



Rangeland degradation in Kazakhstan during the Soviet era: re-examining the evidence

S. Robinson[★], E. J. Milner-Gulland^{†*}, I. Alimaev[‡]

[★]*Ecology & Epidemiology Group, Department of Biological Sciences, University of Warwick, Coventry CV4 7AL, U.K.*

[†]*Department of Environmental Science and Technology, Royal School of Mines, Imperial College, Prince Consort Road, London SW7 2BP, U.K.*

[‡]*Kazakhstan Scientific Research Institute of Pasture and Fodder, Dzandozov Str. 31, 480035 Almaty, Kazakhstan*

The rangelands of Kazakhstan were historically used for nomadic pastoralism, with long migrations to make best use of the seasonal availability of pasture. In Soviet times, livestock production was intensified. From the 1970s concerns were raised in the Soviet literature about rangeland degradation, but very little was written about Kazakhstan's rangelands in the Western literature. Rangeland science in the Soviet system uses rather different methodologies to those in the West; this needs to be taken into account when comparing the two literatures. Here we use literature reviews, fieldwork and modelling to assess the likelihood that Kazakhstan's rangelands were overgrazed in Soviet times. We conclude that the extent of degradation of the pastures in our case study areas was probably lower than suggested in the literature, but that seasonal stock movement was essential to avoid degradation. Since independence, stock numbers have collapsed and stock movements are now limited. Recent field assessments suggest that the rangelands are in good condition. Kazakhstan's rangelands present a rare opportunity for the study of rangeland dynamics under dramatically changing stock numbers.

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Introduction

The steppes and deserts of Kazakhstan stretch from the Caspian Sea to China and from Russia to the Tien Shan mountains covering 184 million ha, much of which is too arid for arable agriculture (Fig. 1). Rainfall and vegetation productivity decrease from the steppe to the desert. Moving southwards through the semi-desert and desert zones, grass species give way to *Artemisia* species, such as *Artemisia sublessingiana* and

*Corresponding author. Fax: +44-020-7589-5319. E-mail: e.j.milner-gulland@ic.ac.uk

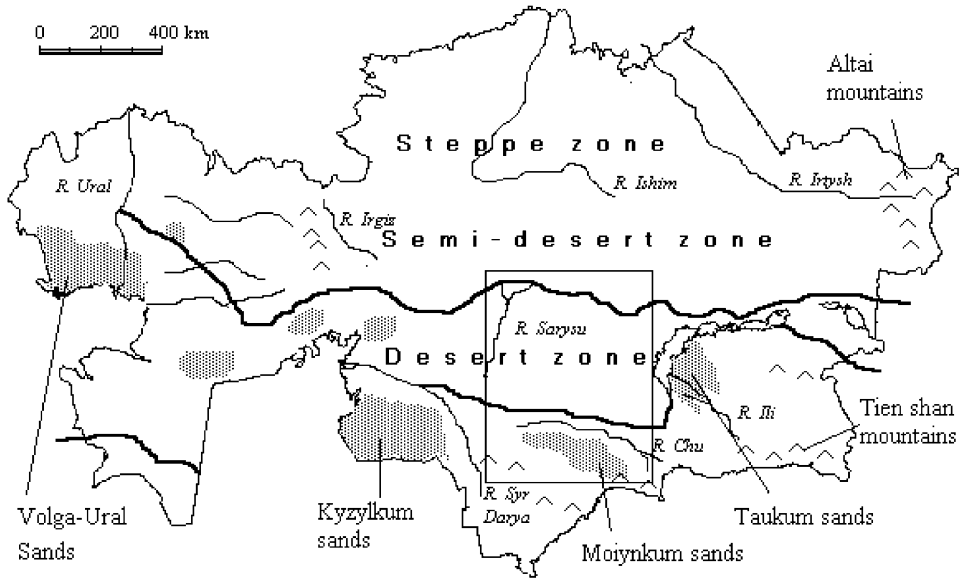


Figure 1. Major ecological zones of Kazakhstan. The box indicates the location of the study area. The bold line indicates the boundaries of the northern desert zone.

Artemisia terrae-albae, followed by saltworts, xerophytic species such as *Anabasis salsa*, *Salsola orientalis*, *Atriplex cana*, and *Salsola arbusculiformis*.

Until the 20th century, the Kazakh people were largely engaged in nomadic pastoralism with little settled agriculture. In 1920, Kazakhstan was absorbed into the Soviet Union and became a major source of livestock products for the other republics. During the Soviet period, high targets for animal production combined with improved animal husbandry led to a strong growth in animal numbers from the 1940s onwards. The productive steppe zone, with rainfall above 300 mm per year, was ploughed up during the virgin lands campaign in the 1950s, and ceased being a major livestock rearing area. Since then, the major pastoral zones have been in the semi-desert and desert regions.

Soviet success in livestock rearing was not without cost, and in the 1970s and 1980s concerns began to be voiced about overgrazing and land degradation (Zonov, 1974; Alimaev *et al.*, 1986; Kharin *et al.*, 1986). In Kazakhstan there are many types of degradation (Babaev, 1985), but in pastoral areas vegetation degradation and subsequent wind erosion are most important. According to Kharin & Kiriltseva (1988), 60% of Kazakhstan's arid areas (i.e. in the desert zone), or 30% of its overall pastures were degraded. These authors blame animal production as the chief cause of this. This could be interpreted to mean that by the end of the Soviet period, Kazakhstan's rangelands were in a state of crisis. However, it is important to look at how degradation was defined in order to be able to make any real assessment of these claims.

There is virtually nothing in the Western literature on Kazakhstan's rangelands, most information having been confined to the Russian-language literature. In this paper, we critically analyse Soviet definitions of, and methodologies for the study of, land degradation. We place this discussion in the context of Western debates on the assessment of land degradation, from which Soviet science was largely isolated. Kazakhstan's rangelands are also interesting from the point of view of recent debates among Western scientists on equilibrium and non-equilibrium systems as Kazakhstan,

despite its aridity, has a relatively low variability of rainfall. The Soviet system of data collection means that a large amount of data are available both on rainfall and biomass fluctuations. We bring some of these newly available data together in an analysis of Soviet grazing systems, including biomass, rainfall and stocking data. We then use these data to estimate grazing pressure in relation to forage availability for a number of case study areas, in order to see how these compare with the levels of overgrazing estimated in the Soviet literature. From these analyses, we assess the likelihood that rangelands were severely degraded in the Soviet period.

Although little has as yet been published on the condition of Kazakhstan's pastures since independence, some preliminary assessments were carried out in 1998 by the Institute of Botany of the Kazakhstan Academy of Sciences. This work suggested that rangelands in Central Kazakhstan were largely in good condition, apart from localized areas around villages (Sadvokasov, 2000). Papers in Kerven (in press) discuss the socio-economic changes that have occurred since independence, including a massive crash in livestock numbers, reducing overall grazing pressure substantially. This work on the current status of Kazakhstan's rangelands casts doubt on recent suggestions that the whole of Southern and Central Kazakhstan is degraded (Kharin *et al.*, 1999). The work which we present below contributes to this debate on the state of Kazakhstan's rangelands by examining in detail the evidence that they were ever degraded at all.

Western and Soviet definitions and assessments of land degradation

Western definitions

There has been some effort in recent years to standardize methods for assessing land degradation, so as to facilitate global monitoring of the problem. Major landmarks in this process include Agenda 21 of the 1992 UN Conference on Environment and Development, and the UN Convention to Combat Desertification (1994), which sets standardization of assessment methodology as a target. However, as discussed by Dregne (1998), the scientific community is still far from a consensus. There is not even a consensus on what constitutes degradation, with various concepts of biodiversity, species transformation, resource value, resilience, and productivity all included among the many definitions (Glanz & Orlovsky, 1983). Perhaps one of the most widely used definitions of land degradation (UNCOD, 1977) is the 'diminution or destruction of the biological potential of the land which can ultimately lead to desert-like conditions' suggesting the state of the land as a resource for human beings is what should be assessed.

