Rangeland Degradation in North China Revisited? A Preliminary Statistical Analysis to Validate Non-Equilibrium Range Ecology

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Over the past decades, the concepts of carrying capacity and Clementsian vegetation succession have come under attack from the theory of Non-Equilibrium Range Ecology. The new theory hypothesises that in arid regions with high rainfall variability the ecology is mainly determined by climatic and not biotic factors, such as animal grazing. The argument carried further implies that 'rangeland degradation' and 'desertification' are not caused by overgrazing but are part of a natural process of vegetation decline and growth in response to rainfall, which ruminant numbers merely follow. Few empirical studies involving time-series data have been executed to substantiate Non-Equilibrium Range Ecology. This article hopes to make a contribution to the current debate with a statistical validation of one of its main postulates: the correlation between ruminant numbers and rainfall. The analysis is conducted with figures from the People's Republic of China: a state in which rangeland policy is an outstanding example of management on the basis of carrying capacities and Clementsian succession theory.

CHINA'S RANGELANDS: LAND TENURE AND DEGRADATION

> 'Sometimes we are so sure of something that we don't need to see the evidence. That rangelands are being reduced to desert through overgrazing by domestic livestock is received wisdom. But … such a view may be seriously flawed' (Mace cited in CSCPRC [*1992: 189*]).

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Of the total surface of the People's Republic (9.6 million km^2), it was estimated in 1989 that 41.7 per cent (or 400 million hectares) was rangeland. This rangeland refers to a natural resource of great geographical and ecological diversity, which varies from the alpine meadows on the Tibet-Qinghai Plateau at an altitude of over 4,000 metres above sea level, to the steppe and desert in arid regions such as Xinjiang (with less than 150 mm of annual precipitation), and the hilly grassland (frequently termed 'wasteland' by Chinese scientists and officials) in the sub-tropical zone of Yunnan Province, or the semi-arid Loess Plateau. Seen from the socio-economic and ethnic perspective, the variation is no less. The people dependent on rangeland include (semi) nomadic Mongols, Tibetans and Kazakhs, as well as sedentary livestock farmers like Hui Muslims, or Han Chinese.

Over 50 per cent of China's rangelands are located in the north, the area that is regarded as the traditional pastoral region. The northern rangelands are strategically important, with their location in the border zones and inhabited by ethnic minorities with possible separatist agendas. They also represent vast grazing areas for a livestock sector with promising future perspectives. China is one of the largest meat producers in the world and could become a major exporter of pork. Since the economic reforms started in 1978, meat production per capita (including pork, beef, and mutton) has gone through a tremendous development (9 kg per capita in 1978, to 39.2 kg in 1996). In 1996, the total output value of animal husbandry accounted for over 30 per cent of the total agricultural output value [*ZT, 1997: 14, 24, 107*].

In order to raise livestock production, political attention was also drawn to the natural resource on which it depends: the rangelands. Currently, the central government believes that the greatest threat to rangeland development is posed by overgrazing and agricultural reclamation. It is said that the rapid increase of grazing animals in the pastoral areas (from approximately 29 million ruminants in 1949, to 90 million in the early 1990s), as well as the decline in the area of rangeland due to reclamation (an estimated loss of 6.5 million ha over 1949–92), has led to serious rangeland degradation and desertification. Li Yutang, the former head of the Grassland Section within the Ministry of Agriculture, wrote in 1994 that over one-third of usable rangeland had been reported degraded to a certain degree, while total biomass production per ha had declined by 30–50 per cent compared with the 1950s [*Li, 1994: 29*].

Since the establishment of the People's Republic, much effort has been spent in rangeland management and protection. However, the Rangeland Law – the first national law pertaining to rangeland policy – was not promulgated until 1985. One of the pillars of Chinese rangeland policy

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encoded in the Rangeland Law is the idea of carrying capacity. It is generally believed that by taking into account the climatic and ecological conditions of a certain site, one can calculate a 'proper use level' at which the grazing pressure of animals does not exceed the regenerative capacity of the vegetation. According to Chinese policy-makers, sustainable rangeland use is a matter of calculating and assigning carrying capacities for rangeland plots, devolving the user and management rights of these plots from the collectives to individual herding households and subsequently seeing to it that the livestock quotas per plot are not exceeded.[1]

However, research in rangeland management in the 1980s and 1990s has given rise to the speculation that biotic factors (animals and humans) have much less influence on rangeland ecology than was initially assumed. In fact, the consequence of these scientific findings go as far as placing conventional notions of rangeland management, such as 'vegetation succession', 'desertification' and 'degradation' in a rather controversial light. As the carrying capacity concept is at the very core of rangeland policy in China, criticism of its use could have far-reaching policy implications.

The critics of conventional rangeland management – for the purpose of the article termed 'New Range Ecologists' and their theory 'New Range Ecology' (or Non-equilibrium Range Ecology) – call for a proper distinction between equilibrium ecological systems, in which conventional notions of vegetational succession and carrying capacity are valid, and the non-equilibrium biotopes, where the concept of carrying capacity cannot be meaningfully applied. In terms of precipitation and precipitation variability, a large proportion of China's rangelands can be characterised as non-equilibrium systems. In order to verify the theory of New Range Ecology, a statistical model has been developed to test its validity for three counties in one of northern China's autonomous regions: the Ningxia Hui Autonomous Region (hereafter: Ningxia). Ningxia is situated in the arid and semi-arid transition zone of the Ordos Plateau and the Loess Plateau. The counties that have been singled out for analysis are: Yanchi, Tongxin, and Guyuan County (see also map below).

The article consists of three sections. The first is an introduction to the premises of the statistical model, the methodology and variables employed, and the research sites (geography, ecology and socio-economic background). After this follows the presentation of the results of the analysis. The article will then close with a discussion of the implications of the analysis for New Range Ecology and Chinese rangeland policy. Before turning to the main sections of the article, I will first give a short summary of the theoretical underpinnings of New Range Ecology.

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RANGELAND MANAGEMENT THEORY: NEW LENSES, NEW PERSPECTIVES

The 'New Range Ecologists' particularly criticise the idea of carrying capacity, which rests on the notion of plant succession, ascribed to Cowles and Clements [*Clements, 1916; Cowles, 1899*]. In the Clementsian view, a particular ecological site is characterised by a typical and persisting vegetation – the climax vegetation – that is in equilibrium with the given climate and soil type. If the vegetation is disturbed, for example, in the case of land reclamation or grazing, it will return from sub-climax to climax through a series of successional vegetation types. The essential task of rangeland management is to assess the stable sub-climax of a site at which grazing pressure is counterbalanced by the natural regenerative power of plants: carrying capacity. Consequently, it is believed that rangeland degradation occurs if the carrying capacity is exceeded due to overstocking. Fairly recently (in the 1980s and 1990s), mainstream rangeland management based on these principles has been strongly criticised by a group of rangeland scientists.

Their first point of critique – actually more a refinement of mainstream rangeland theory – is that the concept of carrying capacity as defined by mainstream rangeland theory, remains void unless it is linked to the objective of rangeland management. Different objectives mean different forms of animal exploitation and desired offtake, and thus, different ecological conditions of the rangeland. Therefore, carrying capacity is dependent on what one aims for with a natural resource; sustaining enough wildlife to attract tourists, maximum production of high quality meat, or subsistence pastoralism. In other words, there are 'no "objective" biological criteria which will permit the specification of carrying capacity without prior reference to the goals and objectives of managers' [*Behnke and Scoones, 1993: 6*].

Secondly, the conventional idea of carrying capacity is that ruminant numbers are held in check through the availability of forage, which ultimately leads to a situation of a steady state through negative feedback. This proposition presumes that the conditions for plant growth – rainfall and temperature – are constant. However, evidence from the field, as well as research on desertification on the basis of satellite images have cast serious doubt on this proposition [*Binns, 1990: 106–13; Forse, 1989: 31–2; Hellden, 1988: 8–12*]. In particular, in arid regions with rainfall between 250–500 millimetres per year and an annual rainfall variability exceeding 30 per cent, the climate and not biomass production, has been found to be the ultimate factor limiting herbivore population growth. The reason is that a steady state (at which biomass production could be in balance with

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grazing pressure) is never reached in such ecological systems, due to erratic climatic fluctuations. The system is thus not one of equilibrium, or Clementsian succession, but a non-equilibrium ecological system. As a result, the term 'rangeland degradation' becomes controversial, as it could be inherent to a natural process of ecological rise and fall, rather than an irreversible process of human or herbivore-induced decline.

The distinction between equilibrium and non-equilibrium systems is not the full story. Whether erosion occurs is not only limited by the extent to which a biotope is climate-driven, but also by the physical and chemical properties of the soil. On this issue, Behnke and Scoones have stated that:

> Sandy, nutrient-poor soils produce vegetation which is relatively stable in productivity, unpalatable, and resistant to herbivore grazing pressure. Rangeland types on these soils may be relatively less exposed to degradation. … Savanna types on fertile clay soils exhibit the opposite characteristics … and may be susceptible to degradation if rainfall is reliable enough to sustain high stock densities [*Behnke and Scoones, 1993: 26*].

The following point of critique touches on the assumption of the fixed boundaries associated with the carrying capacity of one rangeland plot. It is argued that in non-equilibrium grazing systems flexible land tenure arrangements and high herd mobility are a more rational strategy. Grass production of rangelands varies over time and over space. By moving animals from zone to zone, periods of optimal 'carrying capacity' are exploited, while resource-scarce periods can thus be avoided. Calculated as an economic mean, fixed stocking rates pose the problem of underutilisation of the resource during high productivity, while destocking cannot be timely and adequately realised during periods of ecological stress.

