years (1982-2003). However, in 1989 and 2001, there is very little rain in most areas of Xilingol Prefecture. **Figure 2** shows that NDVI changed to a large degree due to the highly variable precipitation. The correlation analysis of NDVI and precipitation in different counties in Xilingol Prefecture also shows the same result (**Table 1**). In all counties of Xilingol Prefecture, NDVI has highly related with precipitation.

Table 1. Correlation analysis of NDVI and Precipitation in different counties of Xilingol Prefecture (1982-2003).

Region	Banner	Correlation coefficient	Data	Sig. probability	Sig.
Eastern region	Dongwuzhumuqing	0.759	270	0.000	0.01
	Xiwuzhumuqing	0.756	234	0.000	0.01
Central region	Abaga	0.756	270	0.000	0.01
	Xilinhot	0.771	270	0.000	0.01
Southern region	Taipusi	0.851	234	0.000	0.01
	Duolun	0.806	270	0.000	0.01
	Xianghuang	0.763	270	0.000	0.01
	Zhenglan	0.801	270	0.000	0.01
	Zhengxiangbai	0.775	270	0.000	0.01
Western region	Dongsu	0.681	270	0.000	0.01
	Xisu	0.597	270	0.000	0.01
	Erlianhot	0.519	270	0.000	0.01

3.2 Middle scale: the radius is 25 km to hundreds km

On middle scale, it is always possible for herders to find resort place in drought because of high spatial heterogeneity of precipitation within this scale. In fact, pervasive drought or wetness throughout Xilingol Prefecture, like 1989 and 1998 in Fig. 2, is very rare. In most years, the precipitation distribution is similar to the status in 2001 in Fig. 2: some regions had good rain and others had little rain. According to our interview in Baiyintala Gacha in western region of Xilingol Prefecture, there is a serious drought in 2006, which compelled herders moving their herds to other places to avoid drought (‘aoter’ in Mongolian). Most herders found rangeland available in the same county, which were over 25 km far away. Of course, herders in Baiyintala Gacha do not always need to go ‘aoter’. They also received ‘aoter’ when they had abundant rain (**Table 2**). Therefore, for middle scale, there is high heterogeneity of rainfall within this scale. But seeing the middle scale as a whole, the total vegetation productivity is comparatively stable and herders can always find available resource to avoid drought impacts within middle scale.

Table 2. Information on receiving ‘aoter’ in Baiyintala Gacha.

Year	Coming from	Distance (km)	Households number	Relationship
2007	Alashanbaolige	>25	1	Relatives
2005	Alashanbaolige	>25	2	Friends
	Baiyinhalatu	>75	1	Friends
2004	Baiyinbaolidao	>50	6	Friends
	Alashanbaolige	>25	4	Friends/relatives
	Abaga	>200	1	Relatives

3.3 Small scale: the radius is less than 25 km

On small spatial scale, water resource is very limited to meet livestock drinking requirement. **Figure 3** shows rangeland map of two herders’ groups in Baiyintala Gacha. The rangeland on the left is 4 km wide and 10 km long, and the rangeland on the right is 8 km wide and 8 km long. Seeing rangeland of herders’ groups as a whole, there is at least one water well in every group, and also some water puddles. After rainfall, livestock can drink water from puddles. If there is no rain for long time, they can drink from water well. In this way, livestock can get enough water resource if they are grazed within the whole group rangeland. However, under the LRDCRS, rangeland was distributed to individual households (four households in left map and five households in right map). Some households, such as Bayaer and Taoga, are very lucky to have water wells, but other households can only have puddles or even no water resources, such as Xiao Xinjiletu, Huaer and Gangsuhe. As we know, it is impossible to dig water well in every household in drylands due to limited distribution of groundwater and high cost. Therefore, it is very difficult for them to meet water requirement of livestock in daily management.