UNEP/FAO (1984) produced a provisional document on methodologies for land degradation assessment, which uses ecological indicators including degradation of vegetative cover, water and wind erosion, and deterioration of soil quality such as salinization and waterlogging. These ecological indicators have been used in various forms for assessing land degradation in Asia (Babaev, 1985; Kharin *et al.*, 1999) and globally by Dregne & Chou (1992). The various types of damage are then rated using categories such as light, moderate, severe and very severe (UNEP/FAO, 1984; Babaev, 1985; Dregne & Chou, 1992; Kharin, *et al.*, 1999). For the moment, methods for measuring the physical indicators or for defining their severity are not standardized from study to study (Dregne, 1998; Eswaran *et al.*, 2001). Furthermore, such assessments do not describe the loss to human populations, and although more attention has been paid recently to economic assessments of degradation, looking at both income foregone and cost of rehabilitation, there are still few studies available (Dregne & Chou, 1992).

Many measurements of degradation are based on concepts of range condition (Joyce, 1993). Dregne & Chou (1992) used a measure of range condition relating the current productivity of a range to what that range is naturally capable of producing. By contrast, the U.S. Department of Agriculture, Soil Conservation Service base their assessment of range condition on criteria proposed by Dyksterhuis (1949) which depend on the relative proportions of different plant types, based on their response to grazing.

Soviet definitions

In Kazakhstan there was no one agreed set of criteria or methodology to monitor land degradation, but most Soviet authors describe the process of degradation as a change in species composition accompanied by a loss in productivity (Zonov, 1974; Kirichenko, 1980; Bykov, 1985). Vegetation climax associations were classified according to climate and soil type much as in the West (Kalenov, 1989; Rachovskaya, 1995), and were considered the 'ideal' vegetation against which degradation could be measured. Some authors (Zonov, 1974; Bykov, 1985) also describe decreases in soil humus content and changes in soil structure. The idea of resilience is also important in some studies (Bykov, 1985), whilst loss of forage production was integrated into some studies, which measured edible biomass rather than total biomass (Asanov *et al.*, 1994; Zhambakin, 1994).

One of the main pieces of evidence which has been quoted to support estimates of the extent of land degradation in the Former Soviet Union is a map of degradation intensity in arid regions of Central Asia, compiled at the Institute of Deserts, Turkmenistan (Babaev, 1985). The authors took the basic UNDP/FAO criteria (vegetation degradation, salinization, water and wind erosion) and used data from previous research, questionnaires, and satellite images to classify the degradation into five classes: none, weak, moderate, severe, and very severe. However, no methodologies for classification are given in the papers which accompany the map (Kharin & Kiriltseva, 1988; Kharin *et al.*, 1986).

The criteria used by Babaev (1985) to classify vegetation degradation included both productivity and species composition indicators. However, only the categories of severe and very severe degradation are cited as having low productivity and a high proportion of non-palatable species (Kharin *et al.*, 1986). For example moderate degradation 'involves the presence of more or less stable associations that have been productive for long periods but still include weed species' whilst weak degradation refers to slight changes in species composition only (quantitative indicators are not given). Therefore, if degradation is to be defined as a real decrease in productivity or as a loss of the pasture's ability to support sustainable livestock production, then the estimate that 30% of Kazakhstan's arid zone is degraded (derived from this map) may be rather high and may not necessarily correspond with estimates of other authors. For example Bykov (1985), working in Kazakhstan, did not classify pasture which had undergone small species changes and losses in productivity of up to 25% as overgrazed. In summary, Soviet methodologies for assessing vegetation change or degradation are similar to those of Western authors, concentrating on species change and/or loss in productivity. As in the West, the studies vary widely in how they quantify the severity of the changes observed.

Equilibrium and non-equilibrium rangelands

In the West, as in the Soviet Union, most ecological assessments of vegetation degradation have been based on comparing the current state with some ideal or standard state. However, this is questioned today for two major reasons; firstly a new

state might not reduce resource potential and secondly the very concept of a stable climax has been challenged. For example, where rainfall is highly erratic, vegetation productivity and composition may also be highly variable. This idea of non-equilibrium rangelands has been discussed mostly in the African context (Bartels *et al.*, 1993; Ellis *et al.*, 1993; Illius & O'Connor, 1999; Cowling, 2000). These debates have led to the recognition that assessments of degradation need to be long term and take climatic variability into account (De Leeuw & Tothill, 1993), and thus many of the dire diagnoses and forecasts of land degradation have been revised (Mace, 1991).

Soviet rangeland science has mainly been outside the currents of recent debates on succession and non-equilibrium systems, mostly due to the nature of scientific enquiry which did not encourage debate, but also because in Central Asian systems rainfall variability is low and most rangelands are almost totally dominated by perennials. Inter-annual rainfall variation in Central Asia has a coefficient of variation of 25–34%. This is around the threshold of 30% below which Shepherd & Caughley (1987) suggest that a system is likely to show equilibrium dynamics.

Perhaps due to the stability of its rangeland ecosystems, it was the concept of carrying capacity which was developed and standardized in the Soviet Union, much more than the concept of monitoring range condition or land degradation. It is partly for this reason that a national system of range condition assessment such as that existing in the U.S.A. was never developed. Carrying capacities were also more amenable to enforcement in a centrally planned system. There was essentially one user, one decision-maker, and one land owner: the state. The goal of livestock production was also simple; to produce maximum meat (or milk) yields per hectare of pasture. Animal movements and herd sizes were fixed by administrators, so individual herders had little or no free choice as to where and how grazing was organized. Economic assessments of land degradation did not exist, so land degradation was never assessed in terms of a reduction in resource potential. This did not mean that such a threat was not recognized; for example, Asanov & Alimaev (1990) pointed out that degradation was leading to higher mortality and lower birth rates in livestock (discussed in Robinson, 2000).

Carrying capacity was sometimes used not to limit damage, but to predict it. In the case of the degradation map of Central Asia, one of the criteria for assessing degradation risk was the existing number of animals compared to the number that the rangeland could theoretically support. The stocking load was defined in Kharin & Kiriltseva (1988) as 'the ratio of the actual load on the rangelands compared to the potentially possible load'. It is therefore important to understand the methods used to calculate potential stocking loads.

Causes of rangeland degradation

According to the literature, rangeland degradation in Kazakhstan was due to two major factors; increases in animal numbers and changes in grazing practices. The increases in animal numbers after the disastrous forced collectivization of the 1930s were spectacular, as can be seen for the case of sheep in Fig. 2. They were brought about mainly by increases in winter fodder provision which eliminated the former major cause of animal death, *dzhut*. This is a Kazakh term which refers to heavy snow or ice cover which prevents stock from feeding.

Pasture damage was also caused by new forms of organization. According to Asanov & Alimaev (1990), land degradation began in the 1960s when 155 specialized sheep raising *sovkhoses* (state farms) were created on state reserve land, with a stock of 50,000–60,000 sheep each. Many of these new farms blocked migratory routes. Pastures which formerly would have been used briefly during migratory periods

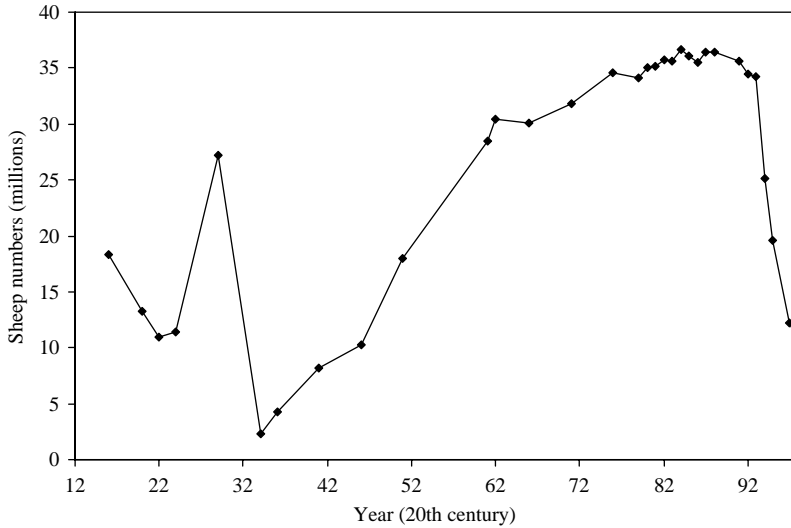


Figure 2. Numbers of sheep in Kazakhstan during the 20th century. *Source:* Goskomstat (1984, 1985, 1987) and Matley (1994).

started to be used for months at a time. According to Alimaev *et al.* (1986), after the establishment of the new farms the frequency of changes of pasture was reduced.

At certain times of the year, vegetation is much more susceptible to damage than at others. For example, some literature suggests that putting stock on the spring–summer–autumn pasture in early March is much more damaging than in mid-late April. According to Zhambakin (1995), controlled grazing experiments have shown that this is a major reason for land degradation in Kazakhstan.