Last but not least, there is the thorny issue of actually calculating carrying capacity. According to Behnke and Scoones, carrying capacity can be termed 'a calculation of short-term livestock feed and demand', as its main focus is not longterm degradation, but 'the capacity of the system to meet immediate goals at alternative stocking densities' [*Behnke and Scoones, 1993: 17; de Leeuw and Tothill, 1993: 77–88*]. In order to arrive at the carrying capacity, one first needs to make an estimate of the total production of edible plant material within a given area, which is normally expressed in tonnes of dry matter per hectare. The total plant production per hectare is then compared to the average forage requirement per animal. There are several methods to calculate the carrying capacity. Some make use of a so-called 'proper use factor' representing the portion of forage that can be consumed without causing degradation of the resource. Other methods deal with vegetation production in terms of quality, rather than the quantity of forage.

However, most calculations of carrying capacity fail to take into account such factors as plant production variability as a result of landscape heterogeneity, herd composition (different animals have different grazing strategies and feed requirements), and compensatory regrowth of browsed plants that can result in higher forage quality and sometimes higher plant production. The main point of critique that has been formulated, however, is the idea that rangeland degradation can be expressed as a direct function of stocking levels (or carrying capacities). In other words, that there are objective criteria for assessing the 'sustainable' stocking level at which no degradation occurs.

As is common in China and in mainstream rangeland science, degradation of rangeland is measured in terms of vegetational change (with each type of vegetation being a particular stage in a scale from non-degraded or climax vegetation to highly degraded rangeland). For example, in Ningxia a higher incidence of the unpalatable dog's bone (Cynanchum komarovii, or *laoguatou*) in rangeland is associated with more serious degradation (see Appendix). Yet, for pastoralists and bureaucrats in China and abroad the main concern is not degradation expressed in stages of vegetational change, grass productivity and soil conditions, but degradation in units of declining livestock production.

As remarked above, large fluctuations in plant species composition are characteristic of arid and semi-arid rangelands in regions with highly variable rainfall. As Walker notes, this vegetation shows an extreme resilience to external shocks, as it is subject to frequent disturbance (Walker cited in Behnke and Scoones [*1993: 21*]). If one attempts to assess degradation in these areas, it is essential that vegetational change due to short-term grazing is distinguished from changes as a result of erratic rainfall conditions. However, it is exactly the ecological dynamics of rangelands in the arid and semi-arid regions that are least well understood, making any attempt to assess degradation in terms of vegetational change a precarious undertaking.[2]

THE VALIDATION OF NON-EQUILIBRIUM RANGE ECOLOGY FOR THE NINGXIA CASE

Research Sites: Yanchi, Tongxin and Guyuan Counties

The statistical analysis will be carried out with data for three counties in Ningxia. Ningxia borders Shaanxi Province on the east, Inner Mongolia on the north and west, and Gansu Province on the south. Instead of being administered as a province, Ningxia was established as an autonomous

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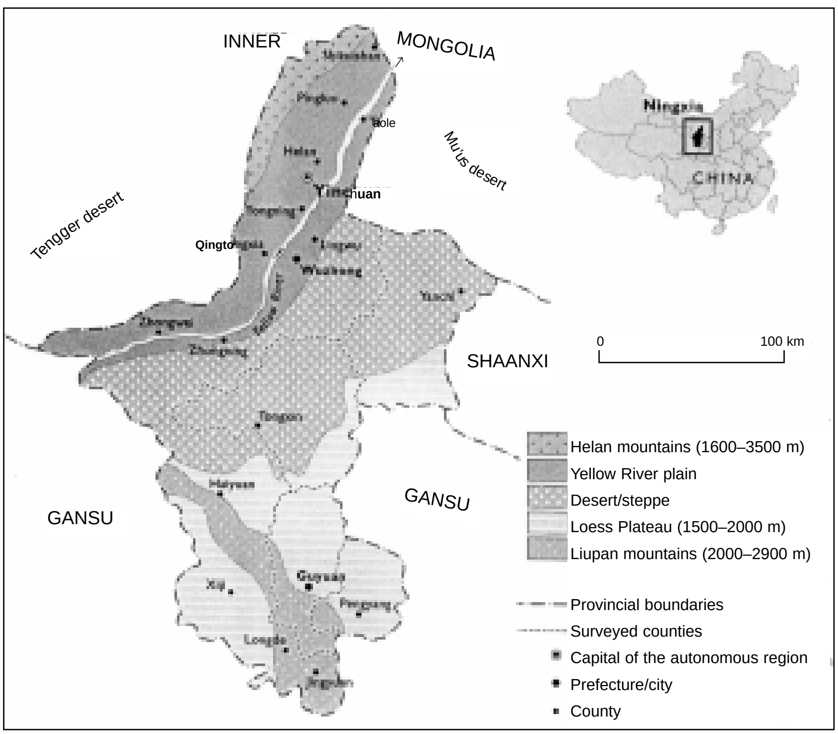
region for the Hui Muslim minority in 1958. Ningxia is situated in the central Asian steppe and desert region with a continental, temperate climate increasing in aridity from the south (subhumid) to the north (arid). In the north, Ningxia is enclosed by the Tengger (north-west) and Mu'us deserts (north-east). The total land surface is 51,800 square kilometres and the total population in 1993 was 4.95 million people, of which 1.64 million (33 per cent) belonged to the Muslim Hui.[3] The Hui is a religious and ethnic minority that socio-economically lags behind the majority of the Han Chinese. This becomes clear by a brief look at the statistics: 64 per cent of the Hui live in the seven poorest counties[4] in the autonomous region – Tongxin, Guyuan, Haiyuan, Xiji, Longde, Jingyuan and Pengyang – in contrast to only 29 per cent of the Han Chinese. Furthermore, 60 per cent of the Hui, which includes 78 per cent of the women, are defined as illiterate, against 36 per cent of the Han, including 49 per cent female [*NSD*, *1994: 65; Gao*, *1995: 57*].

MAP OF THE NINGXIA HUI AUTONOMOUS REGION



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The three counties selected for the analysis – Yanchi, Tongxin, and Guyuan – all belong to the pastoral and semi-pastoral region in Ningxia, characterised by a mixed farming operation of animal husbandry and agriculture. The livestock farmers in the three counties do not practice nomadic pastoralism, but drive their herds to the rangelands in the early morning and return to the village when the sun sets.

Yanchi has a total surface of 6,758.6 square kilometres. It is located in the transition area from the Loess Plateau in the south to the Ordos Plateau in the north. The county is flat in the northwest (the sandy steppe region), and mountainous in the southeast. It is located at approximately 1,400 to 1,500 metres above sea level, with the lowest point at 1,295 metres and the highest at 1,951 metres (Chenjia Mountain). The average annual precipitation (including rain, snow and hail) is 290 millimetres, while the average annual temperature is 6.6ºC. Generally, there are three to five frost-free months per year. The total area of rangeland is 4,598 square kilometres, or 68 per cent of the county area. Yanchi counted 32,246 inhabitants in 1993 [*YXNQB, 1985: 128*].

Tongxin County adjoins Yanchi and shares basically the same climatic and ecological characteristics. Situated on the southwestern corner of the Loess Plateau, the relief gradually rises in elevation from the north towards the south with an altitude between 1,260 and 2,600 metres. The average annual precipitation is 275 millimetres and the average annual temperature is 8.3ºC. The total surface of Tongxin is 7,018 square kilometres of which 63 per cent is rangeland (4,442 km^2). In 1993, there were 62,203 people living in Tongxin [*NTXNQB, 1984: 227*].

In contrast to the previous two counties, Guyuan – in the southern tip of Ningxia – shows considerable diversity in landscape and ecology. The relief varies from 1,450 to 1,800 metres in the Qingshui river valley (20 per cent of the total county surface), to 1,600–2,100 metres on the north-eastern Loess Plateau (46 per cent of surface), and 1,900–2,900 metres in the south-western Liupan mountains (34 per cent of surface). The county has original forest, rangeland, and mountain meadows. The average annual precipitation is 460 millimetres, with an average annual temperature of approximately 6ºC. The frost-free period is 120 to 140 days. The total surface is 3,878 square kilometres, of which rangeland covers 1,684 square kilometres (43 per cent). Guyuan is relatively the most densely populated of the three counties with 89,594 inhabitants [*Chen and Song, 1993: 3, 408*].

Drought is the main natural hazard in the three counties. It severely limits plant growth, causing shortages in forage. In contrast to neighbouring Inner Mongolia, the occurrence of blizzards is limited in Ningxia. Spring is the most difficult period for sheep and goats, as biomass production is still low, while the ewes and young lambs require regular feeding.

In terms of soil properties, both Yanchi and Tongxin have sandy, rather saline, calcium-rich sierozem soils with a large infiltration capacity. The main rangeland categories on the sierozem soils are the semi-desert and desert steppe (*banhuangmo caoyuan/huangmo caoyuan*, see Appendix). The vegetation which thrives at such soils, is drought-resistant, and medium palatable for ruminants (50–70 per cent palatability of biomass production), while biomass production is stable and hovers at 1,500–1,850 kg/ha. This implies that the population of herbivores feeding on the vegetation, will fluctuate less than the population living off vegetation on more fertile, clayish soils. However, due to the high proportion of silt in sierozem soils (approximately 70 per cent), there is a considerable risk of compaction and erosion if stocking densities are high [*NNKS, 1988: 491*].

