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# ASSESSMENT OF LAND CONDITION IN THE KYRGYZ REPUBLIC WITH RESPECT TO GRAZING AND POSSIBLE DEVELOPMENT OF A QUOTA SYSTEM AT THE LOCAL GOVERNMENT LEVEL


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## ABSTRACT


Animal husbandry is the most important source of livelihood for a large proportion of the rural population in Kyrgyzstan. The pastures they depend on are common property, which has encouraged livestock owners to increase their livestock numbers throughout the country and, consequently, has led to land degradation. Kyrgyz pastureland condition has been estimated using different methodologies and the results vary. The aim of this study was to study current global literature on land management in order to understand what is currently acknowledged as good practice, and by using available data on land use, land condition, and vegetation in Kyrgyzstan, to assess the condition of Kyrgyz pastures and suggest appropriate approaches for fighting land degradation. A State and Transition Model (STM) of Jergetal A/O was constructed based on the available data. The model indicates that the upland pasture areas comply with the equilibrium paradigm, where stocking rates play a key role in the transition from one state to another, while the lowland pastures are currently more influenced by the arid climate than by land management. This may be changing, however. Regulation of the stocking rate will be decisive in the fight against the degradation of pastures whereas, in the lower zone of pastures, dynamics comply with the non-equilibrium paradigm and the stocking rate does not play a large role in pasture degradation. In this zone, abiotic factors have a greater impact on the pasture. It seems feasible to apply STM as a tool within individual vegetation zones. A quota system does also seem feasible to control common land use. Such a system could also provide funding for grazing land infrastructure and improvement.

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## 1. INTRODUCTION

From the collapse of the Soviet Union in 1991 and until 2009 Kyrgyz land use was uncontrolled. This changed in 2009 when a new legislation on pasture use and management was enacted and enforced. Now land management is the responsibility of local governments at the *Aiyl okrug*[1] (A/O) level. Local land users are now responsible for managing the land in a sustainable way through formal committees. Communal pastures cover half of the total Kyrgyz land area (Undeland 2005).

The purpose of this new legislation is to improve pasture condition. The task is formidable. About 64% of the Kyrgyz population, or 3.5 million people, live in rural areas and depend on farming (Bussler 2010). It is critical for their livelihood that the land they depend on for their farming, especially livestock production, does not continue to degrade.

However, there are obvious obstacles. Land use during the period 1991-2009 is a classic example of the so-called "tragedy of the commons" situation described in a paper by Hardin (1968). During that time, everyone tried to maximize their production on the common lands but simultaneously neglected the condition of the land. This is evident by looking at livestock numbers from 1997 to 2011. During these 12 years, it rose from 9.5 million livestock units (LU) to 13.8 million LU[2], an increase of 45.3% (Atadjanov et al. 2012).

Another obvious problem is the fact that only 7% of the total land area is arable. Consequently, the main income of rural residents of Kyrgyzstan is from animal husbandry, which creates an enormous pressure on the pasturelands.

Because much of their income is derived from livestock production, all restrictions on land use will affect the farmers in a direct way and very few are prepared for such changes. It does not help that farmers do not realize the problems connected with their current land management practices and do not see the link with land degradation. Consequently it is not easy to convince them to take action. It may well be that it will require repeated severe land degradation episodes over the coming decades for the pasture users to get together to seek ways to control access to the pasture and agree upon a set of rules to limit exploitation, as predicted Feeny et al. (1990). However, the question is: can we wait for that to happen?

Current livestock numbers exceed the estimated land carrying capacity by 1.5-2 times, according to Atadjanov et al. (2012), and land degradation is therefore a real threat today. Enforcing restrictions on land use is a complicated and sensitive issue. Such intervention must be based on the best available knowledge and must also be based on co-operation with the local people, who must at the same time understand what the objectives are and how the imposed restrictions will help them manage their pastures in a sustainable way in the future.

To apply restrictions, we need a viable rationale, which can be achieved through adequate assessment of the pasturelands by taking into account their resistance and resilience.

[1] *Kyrgyz Republic is made up of Oblasts; Oblast are made up of Raions, which consists of Aiyl okrugs.*
[2]*A standard livestock unit (LU) in the Kyrgyz Republic is one cattle. One cattle is equal to 5 sheep.*

## 1.1. Aim of the project

The aim of the project was to:

1. use available data on current and past land use, land condition, and vegetation to assess land suitability for traditional Kyrgyz animal husbandry
2. research current global literature on common land management in order to understand what is currently acknowledged as good practice and what management approaches should be avoided
3. use 1 and 2 above to propose a way to achieve a sustainable management scheme, including considerations on why it might, or might not, be successful (risk assessment).