The Soviet literature suggests that huge areas of Kazakhstan's rangelands suffered a decline in productivity and change in species composition, and that overstocking and reduction in movement were the reason. Indeed, stocking numbers form part of the data for two maps of land degradation (Babaev, 1985; Kharin *et al.*, 1999) and much of the risk assessment for land degradation was based on stock numbers exceeding estimated carrying capacities (Zhambakin, 1995).

Materials and methods

Research design

Our research aims to answer the question of whether forage offtake was really high enough to cause long-term damage during the Soviet period, and if so in what areas. Our work includes both fieldwork and an analysis of existing data. Because we are interested in assessing the maximum level of damage that could have been caused by overgrazing, we use data from the 1980s, when stocking levels were at their highest. The methodology we use is forage inventory to estimate offtakes, which can be compared with proper use factors from the literature. Such methods have been used by many authors including De Leeuw *et al.* (1993) and Sweet (1996). The elements needed for such an analysis are:

- (i) Herbivore density and distribution in space and time.
- (ii) Biomass yield and quality.

- (iii) Proper use factors for each pasture type.
- (iv) Daily intake per animal.

Small differences in the estimates of these four factors may lead to estimates of carrying capacity which vary by several orders of magnitude. Because of both spatial and temporal variability in resources, arbitrary proper use factors and inaccurate estimations of intake, Bartels *et al.* (1993) conclude that for sub-Saharan Africa, the concept of carrying capacity is meaningless and should be abandoned. At first sight, this conclusion may not hold for Kazakhstan during the Soviet period, because herds were of a specific size and were kept in defined areas in each season. These areas did not change according to yearly climatic fluctuations. Those seasons or situations in which feed supplements were given are well documented. However as we will see, proper use factors and animal intake remain as intractable as they have been in other studies.

Stocking rates and grazing patterns are available from State plans in district and provincial offices; however, it was felt necessary to check these statistics on the ground by visiting villages and interviewing those who had worked as shepherds during Soviet times. Proper use factors and estimates of sheep intake are taken from the Soviet literature, and provide a valuable insight into Soviet science and into the accuracy of some of the previous forecasts of degradation. We use these data to determine relative grazing pressures in the different vegetation zones, which are comparable between areas even if they are not accurate in absolute terms.

The study area

The study was conducted in 1997 and 1998 in an area comprising much of Dzhezkazgan *oblast* (province), plus the northern *raions* (districts) of Dzhambyl and South Kazakhstan *oblasts* (Fig. 3). The study area was chosen for a number of reasons. It contains areas identified by Babaev (1985) as suffering from degradation levels ranging from none to severe, and is also representative of the various farm structures and vegetation types found in Kazakhstan's rangelands. It is the site of one of the most enduring long migrations in Kazakhstan, one which continued both through the period of Russian colonization in the 19th century, and the socialist era (Zhambakin, 1995). Our study was carried out in conjunction with a vegetation assessment of the study area by our collaborators at the Institute of Botany (Sadvokasov, 2000). This is one of the few assessments of vegetation composition and condition that has been carried out since the fall of the Soviet Union, which adds to the implications of our work.

Average annual rainfall is above 200 mm per year in the north of the study area, and below 150 mm in the south. Snow cover in the semi-desert zone (above 47° north) exists between November and March and has an average depth of 25–35 cm. Animals cannot obtain food under snow when the depth averages 35–40 cm, or 20 cm when the snow is dense (Sludskii, 1963). Therefore, the semi-desert zone cannot be used as winter pastures if supplementary fodder is not available. Stock originally wintered in the sandy Moynkum desert due to its low snowfall and shrubby vegetation (dominant species are *Haloxylon* and *Calligonum* spp.). The area has dunes, the south facing slopes of which have a fast snow melt, and provide shelter from storms. Until the 1930s, stock spent summer in the steppe pastures of Karaganda *oblast*. Autumn and spring were spent along the river Chu (just north of the Moynkum desert) and crossing the clay deserts of Betpak dala. In Soviet times the migration was shorter and animals went only as far as northern Dzhezkazgan *oblast* (Sary Arka) in the semi-desert zone (Fig. 3). This was due to the establishment of new farms in the region of the former summer pastures. On these new farms shorter migrations took place,

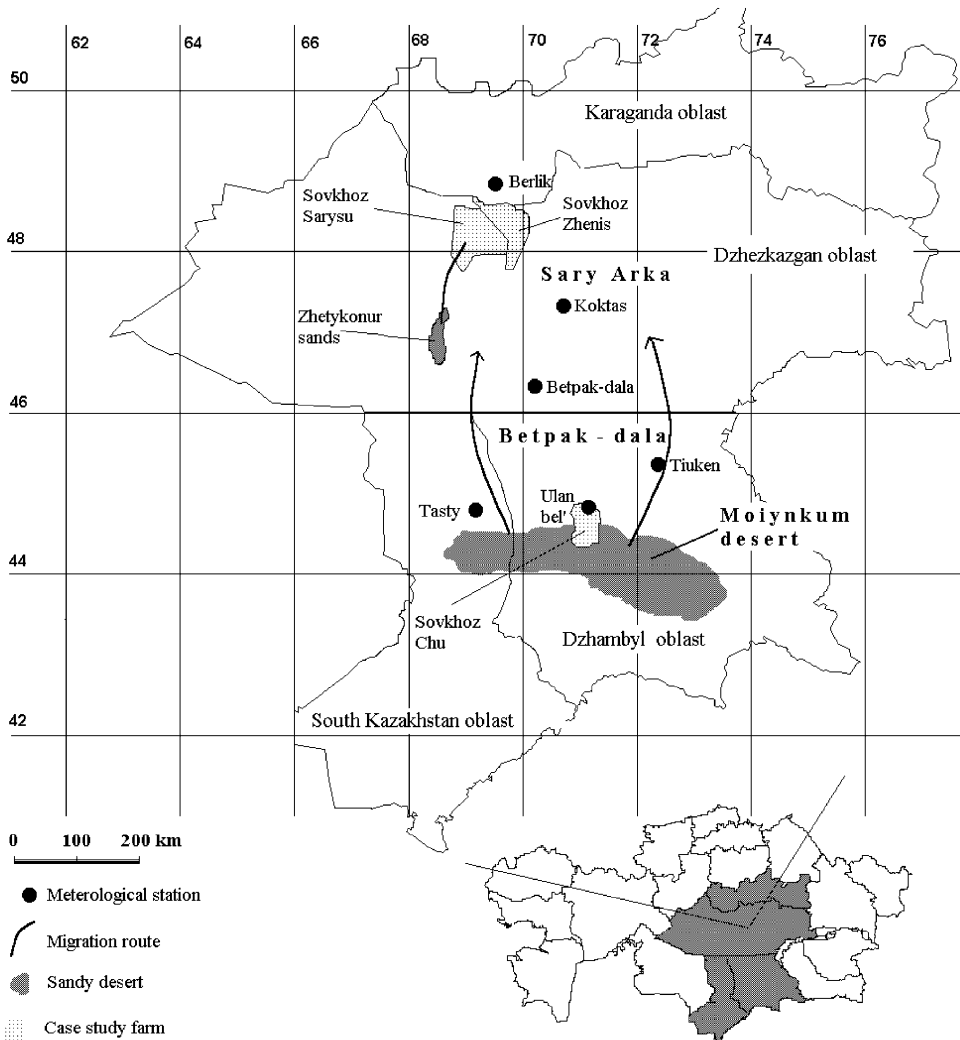


Figure 3. A map of the study area. The study farms and major livestock migration routes are shown, as are meteorological stations for which biomass and rainfall data were available.

animals moving within the farm boundaries or to designated seasonal pastures nearby (see Robinson, 2000, for more details).

Range condition in the study area

Most sources cite sandy deserts as the most degraded pasture types in the study area. This is probably because of their value as winter pastures, which led to high concentrations of animals. The sources agree that the sandy Moynkum desert suffered the most severe degradation (Babaev, 1985; Dzhanpeisov *et al.*, 1990; Zhambakin, 1995). According to Dzhanpeisov *et al.* (1990) land around wells in the area was severely deflated and vegetation cover dropped from 30–50% to 10–15%.