Guyuan, on the other hand, has cultivated and dark loessial soils, with the main exception being the grey cinnamon soils in the Liupan mountain range. The main rangeland category on the loessial soils is the steppe (*gancaoyuan*, see Appendix), which occupies 65 per cent of the total rangeland resources. The vegetation on the loessial soils has a stable and higher biomass production (5,600 kg/ha), yet, with a lower palatability (approximately 30 per cent) than in Yanchi in Tongxin. The risk of wind and water erosion of the sandy loess is great at high stocking densities [*Chen and Song, 1993: 94 and 408; NCZZD, 1985: 144–6*].

Degradation of the Rangelands: Facts and Contradictions

Although Chinese government reports and scientific articles generally present rangeland degradation as an indisputable fact, the reality is more unruly. In the early 1980s, almost one-fifth of the total area of rangeland (840 km²) in Tongxin County and over 90 per cent (4,533 km²) in Yanchi County were reported desertified. The main causes for rangeland degradation identified by the local government were overgrazing, and for Yanchi in particular, digging for medicinal herbs.

On closer inspection, the statistics are not that unambiguous. In 1995, a county government report stated that 3,593 square kilometres rangeland was affected by desertification in Yanchi. In fact, this is a decline of 940 square kilometres compared with the 1980s, for which no explanation is given. Moreover, the actual stocking rates of both counties are well below the estimated carrying capacity (estimated carrying capacity in Tongxin 602,403 sheep equivalents and actual number of sheep and goats 390,015; estimated carrying capacity in Yanchi 400,000 to 420,000 and actually 383,760 sheep and goats) [*NNK, 1995: 95; YXNQB, 1985: 128; NSD, 1994: 278; NTXNQB, 1984: 141*]. The sources from which these figures were derived do not account for this discrepancy. Adhering to mainstream range ecology, one possible explanation could be that grazing is concentrated

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causing degradation within a particular area, which entails that the total stocking numbers can fall below the estimated carrying capacity. Seen from the non-equilibrium perspective, the discrepancy shows that trying to estimate carrying capacities is impractical.[5]

The rangelands in Guyuan County have also been reported degraded to varying degrees. In an internal government report of 1985, 20 per cent of the rangeland was classified as severely degraded, 67 per cent as medium degraded, and 11 per cent as lightly degraded. The stocking rates for Guyuan are more consistent than for Yanchi and Tongxin. The total carrying capacity in Guyuan was estimated at 445,519 sheep equivalents, whereas the actual stocking rate was 527,753 sheep equivalents in 1980 [*NCZZD, 1985: 144, 146*].[6]

The problem of desertification has also been researched through the analysis of historical records. Today scholars generally agree that the origins of desert expansion in northwest China can be traced back to the Ming dynasty (1368–1644), although human influence at the time was said to be limited. Not until the end of the Qing (1644–1911) and the early Republican era (1912–49) did degradation become serious due to agricultural reclamation [*Chen, 1986: 69–82; Zhao, 1981: 24–47; Ma, 1984: 38–47*].

According to the New Gazetteer of Ningxia, compiled in 1540 during the reign of the Ming-dynasty emperor Jiajing, the environment of the town Tiezhuquan in the middle of Yanchi County (formerly: Huamachi), was one of abundant and fertile grassland suitable for reclamation (*wo rang ke geng zhi di*). This description is confirmed by the report of Liu Tianhe, an official who had inspected the area. Towards the end of the Ming dynasty and the beginning of the Qing (1644–1911), chronicles already describe Yanchi (and not Tiezhuquan in particular) as a region of 'flying sands' (*feisha*). On the basis of the above, Chen Yuning concluded (rather cautiously) that military colonisation caused great parts of Yanchi County to be reclaimed for agriculture and livestock farming, which put increasing pressure on the grasslands and led to desert expansion [*Chen, 1993: 175–7*]. However, the existent historical data on reclamation of Ningxia do not warrant Chen's conclusion and the origins of desertification must probably be sought in the first half of the twentieth century [*Ho, 2000b*].

Despite the questions raised by New Range Ecology, the perception of desertification at the grassroots confirms government reports written at the central and provincial level. During fieldwork carried out in 1996, it was found that desertification is widely reported by village cadres and farmers. In the same year, the grain harvest of Shangjijuan village in Ma'erzhuang Township in Yanchi was completely lost as crops vanished under a thick layer of sand. The village leader of Shangjijuan village stated:

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> Rangeland has become so scarce nowadays that we simply *have* to decrease our number of sheep. We cannot raise any more sheep than we do now. In the past, we could still cut grass for fodder up to July, and the sheep were fat by the time of the Festival of Pure Brightness (*Qingming*, fifth lunar month).

From my 1996 rural survey of 194 farm households in the desert steppe area, 92 per cent of the respondents stated that rangeland had degraded. Among them, 87 per cent said that rangeland had mostly deteriorated after the start of the rural economic reforms in 1978. Another 61 per cent found that desertification hampered the establishment of forage bases and artificial rangeland. From the total survey of 284 households (which includes the loess area in south Ningxia) a total of 90 per cent of respondents reported that rangeland had degraded.

Main Proposition and Methodology

Behnke and Scoones have stated that ‘climatic instability, manifested in low annual rainfall levels and high coefficients of rainfall variation …, is probably the most reliable single indicator of the shift from equilibrium to non-equilibrium grazing systems. Soil factors may none the less suppress or exaggerate the effects of an erratic climate’ [*Behnke and Scoones, 1993: 26*]. As we have seen above, the sierozem and loessial soils of Yanchi, Tongxin and Guyuan sustain a stable vegetation of low or medium palatability. These soil types are prone to compaction and erosion at high stocking rates during a long term.

As regards precipitation and precipitation variability, two of the counties can be characterised as non-equilibrium ecological systems. They are situated in the arid zone (250–500 mm) and the precipitation variabilities are respectively 32 per cent (Yanchi) and 30 per cent (Tongxin). Guyuan forms the exception with a lower precipitation variability of 24 per cent – six per cent removed from the 30 per cent norm.[7] In the three counties, the greater portion of precipitation (around 60 per cent) falls in the period July to September. Rain and snowfall in winter and spring are low, and account for 10–15 per cent of the annual precipitation.[8]

For the analysis it is important to note that the main difference between the Chinese pastoral sector and that of African countries, is that livestock farming in China is embedded in an extensive institutional framework of state institutions that can offer a large variety of veterinary services and thus basic security for people and livestock. The Chinese state reaches deeply into rural society. The main state institution responsible for rangeland management and animal husbandry – the Department of Animal Husbandry – is represented at the township level with veterinary stations and a

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rangeland officer, and at the county level with grassland management stations. The reach of the Chinese state provides for a cushioning of natural disasters.

The main question that many New Range Ecologists would like to see answered is: to what extent is rangeland degradation (including desertification) caused by biotic factors – here: overgrazing – and to what extent is it a result of a natural waxing and waning process of rangeland in response to rainfall (and thus is not ‘degradation’ at all)?

The best way to test this would be through an analysis of vegetation and soil conditions in relation to precipitation over a given period. However, as these figures were not yet available at the time of writing this article, I have limited myself to test one of the main theorems of Non-equilibrium Range Ecology: in arid regions with a rainfall variability over 30 per cent the growth of herbivore population is mainly affected by rainfall. If Non-equilibrium Range Ecology applies to the three analysed counties, we might expect fluctuations in sheep and goats numbers (unlike the past, horses and camels are not raised in present-day Ningxia) to correspond to changes in precipitation.

The analysis is complicated through the involvement of many other variables, such as evapotranspiration, price levels, and political and institutional changes. It would be helpful to summarise the data on these variables while preserving the most essential aspects. Therefore, I have employed the Principal Components Analysis (PCA)[9] of the Statistical Package for the Social Sciences software (SPSS).

The PCA is a multivariate technique (literally: analysis of many variables). The aim of the PCA is reducing the number of the original variables (for example, rainfall and temperature; demand and supply) by creating a smaller set of them (climate; economy). The newly created variables are called Principal Components and the total variance explained by a Principal Component is called the Eigenvalue. The price paid for the PCA is a loss in variance. However, the gain is a clearer insight into a complex phenomenon because one has reduced it to its bare essentials.

The period of analysis covers 27 years, starting from 1957 until 1983, roughly corresponding to the period of collective agriculture in China. There are two further remarks that need to be made as regards this period.

First, for a similar analysis in an African setting – on which basis New Range Ecology actually drew its main conclusions – the economic factor must be included. However, the Chinese case offers us with a unique opportunity to test New Range Ecology for a centrally planned economy with a limited role for the economic factor, which greatly facilitates the analysis. There are four reasons for this:

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(i) the prices for wool, cashmere and mutton were set by the state;

(ii) rural collectives had to produce according to annual quotas for state procurement, while decisions about livestock production were taken at the commune level and not at the actual locus of production: the team. In addition, as confirmed by livestock farmers and officials, changes in the sale quantity of live sheep and goats was extremely difficult, even during droughts when it was necessary to relieve the pressure on the limited forage supplies;

(iii) the greater proportion of livestock production in most areas in China was for farmers' subsistence. Self-subsistence is the main driving force for livestock production rather than profitability;

(iv) farmers' production response to prices mainly concerned non-staple foods, such as vegetables, eggs, and fruits.[10]

Naturally, the economic factor cannot be ruled out when analysing a period of 27 years. Over such a considerable span of time, changes in population, infrastructure and technology are likely to have triggered changes in factor prices and production costs.[11]

The second remark is that the choice of this period allows us to eliminate the digging of medicinal herbs as one of the main factors on which rangeland degradation is presently blamed in Ningxia. The commercial exploitation of liquorice root in the steppe area (Yanchi and Tongxin) picked up after the onstart of the rural reforms and developed into its present large-scale, frenzied digging when the medicinal herbs market was liberalised in 1993. The maximum amount of state procurement of liquorice in Yanchi County rose from 754 tons in the 1950s to over 4,000 tons in 1993 [*NNK, 1995: 189*]. If we presume that withdrawal of water for irrigation (the three counties are dominated by dryland agriculture) has no significant influence on rangeland ecology, overgrazing and agricultural reclamation are the two factors of importance for the period of analysis. Agricultural reclamation has not been marked as a factor of rangeland degradation by the Ningxia authorities, but will generally occur in the more fertile areas suitable to cultivation. Unfortunately, reliable figures on reclamation that could be meaningfully employed in the analysis are lacking.