## 1.2. Gender effects

Traditionally, men are responsible for animal management in rural areas in the Kyrgyz Republic. Women are responsible for the produce, such as dairy products, including milking, wool and hide processing. Large numbers of livestock thus increase women's work.

Implementation of a livestock management scheme of a similar nature as the one proposed here may lead to decreasing livestock numbers, but increasing income per unit of livestock. This would make the woman's work easier while at the same time increasing income. Increased income from the herd could then be used to create additional income from other farm activities. It may thus help households to diversify their income sources.

# 2. LITERATURE REVIEW

Applied ecology disciplines such as range management are organized around models that describe how management practices affect ecosystem functions. A model is a system of concepts, generalizations, or assumptions relevant to the interaction between the management and the ecosystem. The model guides what data are collected, and how that information is assembled to arrive at management decisions. Two main schools have governed management approaches for the last decades. Those are the "climax school" based on the "range succession model" (Dyksterhuis 1949) and the "dynamic equilibrium school" derived from Westoby et al. (1989) and often presented as state and transition models.

## 2.1. The range succession model

The range succession model became widely accepted within the range management profession around the middle of the 20th century (Westoby et al. 1989). Its application was, however, associated with concerns on sustainability of pastures.

The range succession model is constructed around the interaction between herbivores and their resources and based on the assumption that every environment has a certain carrying capacity which is determined by biophysical characteristics such as mean annual rainfall, soil type and other biophysical characteristics of the area, which together determine production potential (Bell 1982; Fritz & Duncan 1994). The model predicts that the condition of pastures follows a linear pathway and can therefore be manipulated predictably with the stocking rate (Foran et al. 1978; Trollope 1990). Pastures can therefore be maintained in optimal conditions (subclimax or climax) if the stocking rate is maintained properly.

Continuous intense grazing often leads to vegetation changes such as the replacement of palatable grasses with less palatable plant species, replacement of perennial grasses by annuals, bush encroachment, lower standing biomass and reduced basic vegetation cover (Coppock 1993; Ash et al. 1995; Fynn & O'Connor 2000). These changers are sometimes irreversible, hence contradicting the model's assumptions (Vetter 2003).

At the same time as range managers were realizing that the range succession model did not reflect the plant-herbivore interaction adequately, there was an increasing general recognition among ecologists that equilibrium dynamics included far more complex interactions between ecosystem components than previously thought and were therefore impossible to predict in many ecological systems (Wiens 1984; DeAngelis & Waterhouse 1987).

## 2.2. The State and Transition models (STM)

This discrepancy was addressed by Ellis and Swift (1988) and Westoby et al. (1989) by applying non-equilibrium concepts to rangeland systems. They suggested an alternative approach based on state and transitions (STM), emphasizing non-linear responses of ecosystems under grazing or other varying disturbances. This model also acknowledges the existence of thresholds between different states of pastures (Friedel 1991). The model recognizes the existence of alternative stable states, and that changes between states require certain sets of conditions. Changes from some states to previous states can require major management inputs. Natural grazing systems, where the rate of disturbance is higher than the potential herbivore population response, are unlikely to degrade because the populations are unlikely to reach the necessary critical sizes (Ellis & Swift 1988). It should be noted that the range succession model and the STM are not necessarily incompatible. The range succession model can be seen as focusing on a single state or a limited spatial scale when compared to the STM (Ellis et al. 1993; Stafford Smith 1996; Bestelmeyer et al. 2004), and many of the systems include elements of both (Fernandez-Gimenez & Allen-Diaz 1999). Evidence from arid environments (e.g. Ellis & Swift 1988) suggests that these systems are well described by the non-equilibrium paradigm and may thus be seen as a state within STM that would encompass a larger spatial and temporal scale. Arid pasture areas can be more resilient. Vegetation cover, composition and productivity are influenced more by rainfall, whereas grazing has a smaller influence on those ecosystems.

## 2.3. Controversy surrounding the two models

There is an ongoing debate on the various predictions of the two models regarding the degradation of arid and semi-arid pastures. In some cases, the STM has been supported with such passion that the relevance of the stocking rate has been completely rejected (Dikeni et al. 1996), whereas other scholars believe that the STM is not applicable in areas not experiencing predominantly non-equilibrium dynamics (Fernandez-Gimenez & Allen-Diaz 1999; Illius & O'Connor 1999; Cowling 2000).