According to Asanov & Alimaev (1990), in cases where pasture in the northern desert zone was used for three seasons due to reduced migration, plants were not

given the chance to grow up or go to seed, and in some areas the yields dropped to half of what they considered ecologically possible. Information from *raion* government offices and Zhambakin (1995) suggests that such scenarios applied to some farms in Dzhambyl and South Kazakhstan *oblasts*, because some animals stopped moving north to Sary Arka and stayed in the desert zone all year round. This zone in southern Betpak-dala, just north of the river Chu (Fig. 1), is also marked as being moderately or severely degraded on the map by Babaev (1985). However, on all the farms visited during our fieldwork in these *oblasts*, all those interviewed said that most stock from their farm continued to migrate north to Sary Arka until 1994. Some areas of Central and Northern Betpak-dala were used for increasingly longer periods in spring and autumn during the Soviet period (Zhambakin, 1995), leading to localized degradation (Zonov, 1974; Dzhanpeisov *et al.*, 1990). However, according to Babaev (1985) this area remained in good condition.

In the semi-desert zone of the study area, animals conducted short migrations between winter and summer pastures, both of which were usually within farm boundaries. Some had separate autumn and spring pastures. However, others used the same pastures from May until October. These latter pastures have been described as degraded by the Institute of Pasture and Fodder (Zhambakin, 1995), although again according to the map by Babaev (1985) this area is generally in good condition. Such differences may be due to more detailed field studies being carried out by the Kazakhstan-based Institute of Pasture and Fodder, or to differing definitions of degradation.

In summary, all sources suggest that pastures in the desert zone, and in particular the winter pastures, were the most heavily overgrazed during the Soviet period. In the semi-desert zone, sources disagree as to the extent of degradation.

Data collection

The data were acquired both from fieldwork and from data searches carried out in 1997 and 1998. The fieldwork included visits to nine farms in the south of the study area, based along the north of the Moynkum desert (whose livestock were engaged in the long migration between the sands and Sary Arka), and to four farms in the north of the study area, in the northern part of Dzhezkazgan *oblast* (where animals stayed mostly within farm boundaries). The southern sample included all farms between the villages of Tasty and Ulan bel (see Fig. 3) at which point it was felt that a general picture of the situation (which at that point was very similar from farm to farm) had been gained. The location of the northern sample was chosen because the farms there cover large areas, and were solely involved in extensive sheep raising. These farms are situated adjacent to the summer pasture used by the farms from the southern transect, and thus provide a contrast in grazing strategy to these areas in the same ecological zone. The area between the southern and northern farms is empty and used only as seasonal grazing, thus all components of the north-south grazing system were covered by our sampling strategy.

Semi-structured interviews were conducted with shepherds and officials on farms. All interviewees (chosen to represent a range of stock owners from those who had no animals left, to the largest owners with 500 sheep) were asked to describe patterns of stock ownership, animal husbandry, migration, and grazing organization both in the Soviet period and at present. Interviews were also conducted with those responsible for planning on a district or regional scale in *raion* or *oblast* centres. Here, detailed information on grazing patterns in the Soviet period could be obtained in the form of maps and reports created by *Kazgiprozem* (Kazakhstan State Institute for Land Organisation). Through these methods, a detailed picture of past and present grazing systems on the farms was obtained. In order to compare stocking rates with forage

resources, 30 year time series (1967–1997) of biomass and rainfall data were purchased for six meteorological stations (shown in Fig. 3). Extra rainfall data were also made available by the Institute of Botany of the Kazakhstan Academy of Science.

Analysis of the Soviet data

Herbivore density and distribution

Domestic herbivore density is relatively easy to obtain for Soviet Kazakhstan as animals were kept in specific areas near water holes. There was no flexibility of choice for individual shepherds. Maps are available showing the location and size of the pasture allocated to each herd of sheep in each season. Wells, *zimovki* (winter bases) and migration routes are also given.

The areas allocated to each herd may not always correspond to the real distances that animals travel from water holes. According to Asanov *et al.* (1994) the size of the area used around a well is determined by the type of animal, productivity of the pasture, and the organization of pasturing. The authors estimate that for a herd of 800 sheep, acceptable (or required) travel distances from wells ranged from 1.5 to 4.2 km depending on pasture quality. In interviews conducted for this study, shepherds estimated that they took their sheep 3 km from a water point in summer, but might take them further in other seasons. Therefore, 3 km was used as a conservative estimate of the radius of the area around each well used by livestock. Herd sizes generally ranged from 750 to 900 animals but in some cases several herds would use a common water point, leading to concentrations of up to 3000 animals. A 3 km radius around a well gives a total pasture area of about 2800 ha, which corresponds to the areas allocated to most herds in the semi-desert zone. A herd of 750 sheep thus used 3.7 ha of pasture per head.

Biomass productivity

Long-term rainfall and plant biomass data were available for six weather stations in or close to the study area (Fig. 3). However, the plant species cut for the biomass data varied from year to year, so only about half the data could be used, corresponding to subsets of consistent species composition. Data were also collected near Betpak-dala meteorological station in 1958–1961 by Kirichenko (1966). Although they only cover 4 years, these data are much more thoroughly described than the data collected at the weather stations; biomass is given by species and five different vegetation types were sampled. The methodology used by Kirichenko involved cutting biomass every 20 days under four 2.5 m² quadrats in each of five vegetation associations. Only the leaves and shoots of that year were cut from shrubs and semi-shrubs. The methodology was the same at the meteorological stations, but the biomass was cut every 10 days.

The reliable biomass time series data were quite short, in contrast to the 30 year dataset available for rainfall at the same weather stations. Therefore, we used the existing biomass data to construct statistical relationships between biomass and rainfall, so that the longer rainfall time-series could be used to estimate longer-term biomass variability.

Despite the frequency of cutting of biomass, the data could not be used to predict biomass change over the seasons in a particular year. This is because the dominant plants in the northern desert zone are perennials whose vegetative growth normally ceases early in the season. For example, in the case of *Artemisia terrae albae* accumulation of photosynthetic material is most intense in May and early June, but stops in the second half of June, when the leaves begin to dry out, and 60–70% of

them are shed (Zhambakin, 1995). At this time the plant puts energy into bud formation rather than vegetative growth. In some years of high or late rainfall, vegetative growth can continue into July, but this only occurs about once in 20 years. Therefore, biomass after May is better predicted as a die-off curve from a peak, which can in turn be roughly predicted from rainfall over winter and early spring.

Biomass die-off over the season

We constructed a general die-off model using data for the five vegetation communities in the desert zone studied by Kirichenko (1966). These communities are dominated by:

1. *Salsola arbusculiformis* and *Artemesia terrae albae*;
2. *Salsola rigida* and *Artemesia terrae albae*;
3. *Salsola arbusculiformis*;
4. *Atriplex cana* and *Artemesia pauciflora*;
5. *Anabasis salsa*.

For each community, biomass was available for each month from May to September for the years 1959, 1960 and 1961, and from June to September for 1958, providing 19 data points per community and 95 in all.

The relationship between biomass in month X and month $X-1$ is strong and highly significant (Fig. 4). However, the regression model fails tests on the residuals for heteroscedasticity, functional form and serial correlation. This is mainly because the values for the community dominated by *Atriplex cana* are not predicted well by the model; this community responds to rainfall throughout the season, and sometimes has a second peak in autumn. This community therefore has much larger residuals than the others. However, this community is among the least widespread of all of those given in the area in question (which is mostly dominated by *Artemesia* and *Salsola* communities, Kirichenko, 1980). Hence we removed this community from the

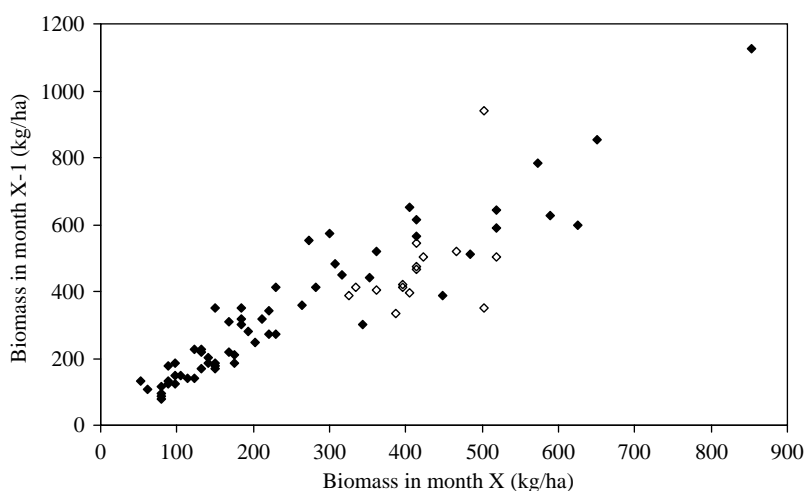


Figure 4. Relationship between monthly biomass yield, and biomass yield lagged one month for five vegetation types in Betpak-dala. $r^2=0.82^{***}$. Ninety-five data points were used, 19 for each vegetation type. White data points indicate vegetation type 4, black points indicate all other types.