THE VARIABLES

The following variables have been included for the statistical analysis (see also Figures 1, 2 and 3, and Tables 1 to 3 in the Appendix):[12]

Sheep Equivalents

The sheep equivalents[13] are measured at the county level at the end of the year. Both sheep and goats are very sensitive to droughts and diseases, but their population growth is simultaneously characterised by rapid recovery and increase. Dahl and Hjört have calculated an annual growth of 18 per cent for sheep and 33 per cent for goats (only for meat production). Cattle herds fluctuate with a much lower frequency, while camel herds are relatively static [*Dahl and Hjört, 1976: 231*]. As there might be a time lag between drought occurrence and the decline in sheep equivalents (in the case that sheep are weakened in the winter when plant growth stops, and eventually die in spring) the analysis has been carried out with the observed number of sheep equivalents at year t, and with a lagged response at year t+1.

Precipitation in Millimetres

Precipitation is measured at the county level at the end of the year. Precipitation includes rain, hail, and snow.

Evapotranspiration in Millimetres

Evapotranspiration is measured at the county level at the end of the year. Evapotranspiration includes evaporation of all water surfaces, as well as the active transpiration by vegetation. The reason why evapotranspiration has also been taken into account is because low rainfall in a particular year does not necessarily imply drought. Drought also depends on the water discharge by rivers and evapotranspiration [*Dietz et al., 1994*]. As no data for water discharge could be obtained, only the figures for evapotranspiration can serve as a check to determine real drought conditions.

Provincial Data for Agricultural Land Affected by Drought in Mu

Agricultural land affected by drought in mu (1/15 ha) is defined as 'a decrease in agricultural production of over 30 per cent' [*ZGTM, 1995: 54*]. The reason for including these figures, is the difficulty in determining real drought conditions as mentioned in the section above. In order to provide a more quantifiable indicator for the impact of drought on livestock production, the figures of agricultural land affected by drought have been included. However, as Chen and Buckwell have rightly stated: 'the definition of a "natural disaster" is itself open to local interpretation. It may sometimes be in the interests of the authorities to declare a natural disaster when crop output is down' [*Chen and Buckwell, 1991: 74*]. In addition, care must be taken with this set of data, as they represent provincial and not county data, while the data are missing over the period 1966–76.

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The Woolprice in Yuan per Kilogram

During the collective period, self-subsistence livestock farming in Ningxia focused on the production of wool, rather than mutton, as sheep were kept as 'small cash' and not slaughtered except during adverse times. Input for livestock production mainly consisted of forage, which was freely grazed or gathered on rangeland, or sometimes cultivated by the team. For this reason, the wool price has been singled out as the main economic factor. However, as stated above, the economic factor is minimal and the inclusion of the wool price as a variable should make no significant difference. Therefore, this variable has been included as an extra verification of the importance of the economic factor in the analysis.

The wool price used here, represents the price set by the government of the Ningxia Autonomous Region according to national standards. During the era of the People's Communes, the prices for wool and mutton were kept artificially low. On the other hand, a boom in price levels occurred after the liberalisation of the market for livestock and animal products. For example, the nominal price for wool in Ningxia has increased by only 39 per cent over the period 1957–84, while it rose 223 per cent from 1984 until 1996. As for the nominal price for mutton in Ningxia, it increased by 92 per cent during 1957–80, whereas a rise of 229 per cent occurred over 1980-88 [*NSD, 1989: 454*].

The Periods of Great Political and Socio-Economic Changes

For the purpose of the analysis, this variable is represented as a dummy variable, expressed in '1' (period of stability) and '0' (period of change) per year. Encoding the political factor as a binary variable involves three basic, yet, disputable propositions: (a) periods of stability and change are relatively clear-cut and evenly spread over one year; (b) there are no differences in the intensity of stability or change in a given period; (c) there are no regional differences in the intensity of stability or change.[14]

For this variable, the following years are of importance: (1) 1957–62; (2) 1965–71; and (3) 1976 (see also Table 1 below). A detailed discussion of the historical background falls outside the scope of this article, and has been treated separately [*Ho, 1998: 201–13*]. The periodisation employed here, basically coincides with what is generally regarded by academics as the periods of great socio-economic and political changes: the period of the Great Leap (1958–61) and the Cultural Revolution from 1966 to 1976 [*Chen and Buckwell, 1991: 52–3*]. However, contrary to the generally accepted periodisation, the year 1957 has also been marked as a period of change for the livestock sector. The reasons are the centralisation of the wool market, and the subsequent establishment of the state production quota and procurement system for wool. In addition, the year 1962 has been

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included, because the institutional structure of the communes did not consolidate until the proclamation of the Sixty Articles in that year. It is hypothesised that this had a significant influence on livestock production.

Concerning socio-economic and political changes in the 1960s and 1970s, the periodisation has been set one year earlier than the start of the Cultural Revolution, because of the official launching of the Dazhai movement in Ningxia in 1965. In this analysis, the entire period of the Cultural Revolution has not been designated as influencing animal husbandry (either negatively or positively). In spite of the negative image of the Cultural Revolution, the early seventies in China saw a shift in developmental goals for animal husbandry towards sustainable and integrated development, while the destructive effects of agricultural reclamation in rangeland were recognised [*Ho, 1999: 82*]. It is postulated that the re-affirmation of the Sixty Articles in 1971 can be regarded as having had a positive impact, after which the livestock sector stabilised as a result of the aforementioned shift in the aims of development. Last but not least, 1976 is regarded as a year of change, because of the many changes at the political center. Possibly the changes at the center also had their impact regionally. It should be noted, however, that 1976 was not an exceptional year politically in Ningxia.

For the period after 1976, the greatest influence of the rural reforms on animal husbandry in Ningxia might be expected in 1983 (and not in 1978, when the rural reforms started), as team members were then allowed to contract and own sheep and goats for their own production, which stimulated production incentives. For this reason, the analysis ends with 1983.

RESULTS OF THE ANALYSIS AND EXPLANATORY FACTORS

The PCA has reduced the total variance of twelve variables to three maximally *independent* (uncorrelated) Principal Components. Table 2 shows that the first component has an Eigenvalue (total variance) of 3.98. Therefore, the first component explains 33.2 per cent of the variance in the original 12 variables. The second component adds 25.3 per cent to it and the third component 18.2 per cent. In total 76.7 per cent of the original variance is explained. This means that a considerable data reduction – from 12 variables to three components – is accompanied with a loss of over 20 per cent of explained variance. More positively, one can also state that almost 80 per cent of the variance of 12 variables can be explained with only three components.

Turning to Table 3, we see that the variables of precipitation and evapotranspiration of the three counties – in statistical terms – ‘load high’

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TABLE 1

OVERVIEW OF NATIONAL AND REGIONAL EVENTS (1957–83)

Year	National events	Local Events in Ningxia
1957	– Rectification campaign, April – Anti-rightist campaign, June	– wool price fixed for Ningxia – January Guyuan Prefecture directive on sheep ownership Higher Agricultural Producers' Cooperative – November directive on the Consolidation of Collectives in Ningxia (animal ownership, tools, etc.)
1958	– First People's Commune in Henan, April – Start of Great Leap Forward, May – Excesses of Great Leap become clear, December – Communist Party resolution: Three ownership levels of People's Commune, December	– First People's Commune, September – People's Commune movement reported fulfilled in October
1959	– Severe droughts in 17 provinces and autonomous regions, in combination with false reporting of communes leads to failure of Great Leap	– Ningxia Communist Party regulation: reaffirmation of three level ownership (private plots and animals for team members, etc.), May – Famine reported in several regions of Ningxia
1960	– 12 Articles about Village Work ('3 freedoms' basis for contracts, labour, production and costs between administrative levels), November – China reveals extent of 1960 natural disasters and worst famine in a century, December	– Beginning of Grain-first policy in Shizuishan Commune, which eventually leads to reclamation of pasture in Ningxia, December – Famine spreads throughout Ningxia, aggravated by natural disasters (drought, hail, storm)
1961	– Sixty Articles (draft), ownership of animals and (range)land vested in Production Brigade	– Ningxia Communist Party report about problems in People's Communes: bad herding, neglect of animals, assessing right proportion between agriculture and livestock farming, February – Famine persists
1962	– Sixty Articles (revised), stabilisation of People's Commune ownership structure, basic accounting unit Production Team, September	
1964	– Mao calls for 'learn from Dazhai' – Beginning of 'Four Clean-ups campaign'	
1965	– Publication of Wu Han's 'Dismissal of Hai Rui' preludes the Cultural Revolution (1966-76), November	– Notice of Autonomous Region Party Committee: official start Dazhai Movement in Ningxia, February

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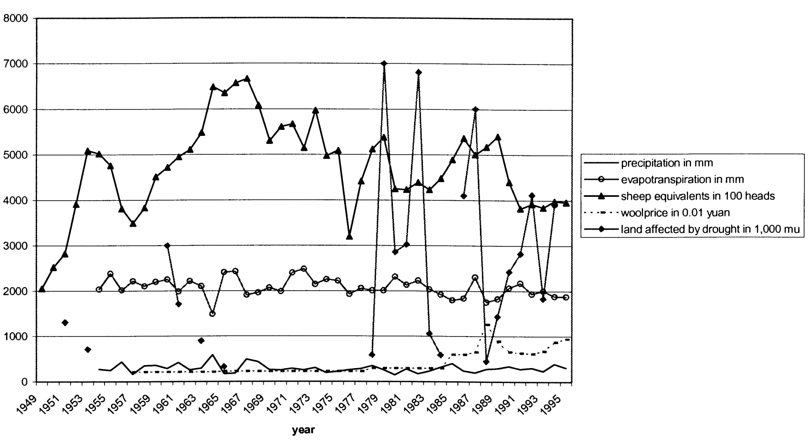
TABLE 1 (cont.)