Based on the hierarchical framework of water resources established in Xilingol Prefecture, the heterogeneity of water resources on different scales has been explained, which can provide theoretical basis for rangeland management and animal husbandry development. First of all, on large scale of Xilongol Prefecture, according to the correlation analysis of precipitation and vegetation growth, precipitation has exerted most important impacts on vegetation growth. Therefore, for policy makers, it is urgent to attach much importance on precipitation in the process of rangeland management. Moreover, it is impossible to achieve the goal of rangeland restoration by using current dominant methods, which only depends on the decrease of livestock population and forage plantation. Secondly, on middle scale with radius of 25 km to hundreds km, there is high heterogeneity of precipitation within this scale. Drought happens frequently and randomly in some areas, which compels herders go ‘aoter’ to avoid loss of livestock. Meanwhile, rainfall is abundant for other regions, which can provide forage for these ‘aoter’ livestock. Therefore, seeing from middle scale as a whole, the total precipitation is comparatively stable and livestock confronted with

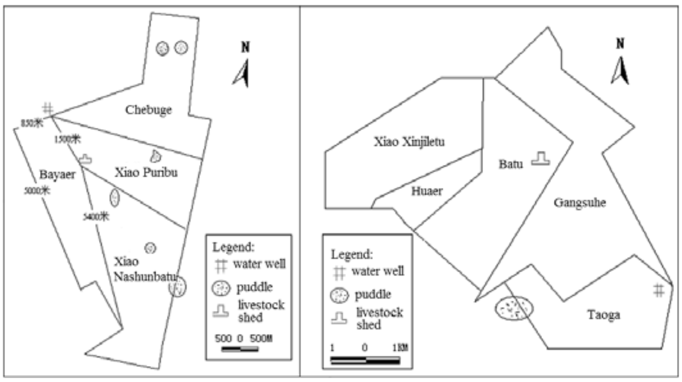

Fig. 3. Rangeland map of herders’ groups in Baiyintala Gacha.

drought can always find resort places to survive. For animal husbandry, it is necessary to provide possibility to move herds within middle scale to help herders maintain their herds, which is the basic asset of their livelihood. Thirdly, on small scale with radius less than 25 km, livestock can find stable water resource provision on this scale under normal weather conditions. However, if rangeland is divided into small pieces, it is very difficult for individual household to find enough water because the heterogeneity of groundwater is very high in these small pieces. Therefore, in daily management of animal husbandry, there is a minimum unit for rangeland use, e.g. rangeland of herders' group, to meet basic livestock requirement for water and achieve stable development of animal husbandry.

Compared the assumptions of LRDCRS with this hierarchical framework of water resources, it is obvious that the LRDCRS is implemented based on over-simplified or even incorrect ecosystem characters. In arid and semi-arid areas in Xilingol Prefecture, it is impossible to have invariable abiotic factors. The precipitation fluctuates to a large degree and the CV of precipitation has exceeded 30 percent in some regions. Under this condition, it is also impossible to have stable and uniform vegetation growth. However, the implementation of LRDCRS had divided rangeland into small pieces and made it impossible to move herds. The extensive use of individual sites as management units has probably contributed to the perception that non-equilibrium vegetation dynamics occur more frequently than if larger land areas had been evaluated (Landsberg *et al.*, 2002). Therefore, herders have been confronted with increased risk and rangeland has been used improperly, which led to degradation. For the LRDCRS, there are four aspects need to be re-thought urgently. First of all, carrying capacity management should be carried out on large scale or middle scale, which has stable total vegetation productivity, rather than on individual household's rangeland. Secondly, for livestock management, it is important to pay attention on its moving and distribution according to the change of precipitation distribution rather than only focusing on total livestock population. Thirdly, it is more reasonable to combat frequent drought by moving herds rather than transport high-price forage to feed livestock in drought. At last, the only way to decrease cost of livestock breeding is herders' cooperation, including rangeland use, livestock management, marketing and so on.

4. Conclusions

In conclusion, institutional arrangement must be designed based on natural resource heterogeneity and ecosystem characters. Otherwise, the institutional change will cause destructive results even though it is started with a good will. Based on the hierarchical framework of water resource in Xilingol Prefecture, there are three recommendations for rangeland management. On large scale, rangeland management policy should pay more attention on the impact of precipitation on vegetation. On middle scale, moving strategy to combat drought should be facilitated by local government to minimize herders' loss. On small scale, it is necessary to promote herders' cooperation to ensure groundwater availability in daily management of livestock breeding.

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