analysis, and produced a robsut model:

$$B_{t+1} = -0.88 + 0.76B_t \quad (\text{Eqn 1})$$

here B = biomass and t = month, $R^2 = 0.88$, $p < 0.001$, standard error of the estimate = 59.6 kg ha^{-1} . There were no very poor years in the dataset used to create this model. However the accuracy of the die off curve for a peak of 200 kg ha^{-1} (an unusually poor year according to meteorological station data) can be checked against some real data from Kirichenko (1980). According to measurements in this source, two *Artemisia*-dominated associations which had peaks of 200 kg ha^{-1} in spring had yields of only 10 and 60 kg ha^{-1} by the autumn (the exact months are not given). The model predicts a mean of 42 kg ha^{-1} in September and 23 kg ha^{-1} in October, and the figures of 10 and 60 kg ha^{-1} from the real data are well within its confidence limits.

Inter-annual biomass change

As stated earlier inter-annual rainfall variation in Kazakhstan is low, with a coefficient of variation of 25–34%. This may explain why, in many cases, rainfall–biomass relationships are poor. However, significant relationships were found at several stations in the desert zone (Fig. 5). For the semi-desert zone, no significant rainfall–biomass relationships were found. However, two sources could be compared in order to establish rough ranges for biomass in this zone. Biomass data were available from Koktas meteorological station, which were compared with biomass data from *sovkhos* Sarysu, only 70 km to the west. These data plus other types of botanical data are available for this *sovkhos* from reports and maps compiled by the Kazakhstan State Institute for Land Planning (Kazgiprozem, 1988). The data include the species composition of each vegetation association and minimum and maximum yield in spring, summer, autumn and winter. On the botanical maps, the farms are divided into polygons according to vegetation type. For each polygon is given:

- the area of the polygon in hectares;
- the vegetation associations present in that polygon;
- the percentage of the polygon covered by each association.

As the grazing area allocated to each herd in a certain season is known, the area covered by each vegetation type available to the herd can be calculated from the above information, and the overall average vegetation composition and yield of each grazing area can be determined as a weighted average of the polygon data. Four herds were chosen representing the different movement patterns existing on the farm. Two of them spent spring, winter and autumn on Zhetykonur sands and summer in the north-east of the farm. The other two spent spring, winter and autumn in the south of the farm territory and summer in the north west of the farm.

The biomass calculated for the grazing areas on *sovkhos* Sarysu in the different seasons falls within the bounds of that recorded at Koktas meteorological station, meaning that the two data sources are roughly in agreement. This enables a reasonable estimation of biomass variability between years and over the seasons of interest (Table 1). The Koktas dataset has wider variability as it includes maxima and minima of 30 years data whilst the Sarysu dataset does not include extreme values.

Proper use factors

These are defined as the offtake which can be sustained by the pasture without reducing its productivity in future years. In Soviet rangeland science these are known as coefficients of use, expressed as permissible offtake as a percentage of total biomass. They are normally given for specific seasons and vegetation types. For example, for

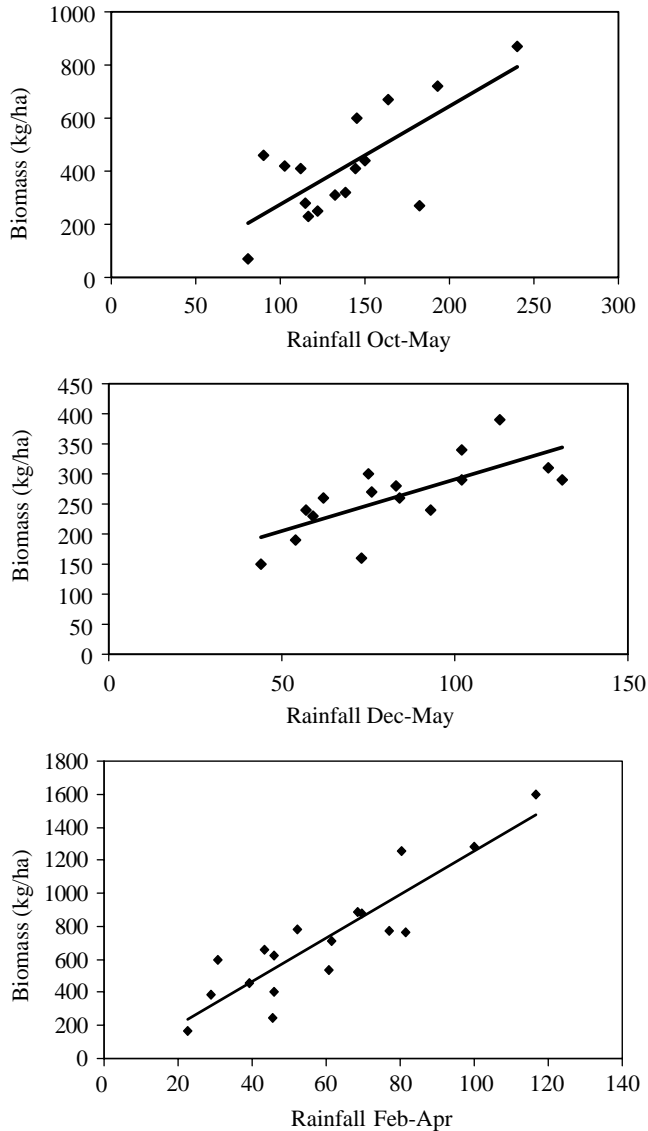


Figure 5. Peak biomass at various meteorological stations in the study area as a function of rainfall. These were obtained by regressing the peak biomass figures against rainfall from April to May, March to May, February to May etc., up to October to May, and choosing that relationship giving the highest r^2 value. This is because soil moisture in spring is determined by precipitation from October onwards (Beloborodova, 1964). At each station the peak biomass figures were available from 1967 to 1997. However, those actually used were those corresponding to the longest series of each dataset for which biomass of a constant species composition was cut. Equations are given as: $B_p = a + bR_{x-y}$, where R_{x-y} is rainfall taken over the period giving the highest r^2 . All regions pass the tests for constant variability and independence of residuals. (a) Tasty 1982–1997 as a function of rainfall from December to May. The regression equation is: $B_p = 118.6 + 1.7R_{\text{Dec-May}}$, $r^2 = 0.522^{**}$, (S.E. = 44 kg). (b) Ulan bel' 1967–1984 as a function of rainfall from October to May. The regression equation is: $B_p = -94 + 3.7R_{\text{Oct-May}}$, $r^2 = 0.53^{***}$, (S.E. = 146 kg). (c) Betpak-dala 1982–1996 as a function of rainfall from February to April. The regression equation is: $B_p = 110 + 12R_{\text{Feb-Apr}}$, $r^2 = 0.8^{***}$, (S.E. = 160 kg).

Table 1. Sources of data for estimating biomass yields over the year in Northern Dzhuzkazgan oblast

Koktas meteorological station			Sovkhoz Sarysu botanical map	
Month	Average biomass (kg ha ⁻¹)	Min–Max biomass (kg ha ⁻¹)	Season	Min–max biomass (kg ha ⁻¹)
April	220		Spring	
May	290	180–690		200–490
June	650	410–860		
July	560	330–970	Summer	330–710
August	560	300–800		
September	430	290–600	Autumn	275–500
October	370	200–550		
Winter			Winter	200–410

semi-shrubs they range from 55% in autumn to 75% in spring (Kirichenko 1980) whilst Zhambakin (1995) gives one-season estimates for *Artemisia*-dominated communities ranging from 50% to 70%. Grass communities have slightly higher proper use factors (60–70%) when used for one season only (Zhambakin, 1995).