Year	National events	Local Events in Ningxia
1966	– Proclamation of 16 points' directive guiding the Cultural Revolution, August	– Local initiatives to revert private plots and trade, egalitarian tendencies re-emerge, Production Team as basic accounting unit instead of People's Commune
1967	– Winter Communist Party directive, 'no change in private plots'	
1968	– Dazhai model of workpoints established for People's Communes	
1971	– Reaffirmation of 60 Articles (again more freedom for sidelines and private plots), April	
1976	– Hua Guofeng becomes premier, Deng Xiaoping dismissed – Death of Mao Zedong, September – End of Cultural Revolution	

Source: Song [*1990*]; NNHJSB [*1988*]; Gray [*1990: lii-lxiv*].

FIGURE 1

VARIABLES FOR YANCHI DATA SERIES (1949–95)



Source: Provided to author by NSD.

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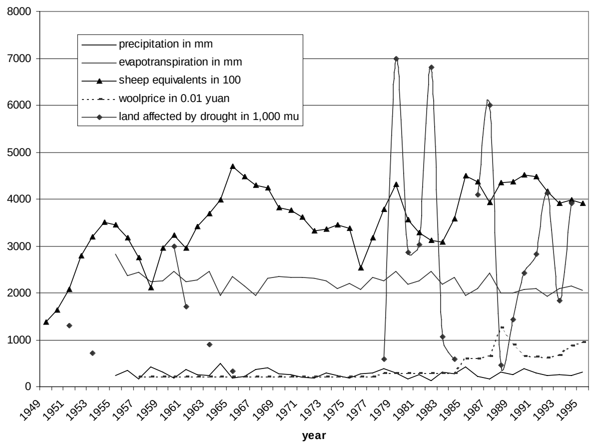
FIGURE 2

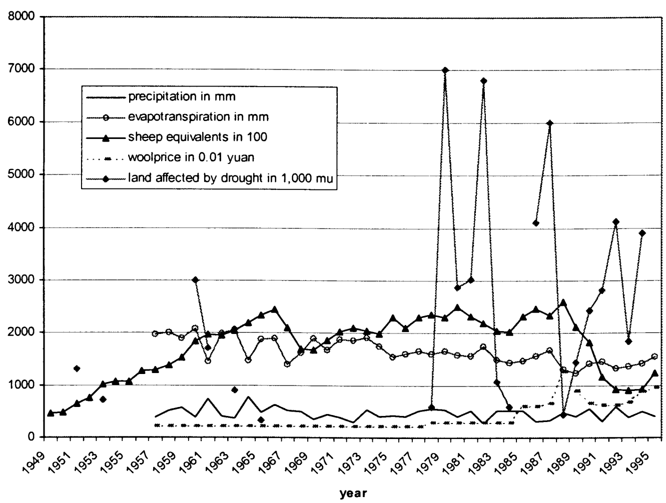
VARIABLES FOR TONGXIN DATA SERIES (1949–95)



Source: Provided to author by NSD.

FIGURE 3

VARIABLES FOR GUYUAN DATA SERIES (1949–95)



Source: Provided to author by NSD.

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TABLE 2

EIGENVALUES AND EXPLAINED PERCENTAGE OF VARIANCE

Component no.	eigenvalue	% of variance	cumulative %
1	3.98192	33.2	33.2
2	3.03275	25.3	58.5
3	2.18364	18.2	76.7

TABLE 3

ROTATED FACTOR MATRIX (VARIMAX)

Variable name	Component 1	Component 2	Component 3
TONPREC	0.91986	–0.12403	–0.12061
YANPREC	0.85651	–0.21644	–0.05320
YANEVAP	–0.84858	–0.12002	0.09206
GUYPREC	0.81151	–0.07967	–0.03118
TONEVAP	–0.69139	0.04066	–0.38384
GUYEVAP	–0.63388	–0.56960	–0.27548
WOOLPRICE	–0.08051	0.88541	0.00432
POLPERIOD	0.03593	0.77115	–0.20133
DROUGHT	–.30940	0.76978	–0.05458
GUYSHLAG	0.06175	0.72211	0.52644
TONSHLAG	–0.03537	0.10751	0.93052
YANSHLAG	–0.03692	–0.20112	0.92730

Abbreviations:

TONPREC	Precipitation in mm, Tongxin
YANPREC	Precipitation in mm, Yanchi
YANEVAP	Evapotranspiration in mm, Yanchi
GUYPREC	Precipitation in mm, Guyuan
TONEVAP	Evapotranspiration in mm, Tongxin
GUYEVAP	Evapotranspiration in mm, Guyuan
WOOLPRICE	Woolprice in yuan per kg
POLPERIOD	Political period (0 = unstable; 1 = stable)
DROUGHT	Land affected by drought in 1,000 mu
GUYSLAG	Lagged sheep equivalents at year t+1, Guyuan
TONSLAG	Lagged sheep equivalents at year t+1, Tongxin
YANSLAG	Lagged sheep equivalents at year t+1, Yanchi

(or show strong mutual correlation) on the first component with negative values for evapotranspiration. The second component brings together the wool price, the political factor, land affected by drought, and the lagged sheep equivalents of Guyuan County alone (the non-lagged response yielded a weaker pattern of variance and has been left out). The lagged sheep equivalents of Yanchi and Tongxin have a high component loading on the third component.

What could be a possible interpretation of these results? The interpretation of the components could be made clearer by first presenting what would have been the ‘ideal results’ confirming Non-equilibrium Range Ecology. In this case, we would have expected that the variables for precipitation, evapotranspiration and lagged sheep equivalents would cluster together per county in three components, with the remaining variables loading high on one or more separate component(s).

In other words, as the theory postulates that sheep equivalents mainly keep pace with precipitation and are negatively correlated to evapotranspiration (higher evaporation means more arid conditions, and thus, a higher death rate and lower animal levels) we should ideally have obtained one ‘Yanchi component’, one ‘Tongxin component’ and one ‘Guyuan component’, each combining three correlated variables: precipitation, evapotranspiration and lagged sheep equivalents. According to the theory, the remaining three variables measured at the provincial level – ‘wool price’, ‘political period’ and ‘drought’ – should show a weaker correlation with precipitation, evapotranspiration and sheep equivalents and would be grouped together in one or more separate Principal Component(s).

However, we have now derived three components of which the first is overtly ‘climatic’ – composed of six variables measured at the same (county) level with positive values for precipitation and negative for its opposite: the evapotranspiration. This means that years of low rainfall are also characterised by high evapotranspiration levels.

The second component is the most problematic among the three. As many data are lacking for the drought variable and it has been measured at a different level than precipitation and evapotranspiration, its appearance in the second component and not in the climatic one – more logical as low precipitation and high evapotranspiration points to drought conditions – should not be accorded much importance. If we restrict ourselves to the remaining three variables, there is a correlation between the wool price, the sheep equivalents of Guyuan and periods of political change. There is no rational explanation for such an outcome, which is specific for Guyuan County alone. I propose to regard this result as an exception until further research has been conducted for its falsification.

The third component unites the lagged sheep equivalents of Tongxin and Yanchi counties and could therefore be termed the ‘livestock’ component, showing a relation between the sheep and goats’ population of the two counties. This component only tells us that the trends in sheep equivalents between the two counties are similar (and correlated), but there are no other variables included that could explain why there is correlation.

In sum, the results of the Principal Components Analysis do not confirm the proposition of New Range Ecology that in a non-equilibrium ecological system[15] the herbivore population dependent on rangeland will fluctuate according to rainfall and evapotranspiration conditions. Several explanations for these results can be proposed.

First, as noted in an earlier section, the sierozem and loessial soils of the three counties can support a vegetation that is drought-resistant, of low palatability, yet relatively stable in biomass production. This implies that the animal population living in this ecosystem will fluctuate less than expected under non-equilibrium conditions. In addition, a region with a higher rainfall variability than in Yanchi, Tongxin and Guyuan might produce a stronger correlation between precipitation and herbivore population.

Second, in contrast to nomadic pastoralists in other parts of China and the world, we are dealing with sedentary livestock farmers in the three counties. Moreover, the farmers run a mixed farming operation in which the dependency on animal husbandry in terms of rural income in 1996, could vary from 19 per cent in the north of Yanchi (Chengjiao Township) to almost 60 per cent in the middle of the county (Ma'erzhuang Township).[16] Mixed farming enables farmers to provide their animals with the remains of agricultural crops as forage, and – especially after the economic reforms – to escape into alternative sources of income when times are hard for the sheep and goats. As a result, a more conservative stocking strategy seems likely with lower and more constant animal numbers. Subsistence nomadic pastoralism, on the other hand, is characterised by an opportunistic strategy in which the number of livestock is maximised according to the availability of forage [*Sandford, 1983: 38*]. The sedentary character of livestock farming in Ningxia puts farmers more in the reach of the state.

The last possible explanation lies in China's well-developed and comprehensive structure of state institutions catering to the needs of nomadic herdsmen and sedentary livestock farmers, as compared to African nations. During times of droughts, blizzards or other natural disasters, the local state can provide support with extra forage, relief grain, and the like. Generally, the local state organs engage in aerial sowing of rangeland, extend loans (and during the collective period also experimented with livestock insurance), provide veterinary services, assist in the introduction of improved livestock varieties, the construction of sheep folds, and the digging of wells.

In the agro-pastoral regions, the township is the institutional node where most services come together in the veterinary station, the forestry station, and the credit cooperative. The veterinary stations carry out vaccination programs twice per year at relatively low cost. The township rangeland officer is responsible for the monitoring of rangeland resources, the provision of free grass seeds, and the construction of forage bases in the vicinity of villages to alleviate grazing pressure. He sometimes cooperates

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with forestry cadres in the township and the (administrative) village in afforestation activities (shelterbelts against desertification) and the planting of drought-resistant forage and shrubs on rangeland. Furthermore, livestock farmers can obtain low-interest credit for the purchase of fodder through the township credit cooperative.

As a result of the above, the shock of natural disasters in China is buffered by local state organs, causing less fluctuations in herd population and a more constant pressure on rangeland. However, it should be noted that the quality of livestock services has not been constant in time, in particular the period of the Cultural Revolution and the reform era may have been of influence.

Confirming experiences elsewhere in China, respondents in Ningxia stated that livestock was in a rather poor condition during the Cultural Revolution as the forage supply stalled, veterinary services collapsed, and collective livestock was neglected by dispirited herdsmen. As a result, livestock was more vulnerable to diseases and natural disasters, which led to higher herd losses than after 1976.[17]

However, the statistical analysis did not yield any evidence for a correlation between periods of socio-economic and political change, and livestock population. It appears that the production teams, brigades and communes were still able to muster enough manpower and resources to protect animals from adverse weather conditions and diseases, even during the Cultural Revolution when certain state organs were abolished. In this respect, the Wushenzhao and Dazhai mass campaigns which called for better forage supply, afforestation, and rangeland management most certainly had a positive impact. In addition, the descriptions of experiences during the Cultural Revolution must be approached with care, due to its official labelling as an historic mistake, which might have led to a misrepresentation of facts.

Furthermore, during fieldwork in 1996, many respondents stated that the late 1980s have seen an obvious decline in livestock services in Ningxia. The provision of free grass seeds, afforestation, aerial sowing, and rural credits have been stalled due to budgetary constraints of the central and local government. The veterinary stations were leased to their former employees, who now have to struggle to turn the stations into profitable enterprises. Due to rising vaccination fees (2 yuan for cattle, 0.5 yuan for sheep and goats, 0.1 yuan for poultry in 1996), farmers in poverty regions, such as Guyuan County (annual net rural income 250 yuan in 1996), generally chose to have only the draught animals vaccinated. According to a veterinarian only about 50 per cent to 60 per cent of the farmers can still afford to have their cattle vaccinated, resulting in more frequent livestock diseases. But the retrenchment of veterinary institutions during the reform era falls outside the period of my analysis.

CONCLUDING REMARKS: A NEW ROAD FOR CHINESE RANGELAND POLICY AND MANAGEMENT?

New Range Ecology has warned us to be cautious in dealing with the widely accepted causal relation between overgrazing and rangeland degradation. The main experimental zone that has provided New Range Ecology with its theoretical underpinnings is Africa. However, to my knowledge to date few attempts have been undertaken to test the theory empirically. Through a so-called Principal Components Analysis, I have attempted to validate the theory for three counties in China. The analysis included the following variables: precipitation, evapotranspiration, land affected by drought, sheep equivalents, wool price, and political change.

The Principal Components Analysis has yielded no evidence for the proposition that in a non-equilibrium system, animal herd growth and decline are primarily determined by the level of precipitation. It appears that other factors may be at play. New Range Ecologists have already suggested soil properties as an additional (minor) factor. I have argued further that the socio-economic and institutional environment play an essential role. The fact that China's economy was centrally planned with little change in economic conditions for a long period, allows us – as I have postulated – to downplay the economic factor. It has given us the unique opportunity to test Non-equilibrium Range Ecology in its most bare ecological essentials as conceived by New Range Ecologists. According to them, the economic element might be of less influence in subsistence nomadic pastoral societies like in Africa, as these have adopted an opportunistic herding management in order to adapt to environmental insecurity. Stocking rates in such societies are higher and tend to fluctuate more markedly in relation to forage availability. Yet, outside the African subsistence pastoralist setting, the offtake of livestock through marketing channels cannot be excluded from a scrutiny of livestock population response to external influences. An extension of my analysis with the period after 1983, would inevitably involve an elaborate economic analysis with variables such as mutton, wool, and cashmere prices; price level indices; and marketed produce.

Furthermore, comparing China with the majority of pastoral regions in African nations, the difference in the veterinary institutional structure catering to livestock farmers and pastoralists stands out. This system of veterinary services might well be able to buffer the shocks of natural disasters to animal herds. In addition, the sedentary and semi-nomadic character of livestock farming (in present-day China traditional pastoral nomadism with migratory movements throughout the year is no longer practised) gives the state a stronger and more pervasive reach into rural

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society. As a result, herds might be less hard hit when rainfall is scarce, than in the African case.

Applying the non-equilibrium framework for alpine sheep and yak rearing among nomadic Tibetans and Muslim Hui in Qinghai Province, Cincotta *et al.* have reached similar conclusions. They stated:

> … while … the equilibrial/non-equilibrial dynamics framework is extremely useful in investigating a pastoral system, it must be remembered that it draws only upon simple ecological models for its basic concepts. … The 'fully ecological' approach to a human-managed system may fall short in characterizing forage-livestock systems that are attached to markets, imported forage, and government services [*Cincotta et al., 1992: 21*].

However, it should be noted that the research of Cincotta *et al.* was *not* conducted in an arid non-equilibrium biotope (623 mm annual precipitation with a 22 per cent variability) and did not include time-series climate data.

It can be concluded that New Range Ecology is in need of further improvement. Further research on non-equilibrium ecological systems must not only consider other variables than rainfall and rainfall variability, but also needs to be extended for different countries in the world. As regards the model presented in this article, it can be refined in various aspects. First, more variables can be included that account for natural disasters other than drought (livestock pests, frost, etc.). Second, differences in the institutional infrastructure, or the sedentary/nomadic character of livestock farming can be accounted for through dummy variables. Third, analyses over time sequences longer than 27 years can be run, which in the Chinese case means that a distinction must be made between the period under central planning and free market forces. Furthermore, the dummy variable for socio-economic and political change can be improved by applying grading on the basis of economic indicators such as the nominal or real animal husbandry output value, and the animal husbandry commercial output value.

Now that we have found that New Range Ecology does not apply to the three counties, does that also imply that there is a more constant grazing pressure, and as a result, rangeland degradation and eventually desertification?

The only way to answer this question would be to link figures of the degraded area to ruminant numbers. However, reliable historical data about rangeland degradation and desertification, as well as figures of the ruminant population living on rangeland are generally fragmentary and difficult to obtain. An interesting option for the near past (1980s and 1990s) is the analysis through satellite images with time series data: research which is

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currently being undertaken for Yanchi, Yulin (Shaanxi) and the Ordos Plateau (Inner Mongolia).[18]

Yet, there seems to be some evidence that rangeland degradation and desertification does take place in regions classified as non-equilibrium ecological systems. For example, in the case of the Xinjiang Uyghur Autonomous Region, Tony Banks has remarked that 'the estimates given above of the long-term decline in natural grassland productivity, coupled with a long-term increase in sheep equivalent units, suggest that more than natural, rainfall-induced, perturbations may be at work. Some degree of long-term overstocking appears to be taking place' [*Banks, 1997: 9*]. Drawing on research material from Qinghai, Cincotta *et al.* also remain very sceptical towards the claims of Non-equilibrium Range Ecology and write: 'It can sometimes be difficult in high-altitude pastoral systems to sort out density-dependent (grazing, P.H.) from density-independent effects (climate, P.H.). … However, there is substantial evidence of grazing impacts on vegetation in common grazing areas' [*Cincotta et al., 1992: 18, 20*]. And as we have seen earlier in this article, also in the case of Ningxia, it appears that rangeland is degrading, or at least widely perceived as degrading by farmers and village cadres.

New Range Ecology has set the cat among the pigeons by posing the question whether rangeland degradation and desertification in semi-arid and arid regions result from overgrazing by animals, or whether it is part of a natural process of ecological waxing and waning due to highly variable rainfall conditions. However, much research is still necessary to refine the theory and test it in different areas. Whatever results future research of New Range Ecology will yield, it should not be forgotten that the theory has made a major contribution to rangeland science by drawing attention to the practical value of the carrying capacity as a guiding principle for rangeland policy and management.