These proper use factors are much higher than Western figures for perennial grasslands, which are usually between 30% and 45% (De Leeuw & Tothill, 1993). This is possibly because they are for specific seasons. According to Zhambakin (1995), proper use factors are only valid in conjunction with 'sound grazing practice'. For example, proper use factors were usually calculated by removing various percentages of the vegetation in specific seasons and looking at production in future years (Kirichenko, 1980; Zhambakin, 1995). However, it was also found that an early start to spring grazing (early March) followed by grazing into the summer on the same pasture was just as harmful as high offtakes (Zhambakin, 1995).

Consumption of biomass per animal

Estimates of this factor given by Soviet scientists (Table 2) are very different from those in Western range science. Western estimates tend to be lower. For example, Short (1987) gives an estimate of 1.3–1.7 kg day⁻¹ for a sheep of 60 kg, about half the Soviet estimates. Similarly Elsen *et al.* (1988) reviewed 11 models, each of which predicts sheep intake according to number of factors. Some of these factors are characteristics of the animal itself (weight, stage of growth) which determine potential intake, and some are characteristics of the pasture (height, digestibility and biomass) which determine actual, or relative intake. Only one of the models reviewed predicted that sheep intake would ever exceed 2 kg DM day⁻¹.

The reasons for the high Soviet estimates are probably because their predictions of sheep intake are based solely on the sheep's daily requirement of digestible matter, with the assumption that the sheep will take in the amount needed to fulfil this requirement (Asanov *et al.*, 1994). The required intake predicted from average pasture digestibility is thus too high, as the digestibility of the biomass actually eaten is always higher than the average pasture digestibility. Also sheep eat less when digestibility is low (Freer, 1981) contradicting the Soviet assumption that sheep will eat more poor-quality winter pasture than good-quality spring pasture.

Table 2. Estimates of daily sheep intake from Soviet literature

Intake (kg DM day ⁻¹)	Sheep type/ weight	Pasture type	Source
1.8–2.6	Adult Karakul	General, spring– summer	Tamme & Balaban in Asanov <i>et al.</i> (1994)
2.6–3.0	Adult Karakul	General, autumn– winter	Tamme & Balaban in Asanov <i>et al.</i> (1994)
3.7–4.5	80 kg	<i>Artemesia</i> , <i>Artemesia</i> – <i>Stipa</i>	Larin quoted in Asanov <i>et al.</i> (1994)
2.2–2.6	40 kg	<i>Artemesia</i> , <i>Artemesia</i> – <i>Stipa</i>	Larin quoted in Asanov <i>et al.</i> (1994)
2.5	General	General	Kirichenko (1980)

In this analysis, intake was taken to be 1.4 kg day⁻¹, the average of the predictions of nine models in Elsen *et al.* (1988) for sheep weighing 50 kg (12 kg heavier than the average for the region), on good pasture with 75% digestibility. This high level of digestibility is probably unrealistic after May. Such an intake also corresponds to the upper limit of intake for a sheep weighing 50 kg described by Short (1987), and therefore is almost certainly an overestimate. This is as required, because the goal here is to look at 'worst case' situations.

Case studies

Using parameter estimates derived as discussed above, we use case studies of specific farms to compare likely offtakes by herds of sheep with forage availability on seasonal pastures during the Soviet period. The aim is to see if those areas where offtakes were highest compared to availability correspond to those described as degraded in the literature.

Description of case study areas

The examples discussed here were chosen to represent the three major pasture types: sand desert winter pasture, clay desert spring/autumn pasture and semi-desert pasture which may be used either for three seasons or in summer only. The locations of the case study areas are shown in Fig. 3. *Sovkhoz*es Sarysu and Zhenis are used to represent farms from the semi-desert zone with short local migration routes. In the desert zone the autumn–spring pastures along the river Chu were supposedly highly degraded (Babaev, 1985). *Sovkhoz* Chu is used to look at stocking rates in this area and in the Moynkum desert. Since 1994, movement to summer pastures has ceased entirely, leading to three season grazing of the former autumn–spring *Artemesia*–*Salsola* pastures on all the farms. The possible effects of this are also investigated with respect to forage resources.

*Summer pasture in the semi-desert zone (sovkhoz*es Zhenis and Sarysu)

The vegetation on this pasture is mostly dominated by *Artemesia terrae-albae*, *A. lercheana*, *Atriplex cana*, *Stipa* and *Festuca* species (Kazgiprozem, 1988, 1991). Die-off from May to October influences the amount of fodder available as the season progresses. The grazing period on the two farms varies slightly; *sovkhoz* Sarysu has

Table 3. Pasture availability and offtake over an average and a poor growing season in the semi-desert zone

Month	Minimum biomass (kg ha ⁻¹)		Total resources (tonnes)		Pasture left after offtake & die-off (tonnes)		Offtake (%)	
	Poor	Average	Poor	Average	Poor	Average	Poor	Average
May	230	485	644	1358	612	1327	4.9	2.3
June	380	747	1064	2092	980	2011	7.9	3.8
July	306	620	857	1736	748	1630	12.7	6.1
Aug	253	479	708	1341	573	1211	19.1	9.7
Sept	240	384	672	1075	507	919	24.5	14.5
Oct	196	354	548	991	358	806	34.7	18.6

Figures given for biomass are averages for each month and are taken from Koktas meteorological station. Herd sizes are taken to be 750 animals.

areas of separate spring and autumn pasture, so that summer pasture was used only from June to September. On *sovkhos* Zhenis, summer pasture was used from 1st May to 15th October during which time, according to interviewees, the stock would have been on the pasture only, with no access to other feeds or crop residues. According to Zhambakin (1995) this long period of use caused pasture damage on that particular *sovkhos*. Data on minimum biomass values for each month were taken from Koktas meteorological station (Table 1). These were adjusted each month to allow for offtake in previous months. The offtake for the whole herd in each month is taken as: $1.4 \text{ kg} \times 750 \text{ sheep} \times 30 \text{ days} = 31.5 \text{ tonnes}$.

The expected forage availability and offtake around one well were calculated for poor and average years (Table 3). The amount of pasture removed by the end of the growing season is not simply the sum of offtakes in preceding months, as this would result in vegetation loss being double-counted, both as offtake and as die-off. The offtakes in previous months are therefore corrected for die-off, by reducing them at each time step by the amount that would be expected to have been lost. This is calculated from the ratio of vegetation available in a given month to that of the month before, except that in the first time step, vegetation is still increasing so there is no correction made for die-off.

From Table 3 we can see that by October of a poor year, 34.7% of the pasture has been removed. This is about equivalent to Western estimates of proper use factors, but much lower than the Soviet estimates for such pasture. In a year of average rainfall, the offtake by October is 18.6%, easily inside all estimates of permissible levels. Due to die-off, the effects of grazing on the pasture increase exponentially over the season. Therefore, moving the sheep in October, as was done on *sovkhos* Sarysu, was probably beneficial for the animals in terms of foraging efficiency.

Overall it therefore seems likely that a herd of 750 sheep in the semi-desert zone should have minimal effects on the herbage, even under prolonged grazing. This supports Babaev (1985), whose map shows this area to be in good condition. However, it should be remembered that the long grazing period seen in this area may have had deleterious effects on the pasture which cannot be predicted from offtake alone.

Pastures in the northern desert zone (Sovkhos Chu)

Animals from the desert zone usually spent summer in the semi-desert zone. However, towards the end of the Soviet period animals were sometimes kept in the desert zone

Table 4. Pasture availability and offtake over an average and a poor growing season in the desert zone

Month	Minimum Biomass (kg ha ⁻¹)		Total resources (tonnes)		Pasture left after offtake and die-off (tonnes)		Offtake (%)	
	Poor	Average	Poor	Average	Poor	Average	Poor	Average
May	200	400	560	1120	528.5	1088.5	5.6	2.8
June	143	295	401	827	346.9	771.8	13.5	6.6
July	100	215	280	604	204.0	525.8	27.2	12.9
Augt	67	155	188	434	91.0	333.7	51.7	23.1
Sept	42	109	118	305	1.4	182.7	98.8	40.1
Oct	23	74	65	207	0	63.4	100	69.4

The biomass figures are taken from a model of biomass die-off from peak biomass [equation (1)] in poor and average years. The poor peak biomass (in May) is as reported by Kirichenko (1980). The average peak biomass is taken from the averages at meteorological stations Tiuken and Ulan bel', those nearest to Sovkhoz Chu. Herd sizes are taken to be 750 animals.

for the whole of the summer season (Zhambakin, 1995). Interviews with shepherds showed that today, with the loss of animals and lack of logistical support for migration, animals are also tending to spend the entire spring to autumn season, or even the entire year, in the desert zone, although herd sizes are much smaller. Table 4 shows forage resources and estimated offtakes in the desert zone under the same stocking parameters as those given in Table 3.