Not only in Africa, but also in China, rangeland management on the basis of carrying capacities has proven to be unfeasible, or to involve very high enforcement costs. As Bartels has remarked: 'Though there are numerous attempts, we know of no case in which a government agency in Africa has successfully persuaded pastoral households, or a pastoral group to voluntarily reduce livestock numbers on rangeland to satisfy an estimated carrying capacity' [*Bartels et al., 1993: 99*].

Mainstream rangeland management attempts to fix the number of livestock on a certain plot of rangeland, which inevitably entails lower, conservative stocking rates (leading to an underutilisation of the resource during periods of rain abundance). In addition, many governments around the globe, including the Chinese, combine such measures with the sedentarisation of pastoralists. New Range Ecology, on the other hand,

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focuses on maintaining and supporting opportunistic herd management with high mobility and high stocking rates, which can be achieved by devolving decision-making to the community of direct rangeland users.[19] Moreover, instead of trying to avoid risk by cushioning shocks through veterinary care and services, some scientists have proposed to shift the emphasis to the development of an efficient marketing structure for a swift destocking of the surplus livestock in times of drought.

In response to the implementation difficulties of the Pasture Household Contract Responsibility System, scholars and officials within the Chinese Ministry of Agriculture have suggested that the responsibility of management and control for rangelands should be vested in the collective, be it the administrative or natural village, or smaller traditional social groups, such as the Mongolian *khot ail*. Not only are transaction costs (costs for contracting, enforcement, and information) lower in community-based management systems, but another advantage of rangeland management by the village lies in the fact that the village has many different economic responsibilities and administrative tasks. Like communicating vessels the village leaders can channel revenues from other economic activities to rangeland improvement. Operations not directly related to rangeland management could thus also contribute to the improvement of pasture.

Since the 1960s, Yanchi County has attempted to revive rotational grazing on the basis of what were deemed 'traditional' practices of Mongolian nomadism. The Yanchi experiments have already proven that rangeland can be successfully managed by a village community on the basis of a community-based arrangement at low transaction costs [*Ho, 2000: 407–8*]. In this sense, it may have opened up the way for possible reforms in current Chinese rangeland policy.

final version received March 2000

ACRONYMS

CSCPRC	= Committee on Scholarly Communication with the PRC
NCZZD	= Ningxia Caochang Zhibei Ziyuan Diaochadui
NNHJSB	= Ningxia Nongye Hezuo Jingji Shiliao Bianxiezu
NNK	= Ningxia Nonglin Kexueyuan
NNKS	= Ningxia Nongye Kancha Shejiyuan
NSD	= Ningxia Statistical Department
NTXNQB	= Ningxia Tongxin Xian Nongye Quhua Bangongshi
YXNQB	= Yanchi Xian Nongye Quhua Bangongshi
ZGTM	= Zhongguo Guojia Tongjiju and Minzhengbu
ZT	= Zhongguo Tongjiju

NOTES

1. For examples of the present calculations of carrying capacity in China, see Shi [*1996: 211–24*].

2. In order to circumvent the problem of vegetational change as an indicator for livestock production, it has also been proposed to look at rates of soil erosion in relation to livestock production [*Behnke and Scoones, 1993: 23*].
3. The official statistics give a total surface of 66,400 km². But recent surveys have shown that the actual surface is much smaller.
4. The rural net annual income per capita has been taken as indicator for poverty of the counties.
5. Sheep equivalents include sheep, goats, as well as larger livestock. However, the number of cattle cannot account for the difference between estimated carrying capacity and actual stocking rates as cattle are generally not herded on rangeland.
6. The total sheep and goats number in 1980 was lower than the actual carrying capacity: 251,000. However, due to a prolonged drought this had dropped to a mere 90,000 to 92,000 animals in the early 1990s, which must have considerably relieved grazing pressure (data provided to the author by NSD).
7. The figure of 30 per cent has been taken in arid areas by Shepherd and Caughly, and confirmed by Ellis *et al.* [*1993: 33*]. This norm is probably not an absolute standard, but a zone on a continuum. More research on the classification of non-equilibrium and equilibrium biotopes by means of precipitation variability is needed. However, in this article I will employ the 30 per cent norm as a strict dividing line. Including Guyuan County in the analysis will allow us to probe into the significance of this norm. As this county has a lower precipitation variability than 30 per cent it can be postulated that there is no or a weaker correlation between ruminant numbers and precipitation.
8. From the Yanchi county data 1954–95, the standard deviation (S) is 91.7 mm and the mean 291.3 mm. The standard deviation divided by the mean, multiplied by 100 per cent gives a variability of 31.5 per cent, rounded up to 32 per cent. For Tongxin the standard deviation (S) is 82.3 mm over 1954–95 and the mean 275.7 mm. This results in a variability of 29.9 per cent, rounded up to 30 per cent. Guyuan has an S of 109.3 over 1957–95, and a mean of 464.3 mm, resulting in a variability of 23.5 per cent, rounded up to 24 per cent.
9. Wrongly called 'Factor analysis' in SPSS.
10. In the case of grain production, the insignificant role of the grain price during the collective period has also been confirmed by Claude Aubert and Li Weimin (oral communication, 1998).
11. In a statistical analysis of farmers' supply response for grain production over the period 1952–84, Chen Liang Yu and Allan Buckwell have reached similar conclusions regarding the role of the economic factor during the collective period. They write: ' … the scope for the nation's grain producers in responding to price signals is significantly constrained'. Contrary to their earlier statements, the purchasing prices of grain, and the selling prices of all relevant inputs are included in their analysis, while stating that 'the main price signal for producers' supply response is hypothesized to be the grain purchasing price'. In addition, the two authors do not account for the role of inflation, with the argument that no suitable deflator is available for the 1960s and 1970s. However, it seems that an analysis that so prominently includes the economic factor as a determinant in farmers' supply response, could – even with general indices for rural retail prices – be much improved by considering inflation [*Chen and Buckwell, 1991: 59–61*].
12. In the graphs the sheep equivalents have been represented per 100 heads and the woolprice per 0.01 yuan in order to allow a better overview of the variables.
13. I have relied on the same conversion coefficients to standardize livestock numbers as employed by Longworth and Williamson: 1.00 for sheep and 0.82 for goats [*Longworth and Williamson, 1993: 24*].
14. One needs to research the (regional) impact of political changes in detail in order to justify a quantification of the intensity of a period of stability and change. For example, Dwight Perkins has shown that the economic consequences were more profound for the Great Leap Forward than for the Cultural Revolution. See also Perkins [*1991: 482–4*]. As my aim here is to present a simplified model for a preliminary examination of New Range Ecology theory, I would welcome any comments for its further refinement.
15. Note again that Guyuan does not meet the ideal-typical standards of a non-equilibrium

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biotope.

16. Figures derived from a rural survey carried out by Eduard B. Vermeer and myself in the summer of 1996, comprising 96 farm households in Tongxin and 98 in Yanchi. For Tongxin the proportion of dependency on animal husbandry fluctuates between 25 and 44 per cent.
17. This is also confirmed by Cincotta *et al.*, who stated that 'during collectivized management there where years when individual herdsman were known to have lost up to 20 per cent of their herd to winter mortality'. See Cincotta *et al.* [*1992: 15*].
18. The research on the basis of satellite images is done by Micael Runnström of the department of Physical Geography at the University of Lund. The initial stage of research employs the National Oceanographic and Atmospheric Administration (NOAA) satellite sensor, which are ten days', coarse resolution time series data of eight km pixels over the period 1982–93. The study uses a vegetation index (NDVI) showing the photosynthetic activity per eight km pixel, which is correlated to precipitation. In this way, increases or decreases in vegetation can be assessed. At present, results are still too preliminary to base any conclusions on [Brogaard and Runnström, 2000: 10–15].
19. It is at this point that New Range Ecology can be linked to Common Property Resource Management theory. As Jeremy Swift has stated: 'The non-equilibrium view of range ecology suggests … less rather than more centralised regulation, the devolution of control over local resources to producers and producer groups, and a shift in emphasis from enforcement to monitoring critical developments and servicing local needs' Swift cited in Behnke *et al.* [*1993: 30*].

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APPENDIX

TRANSLATION OF OVERVIEW OF RANGELAND AND RANGELAND DEGRADATION CLASSIFICATIONS IN NINGXIA ACCORDING TO NATIONAL STANDARDS

Rangeland Class (*deng*) according to typical vegetation per Rangeland Category (steppe, desert steppe, mountain meadow, etc.) determined by physical factors such as climate, soil and relief [*NCZZD, 1985: 25–42, 122–23, 127; NNKS, 1988: 279–89*].[1] A further subdivision into Groups and Types has been left out for reasons of space:

(1) Superior Class (*youdeng*): Superior class forage grass covers 60 per cent of total area.

Not further defined for Ningxia in terms of vegetation types per rangeland category, because the superior class occupies only 0.04 per cent (20,000 mu) of the total rangeland surface.

(2) Good Class (*liangdeng*): Superior class forage grass covers over 40 per cent of total area, good class over 60 per cent, mediocre class covers over 40 per cent.

steppe (*gancaoyuan*)

Artemisia frigida, Artemisia subdigitata
desert steppe (*huangmo caoyuan*)
Artemisia frigida, Artemisia subdigitata, Stipa breviflora

(3) Mediocre Class (*zhongdeng*): Good class forage grass covers over 40 per cent of total area, mediocre class over 60 per cent, and low quality over 40 per cent.

meadow (*caodian caoyuan*)
Artemisia gmelinii, Artemisia subdigitata, Carex heterostachya
semi-desert steppe (*banhuangmo caoyuan*)
Stipa bungeana, Artemisia giraldii, Artemisia desertorum, Glycyrrhizia uralensis
desert steppe
Stipa breviflora, Glycyrrhizia uralensis, Lespedeza potaninii, Ajania
grassy steppe (*caoyuanhua huangmo*)
Salsola passerina, Reaumuria soongorica
mountain meadow (*shandi caodian*)

Festuca rubra, Saussurea, Artemisia subdigitata

(4) Low Class (*dideng*): Mediocre class forage covers over 40 per cent of total area, low class over 60 per cent, and bad quality over 40 per cent.

desert steppe
  Convolvulus tragacanthoides, Sophora alopecuroides, Caragana
grassy steppe/steppe
  Nitraria tangutorum, Nitraria sibirica
mountain meadow
  Schigacoisporites, mesophytic grasses
bushy grassland (*guancong caoyuan*)
  miscellaneous shrubs
steppe
  Thymus mongolicus

(5) Inferior Class (*liedeng*): Inferior class forage grass covers over 60 per cent of total area.

desert steppe
  Oxytropis aciphylla, Cynanchum komarovii, Convolvulus tragacanthoides
arid desert (*ganhuangmo*)
  Kalidium foliatum, Nitraria
swamp (*zhaoze*)
  Scirpus tabernaemontani

Rangeland Grade (*ji*) according to grass productivity:

(1) grass production per mu (1/15 ha) over 1,600 jin (0.5 kg)
(2) grass production per mu between 1,200 and 1,600 jin
(3) grass production per mu between 800 and 1,200 jin
(4) grass production per mu between 600 and 800 jin
(5) grass production per mu between 400 and 600 jin
(6) grass production per mu between 200 and 400 jin
(7) grass production per mu between 100 and 200 jin
(8) grass production per mu below 100 jin

Degree of rangeland degradation
(1) lightly degraded (*qingdu tuihua*):

Original vegetation type dominates; slight decrease in good forage grasses in terms of growing season and palatability; beginning of growth of mediocre and low class forage; no poisonous and harmful grasses or only observed occasionally; slight decrease in cover rate and productivity of grasses; soil erosion not obvious; no distinguishable tracks of livestock.

(2) mediocre degraded (*zhongdu tuihua*):

Original vegetation has not yet changed, but growth is obviously unhealthy; good forage grasses in terms of growing season and palatability have decreased; mediocre and low class forage, poisonous and harmful grasses have obviously increased; the vegetation indicators for degradation of rangeland of the various regions, such as Peganum nigellastrum, Convolvulus ammanii, Artemisia scoparia, Neopallasia pectinata, Artemisia frigida, Artemisia desertorum, Ajania, Potentilla acaulis, Thymus mongolicus, Heteropappus altaicus, etc. have begun to emerge; decrease of cover rate and grass productivity; intensification of soil erosion; clearly visible tracks of livestock.

(3) heavily degraded (*zhongdu tuihua*):

Clear change in original vegetation and replaced by low and inferior class forage grasses; or the original vegetation has still been preserved, but the grass level is low, grass is scattered and few, and grass productivity and cover rate have obviously decreased; indicators for

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degradation have widely emerged; poisonous and harmful grasses have clearly increased; soil erosion is relatively serious; dense tracks and furrows by livestock; destruction of rangeland has already attained a very serious level.

NOTE

1. The standards set out in this overview are according to the national Technical Rules for the Investigation of Rangeland Resources in Key Pastoral Areas (*Zhongdian Muqu Caochang Ziyuan Diaocha Jishu Guicheng*) drafted by the Secretariat for the Investigation of Rangeland Resources in North China.

TABLE A1

PRECIPITATION AND EVAPOTRANSPIRATION IN MM (1954–95)

year	Yanchi County		Tongxin County		Guyuan County	
	precipitation	evapotransp.	precipitation	evapotransp.	precipitation	evapotransp.
1954	270.9	2039.3	–	–	-	–
1955	248.5	2379.2	235.0	2833.9	-	–
1956	435.0	2013.8	342.2	2369.1	-	–
1957	156.7	2215.3	160.3	2449.3	391.6	1960.9
1958	346.4	2100.4	417.2	2236.8	506.3	2005.3
1959	357.8	2198.4	307.5	2254.1	578.5	1903.3
1960	289.6	2251.2	181.0	2467.5	394.0	2071.9
1961	420.8	1982.5	358.1	2237.1	732.4	1460.6
1962	261.9	2216.5	264.4	2277.1	412.5	1978.8
1963	293.9	2105.8	233.5	2454.1	373.4	2065.6
1964	586.8	1491.0	491.8	1937.5	766.4	1475.4
1965	169.7	2412.3	178.7	2350.2	475.9	1879.2
1966	184.6	2430.0	217.5	2148.4	619.2	1887.2
1967	487.5	1908.9	367.5	1945.2	515.6	1403.8
1968	436.9	1961.6	401.6	2319.6	501.1	1612.7
1969	259.1	2065.7	270.2	2345.9	352.6	1887.0
1970	251.4	1985.6	260.0	2335.0	434.2	1679.1
1971	286.7	2394.7	193.2	2324.6	377.4	1872.4
1972	256.0	2481.1	191.6	2317.0	290.5	1859.6
1973	302.7	2145.9	292.3	2252.0	531.1	1916.7
1974	190.1	2252.4	242.9	2086.0	399.9	1742.0
1975	222.7	2220.7	188.6	2197.0	419.6	1552.4
1976	257.4	1925.4	274.9	2069.0	407.9	1599.2
1977	283.3	2055.8	286.7	2333.2	506.8	1662.4
1978	344.9	2008.0	384.6	2253.4	559.5	1599.2
1979	257.7	2006.6	295.8	2459.3	534.2	1654.9
1980	145.3	2307.3	164.4	2178.7	395.5	1584.8
1981	276.9	2131.1	264.6	2253.4	506.6	1557.2
1982	171.7	2227.0	128.4	2459.3	282.1	1739.5
1983	227.6	2039.9	311.7	2178.7	508.6	1497.6
1984	316.6	1920.2	274.9	2321.9	523.9	1442.0
1985	399.0	1798.5	427.8	1946.0	518.9	1473.2
1986	236.8	1838.9	224.1	2088.3	320.1	1557.9
1987	192.2	2301.9	160.7	2429.1	340.0	1667.4
1988	276.2	1757.3	315.0	1993.4	478.5	1313.1
1989	296.4	1824.3	257.3	1996.4	402.4	1226.5
1990	333.3	2070.1	386.7	2082.1	552.9	1412.7
1991	276.8	2176.6	296.0	2091.6	313.9	1448.7
1992	299.3	1940.5	241.6	1921.0	591.0	1326.0
1993	230.1	2003.9	252.1	2090.9	384.4	1366.6
1994	392.4	1886.4	241.4	2138.2	503.3	1418.0
1995	303.4	1880.3	317.8	2060.1	406.7	1536.9

Source: Provided to the author by NSD.

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TABLE A2

SHEEP EQUIVALENTS IN 1,000 HEADS (1949–95)

year	Yanchi County	Tongxin County	Guyuan County
1949	205	137	46
1950	252	164	48
1951	282	208	65
1952	391	279	75
1953	509	319	101
1954	502	351	107
1955	476	345	107
1956	381	317	127
1957	349	276	128
1958	383	211	138
1959	451	296	153
1960	472	323	184
1961	495	295	197
1962	511	341	195
1963	548	369	204
1964	648	398	218
1965	635	469	233
1966	657	448	245
1967	666	429	209
1968	608	423	169
1969	530	382	168
1970	561	377	185
1971	567	362	203
1972	514	333	210
1973	597	335	204
1974	497	345	199
1975	509	338	229
1976	319	253	210
1977	441	318	230
1978	512	378	236
1979	538	431	230
1980	425	356	251
1981	423	329	232
1982	439	312	219
1983	423	308	205
1984	448	358	203
1985	489	449	232
1986	536	436	247
1987	500	392	233
1988	517	434	259
1989	540	437	212
1990	440	451	182
1991	382	447	116
1992	392	416	92
1993	384	390	90
1994	398	398	92
1995	396	391	124

Source: Provided to the author by NSD.

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TABLE A3
WOOL PRICE AND AFFECTED LAND IN NINGXIA (1949–95)

year	woolprice in yuan	land affected by drought in 1,000 mu
1949	–	0
1950	–	0
1951	–	1310
1952	–	0
1953	–	710
1954	–	0
1955	–	0
1956	–	0
1957	2.12	0
1958	2.12	0
1959	2.12	0
1960	2.12	3000
1961	2.12	1710
1962	2.12	0
1963	2.12	900
1964	2.12	0
1965	2.26	330
1966	2.26	–
1967	2.26	–
1968	2.26	–
1969	2.26	–
1970	2.26	–
1971	2.26	–
1972	2.26	–
1973	2.26	–
1974	2.26	–
1975	2.26	–
1976	2.26	–
1977	2.26	–
1978	2.94	590
1979	2.94	7000
1980	2.94	2860
1981	2.94	3020
1982	2.94	6810
1983	2.94	1060
1984	2.94	590
1985	6.00	0
1986	6.00	4100
1987	6.55	6000
1988	12.66	450
1989	8.95	1440
1990	6.62	2420
1991	6.34	2820
1992	6.19	4120
1993	6.8	1830
1994	8.8	3900
1995	9.5	0

Source: Provided to the author by NSD.