This analysis suggests that a single herd remaining at the same well from May onwards would, in a drought year, have removed all the biomass by September. From this analysis it is clear that in poor years, only very small herds can graze on desert pasture for three seasons, and certainly during Soviet times when herds were usually not smaller than 700 sheep, damage would probably have been considerable. From this it is easy to see the advantages of moving to summer pasture further north, and of moving stock to new autumn pasture.

On the *sovkhozes* visited, desert pasture was not used in summer, but only for a short period in spring and up to 1 month in autumn, although there was more than one herd round each well. On *sovkhoz* Chu, four herds of 700 sheep (corresponding to 2800 animals) were apportioned only an average of 1800 ha, or 0.64 ha per sheep. If the biomass was 100 kg ha⁻¹ at the start of September, as it would have been in an average year (Table 4), by the end of the month such herds could have removed 65% of it, without taking die-off into account. The same areas were used in spring, but in this case offtake over 1 month would have been around 16% (probably higher as the sheep were lactating). Of all the areas analysed here, these seem to be the most susceptible to degradation given the stocking rates described. If such stocking rates were common on farms along the river Chu, then it is clear why all sources suggest that such pasture was degraded in Soviet times.

Moiynkum desert

According to the literature, it appears that the *Moiynkum* desert was the most degraded of the pastures in the study area. Here, proper use factors do not exceed 70% for winter grazing, and according to Zhambakin (1995), biomass levels range in winter from 70 to 200 kg h⁻¹ according to vegetation type. According to Asanov *et al.* (1994) and Zhambakin (1995), sheep would have spent 120 days outdoors and only 1

month indoors on such sand massifs in the desert zone, but even during the pasture period the animals would also have been receiving some fodder in the form of hay and concentrates. According to these authors and the map of *Sovkhoz* Chu, stocking densities were high in some areas, reaching 1.5–1.2 ha per sheep. These parameters would lead to offtakes of 56–70% given a biomass of 200 kg ha⁻¹ and an intake of 1.4 kg ha⁻¹. However, intake cannot be properly estimated as sheep were receiving extra fodder for much of the winter period. More research is needed to verify these parameters, but our preliminary results suggest that, despite the very high stocking rates and low biomass production, degradation may have been exaggerated in the Moynkum desert. This is due to high Soviet intake estimates and high levels of additional fodder provision.

Summary and discussion

Both annual rainfall and variability in rainfall are low in southern Kazakhstan. The coefficient of variation of rainfall is around 30%, which is comparable to many other temperate rangelands (Le Houérou *et al.*, 1988). In the desert zone of the study area, rainfall remained between 100 and 250 mm for 30 years with only three exceptions. This may explain how it was possible to sustain the highly planned and inflexible grazing systems which existed in Kazakhstan during the Soviet period, despite high stocking rates. However, stock movement was essential to the functioning of this system.

The Soviet data provide a historical source without parallel, because highly detailed stocking and forage information are available for every state farm. Although this information may not have been accurate for areas around villages where private stock were kept, it seems from this study that it was reasonable for the farms as a whole. Here we use these data to examine the relationship between stocking rates and forage availability for a case study area. Although the analysis is too theoretical to draw any firm conclusions on the actual severity of degradation in the 1980s in the study area, it does provide a guide to relative grazing pressures and the exercise itself provides a valuable insight into Soviet rangeland science.

Vegetation degradation was generally described in the literature as a change in species composition combined with a loss in productivity. It was reported to be highest in winter pastures on sands. Our preliminary analysis of stocking rates in the Moynkum desert suggests that stocking rates could have come close to those causing unacceptable offtakes; however, it is important to note that some of the alarming warnings of overstocking in Moynkum (Zhambakin, 1995) were based on unrealistic estimations of sheep intake which are more than double those of Western workers.

Our analysis also suggests that the *Artemisia-Salsola* pastures of southern Betpak-dala were very highly stocked; even 1 month's grazing on such pastures in autumn would have resulted in vegetation damage, given the stocking densities existing on *sovkhos* Chu. However, although some literature (Asanov & Alimaev, 1990) suggests that migration systems had broken down in this region, and that these desert pastures were sometimes grazed for three seasons, our fieldwork found that farms situated in southern Betpak-dala still conducted four season migrations right up to 1994 (when stock numbers collapsed). Thus, although time spent on autumn pasture had increased over the Soviet period, these pastures were never grazed in summer.

Concerning the semi-desert zone further north, even taking the worst case scenarios (largest possible herd sizes, drought years, and conservative estimates of available hectareage per herd), the offtakes calculated for this spring–summer–autumn pasture would have been too low to cause damage to the pasture.

The pastures described here are now either ungrazed, or grazed by a tiny fraction of the animals which would previously have used them. Sheep numbers in Dzhambyl and South Kazakhstan *oblasts* dropped by more than two-thirds between 1991 and 1998 (Fig. 2), and stock no longer move to remote summer pastures in Sary Arka, but stay in southern Betpak-dala or in the Moiynkum desert all year round with greatly reduced herd sizes. Given the changed circumstances since 1994, it seems reasonable to conclude that overgrazing is not now a major problem in Kazakhstan. However, there is an increasing tendency for shepherds to graze their animals all year round in the same place (usually in the winter or autumn pastures where permanent houses exist) although it was clear from our fieldwork and from Kerven (in press) that those few shepherds who have many animals do still conduct limited migrations. Grazing practices today are changing rapidly, along with their socio-economic and political framework, thus it is too early as yet to say what kind of grazing practices will eventually emerge, and future degradation risks cannot yet be predicted.

The pastures discussed in this paper (other than the Moiynkum desert) were visited for mapping purposes by the Institute of Botany in 1998. They found that altered vegetation associations do still exist on sandy soils, but mostly the vegetation cover consists of 'climax' perennial plants in good condition with normal cover (Sadvokasov, 2000). However, a recent map by Kharin *et al.* (1999), which was not based on fieldwork but on satellite imagery and other publications, describes the whole of the study area as moderately to severely degraded with a loss of climax species, total plant cover and forage. Both past and present assessments of land degradation in Kazakhstan (as elsewhere) have been plagued by methodological inconsistencies and false assumptions. Assessments that do not include fieldwork are particularly suspect. Since the collapse of stock numbers there is an urgent need for a reassessment of the state of Central Asia's rangelands, and for the development of standardized methods for this assessment (for details of some ongoing work on pasture regeneration, refer to the Acknowledgements). The change in stocking rates from an all time high to almost zero constitutes a rare natural experiment, which should be an ideal opportunity for researchers to study recovery processes and the relative influences of climatic and human influences on the rangelands of Kazakhstan.

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References

- Alimaev, I.I., Zhambakin, A. & Pryanoshnikov, S.N. (1986). Rangeland farming in Kazakhstan. *Problems of Desert Development*, 3: 14–19.
- Asanov, K.A., Alimaev, I.I., Pryanishnikov, S.N., Zhumabekov, E. Zh. & Eleshev, P.E. (1994). *Praktikum Po Pastbish'nomu Khozyaistvu* [Practical Rangeland Farming]. Almaty: Kainar.
- Asanov, K.A. & Alimaev, I.I. (1990). New forms of organisation and management of arid pastures of Kazakhstan. *Problems of Desert Development*, 5: 42–49.
- Babaev, A.G. (Ed.) (1985). *Map of Anthropogenic Desertification of Arid Zones of the USSR*. Ashkabad, Turkmenistan: Institute of Deserts.

- Bartels, G.B., Norton, B.E. & Perrier, G.K. (1993). An examination of the carrying capacity concept. In: Behnke, R. J., Scoones, I. & Kerven, C. (Eds), *Range Ecology at Disequilibrium*, pp. 89–103. ODI/IIED/Commonwealth Secretariat, London.
- Behnke, R. & Abel, N. (1996). Revisited: the overstocking controversy in semi-arid Africa. *World Animal Review*, 2: 4–27.
- Beloborodova, G.G. (1964). Meteorologicheskie usloviya i yrozhai pastbish'noi rastitel'nosti Betpak-daly [Meteorological conditions and yields of rangeland plants of Betpak-dala]. *Trudy Instituta Botaniki ANKazSSR [Proceedings of the Botanical Institute of the Kazakhstan Academy of Sciences]*, 18: 87–112.
- Bykov, B.A. (1985). Anthropogenic effects on desert pastures. *Problems of Desert Development*, 1: 20–26.
- Cowling, R.M. (2000). Challenges to the 'new' rangeland science. *Trends in Ecology and Evolution*, 15: 303–304.
- De Leeuw, P. N., Diarra, L. & Hiernaux, P. (1993). An analysis of feed demand and supply for pastoral livestock: the Gourma region of Mali. In: Behnke, R. J., Scoones, I. & Kerven, C. (Eds), *Range Ecology at Disequilibrium*, pp. 136–152. ODI/IIED/Commonwealth Secretariat, London.
- De Leeuw, P.N. & Tohill, J.C. (1993). The concept of rangeland carrying capacity in Sub-Saharan Africa, myth or reality? In: Behnke, R. J., Scoones I. & Kerven, C. (Eds), *Range Ecology at Disequilibrium*, pp.77–88. ODI/IIED/Commonwealth Secretariat, London.
- Dregne, H.E. (1998). Land degradation: assessment and monitoring. *Newsletter of the International Taskforce on Land Degradation*, 3: 4–8.
- Dregne, H.E. & Chou, N.T. (1992). Global desertification dimensions and costs. In: Dregne, H.E. (Ed.), *Degradation and Restoration of Arid Lands*. Lubbock: Texas Technical University.
- Dyksterhuis, E.J. (1949). Condition and management of range land based on quantitative ecology. *Journal of Range Management*, 2: 104–115.
- Dzhanpeisov, R., Alimbaev, A.K., Minyat, V.E. & Smagulov, T.A. (1990). Degradation of soils of mountain and desert pastures in Kazakhstan. *Problems of Desert Development*, 4: 19–26.
- Ellis, E.J., Coughenour, M.B. & Swift, D.M. (1993). Climate variability, ecosystem stability, and the implications for range and livestock development. In: Behnke R.J., Scoones I. & Kerven, C. (Eds), *Range Ecology at Disequilibrium*, pp.31–41. ODI/IIED/Commonwealth Secretariat, London.
- Elsen, J.M., Wallach, D. & Charpentreau, J.L. (1988). The calculation of herbage intake of grazing sheep: a detailed comparison between models. *Agricultural Systems*, 26: 123–160.
- Eswaran, H., Lal, R. & Reich, P.F. (2001). Land degradation: an overview. In: Bridges, E.M., Hannam, I.D., Oldeman, L.R., Pening de Vries, F.W.T., Scherr, S.J. & Sompatpanit, S. (Eds), *Responses to Land Degradation. Proceedings of the 2nd International Conference on Land Degradation and Desertification*, Khon Kaen, Thailand. New Delhi, India: Oxford Press.
- Freer, M. (1981). The control of feed intake by grazing animals. In: Morley, F. H. W. (Ed.), *Grazing Animals, World Animal Science B1*, pp. 105–124. Amsterdam: Elsevier.
- Glanz, M.H. & Orlovsky, N.S. (1983). Desertification, a review of the concept. *Desertification Control Bulletin*, 9: 15–22.
- Goskomstat [State Statistical Committee] 1984, 1985, 1987. Narodnoe. Khozyaistvo Kazakhstana, Statisticheskii Yezhegodnik [The economy of Kazakhstan, Statistics Yearbook]. Alma-Ata, Goskomstat.
- Illius, A.W. & O'Connor, T.G. (1999). On the relevance of nonequilibrium concepts to arid and semi-arid grazing systems. *Ecological Applications*, 9, 3: 798–813.
- Joyce, L.A. (1993). The life cycle of the range condition concept. *Journal of Range Management*, 46: 132–138.
- Kazgiprozem [Kazakhstan Institute for Land Planning] (1988). *Natural Forage Resources of Sovkhoz Sarysu, Ulutau raion, Dzhezkazgan oblast*. Dzhezkazgan: Ministry of Agriculture.
- Kazgiprozem [Kazakhstan Institute for Land Planning] (1991). *Natural Forage Resources of Sovkhoz Zhenis, Zhana-arkin raion, Dzhezkazgan oblast*. Dzhezkazgan: Ministry of Agriculture.
- Kalenov, G.S. (1989). Principles for compiling a map of degraded vegetation in the deserts of Turkmenistan and possibilities for practical use. *Problems of Desert Development*, 1: 10–19.
- Kharin, N.G., Orlovskii, N.S., Kogai, N.A. & Makulbekova, G.B. (1986). Contemporary status of and prognosis for desertification in the USSR arid zone. *Problems of Desert Development*, 5: 58–68.

- Kharin, N.G. & Kiriltseva, A.A. (1988). New data on areas of desertified lands in the arid zone of the USSR. *Problems of Desert Development*, **4**: 3–8.
- Kharin, N.G., Tateishi, R. & Harahsheh, H. (1999). *Degradation of the Drylands of Asia*. Japan: Chiba University.
- Kerven, C. (Ed.) (in press). *From State Farms to Private Flocks: Prospects for Pastoralists in Kazakhstan and Turkmenistan*. London: Curzon Press.
- Kirichenko, N.G. (1966). Dinamika urozhaya i khimizma osnovnykh pastbish pustyni Betpak-daly [Yield dynamics and chemical content of pastures of Betpak-dala]. *Trudy Instituta Botaniki AN KazSSR [Proceedings of the Botanical Institute of the Kazakhstan Academy of Sciences]*, **23**: 3–53.
- Kirichenko, N.G. (1980). *Pastbisha Pustin' Kazakhstana [Desert Pastures of Kazakhstan]*. Almaty: Nauka.
- Le Houérou, H.N., Bingham, R.L. & Skerbek, W. (1988). Relationships between the variability of primary production and the variability of annual precipitation in world arid lands. *Journal of Arid Environments*, **15**: 1–18.
- Mace, R. (1991). Overgrazing overstated. *Nature*, **349**: 280–281.
- Matley, I.M. (1994) Agricultural development. In: Allworth (Ed.), *Central Asia: 120 years of Russian Rule*, pp. 92–130. NC: Duke University Press.
- Rachovskaya, E., Ed. (1995). Vegetation map of Kazakhstan and Middle Asia, including legend and explanatory text. Saint Petersburg, Russia.
- Rietkerk, M. & Van de Koppel, J. (1997). Alternate stable states and threshold effects in semi-arid grazing systems. *Oikos*, **79**: 69–76.
- Robinson, S. (2000). Pastoralism and land degradation in Kazakhstan. Ph.D. thesis, University of Warwick, U.K.
- Sadvokasov, R. (2000). The current state of the northern deserts, a case study of Betpak-dala. *Proceedings of the 7th Conference of Young Botanists*, Saint Petersburg.
- Scoones, I. (1992). Coping with drought: responses of herders and livestock in contrasting savanna environments in Southern Zimbabwe. *Human Ecology*, **20**: 31–52.
- Shepherd, N. & Caughley, G. (1987). Options for management of Kangaroos. In: Caughley, G., Shepherd, N. & Short, J. (Eds), *Kangaroos: Their Ecology and Management in the Sheep Rangelands of Australia*, pp. 188–219. Cambridge: Cambridge University Press.
- Short, J. (1987). Factors affecting food intake of rangeland herbivores. In: Caughley, G., Shepherd, N. & Short, J. (Eds), *Kangaroos: Their Ecology and Management in the Sheep Rangelands of Australia*, pp. 84–89. Cambridge: Cambridge University Press.
- Sludskii, A.A. (1963). Dzhuts in Eurasian steppes and deserts. *Trudii Instituta Zoologii AN KazSSR [Proceedings of the Zoological Institute of the Kazakhstan Academy of Sciences]*, **20**: 5–88.
- Sweet, J. (1996). A procedure for range resource assessment: a Swaziland example. *World Animal Review*, **2**: 28–37.
- UNEP/FAO, 1984. A provisional methodology for assessment and mapping of desertification. FAO, Rome.
- Wilson, A. & Macleod, D. (1991). Overgrazing: present or absent? *Journal of Range Management*, **44**: 475–482.
- Zhambakin, Z. A. (1995). *Pastbisha Kazakhstana [Pastures of Kazakhstan]*, Almaty: Kainar.
- Zonov, A.G. (1974). Wind erosion in grazing lands north of Betpak-dala. *Problems of Desert Development*, **3**: 38–42.