Some authors (e.g. Cowling 2000) have portrayed the non-equilibrium paradigm as irresponsible in its views on the degradation of pastures and its recommendations on opportunistic strategies. Proponents of the non-equilibrium paradigm, on the other hand, criticize the equilibrium view, because of its general assumptions, such as that climate is constant, and because of inflexible management strategies (Vetter 2004).

The assumption that forage production is largely determined by rainfall and is unaffected by animal population density leads to the conclusion that stocking rates are not the critical factors in land degradation because severe mortality during droughts keeps livestock densities well below the system's carrying capacity (Ellis & Swift 1988). This leads to the assumption that grazing has a limited effect on long-term forage production. However, this assumption may not be true for all arid ecosystems. If animals grazing in arid pastures are fed during periods when natural forage is insufficient, their numbers are no longer being controlled top-down by, for example, the climate. Their effect on the pastures may therefore increase dramatically, as appears to be the case in Kyrgyzstan.

### 2.4. Pasture management models in Kyrgyzstan

Based on the discussion above, it is interesting to compare the two paradigms to pasture management in Kyrgyzstan. Animal husbandry started in Kyrgyzstan about 8,000 years ago by domesticating cattle, yaks, sheep, goats and horses (Blench & Sommer 1999). Nomadic societies were organized based on kin and tribal groups. Since much of the pastures could only be used briefly each season for grazing due to low rainfall and weather extremes (Rischkowsky & Pilling 2007), livestock was moved within the regions to use seasonal changes in natural vegetation from summer to winter. Pastures were common property and their use was regulated by tribal councils through a decentralized decision-making process. This method of regulation appeared to be successful as land degradation due to grazing was not a problem (Schillhorn-van-Veen et al. 2003). Tribes used to alter their management routines every year so the same area was grazed only every third to fifth year (Undeland 2005). This pattern of land management bears some resemblance to the underlying concept behind STMs but was based on the nomad experience gathered through the generations. In the form of the land management they practiced, pastures were used extensively but only for a relatively short period of time (Suttie 2003).

This scenario changed in the 1930's. Under the modernization theory adopted by the new Soviet regime, rural people were forced to settle down and hand over their livestock to local authorities. The animals were then distributed to the *kolkhozes* and *sovkhozes*[3]. The idea was to increase production and people's welfare. Nomads were especially targeted by this new policy. (Kreutzmann 2013). With the beginning of the sedentarization in Kyrgyzstan radical changes followed. All livestock and land became the property of co-operatives and were managed by them or the state. Nomads were forced to settle and work on the large kolkhozes and sovkhozes. Decisions on pasture use and management were made by state agencies; they organized the herd rotations and land use, including use of remote areas. The main objective was to maximise livestock production and that was achieved by moving the herds to the lowland winter pastures in lowland valleys in early spring, then to higher pastures in late spring and finally to summer pastures in the highlands in June-July. The herds were then brought back to the lowland winter pastures in the autumn (Undeland 2005).

Pasture management plans were developed by the government based on the estimated carrying capacity of pastures. The carrying capacity was estimated for 80 different vegetation types and became the main management tool to avoid land degradation. However, serious pasture degradation occurred in the late 1980s, though it had started earlier. From 1960 to 1990 the average productivity of the summer pastures declined from 640 kg/ha to 410 kg/ha (-36%) and

[3] *The term kolkhoz describes a form of collective farming in the former Soviet Union. Kolkhoz members received shares in the farm's production and profits according to the number of days they worked. Along with kolkhozes there were also state-owned sovkhozes.*

the spring and autumn average pasture yield went from 470 kg/ha to 270 kg/ha (-43%). The productivity of winter pastures declined even more dramatically or from an average of 300 kg/ha to less than 100 kg/ha (-67%), of which 50,000 $km^2$ were affected by encroachment of woody and unpalatable species, making over 5,400 $km^2$ of pasturelands useless for grazing (Fitzherbert 2005).

Today it is a commonly accepted assumption among scientists that pastures in Kyrgyzstan are in a degraded state. According to the Kyrgyz State Project Institute of Land Management (Kyrgyzgyprozem), 29% of all pastures show signs of or are severely degraded (Penkina 2004) and 25% of pastures are deteriorating (Khusamov et al. 2009). Various projects have been implemented by the government to change this development but they have often been based on questionable ideas or limited understanding of the grazing ecosystems.

New field studies assessing the causes, effects, characteristics, and implications of grazing and pasture degradation in the Central Asian mountains question the previous assumptions of simple causal relationships between overgrazing and land degradation (Bimüller et al. 2010). This situation underlines the importance of empirical studies on the impact of grazing on pasture conditions to determine what main factors are affecting pasture capacity and condition.

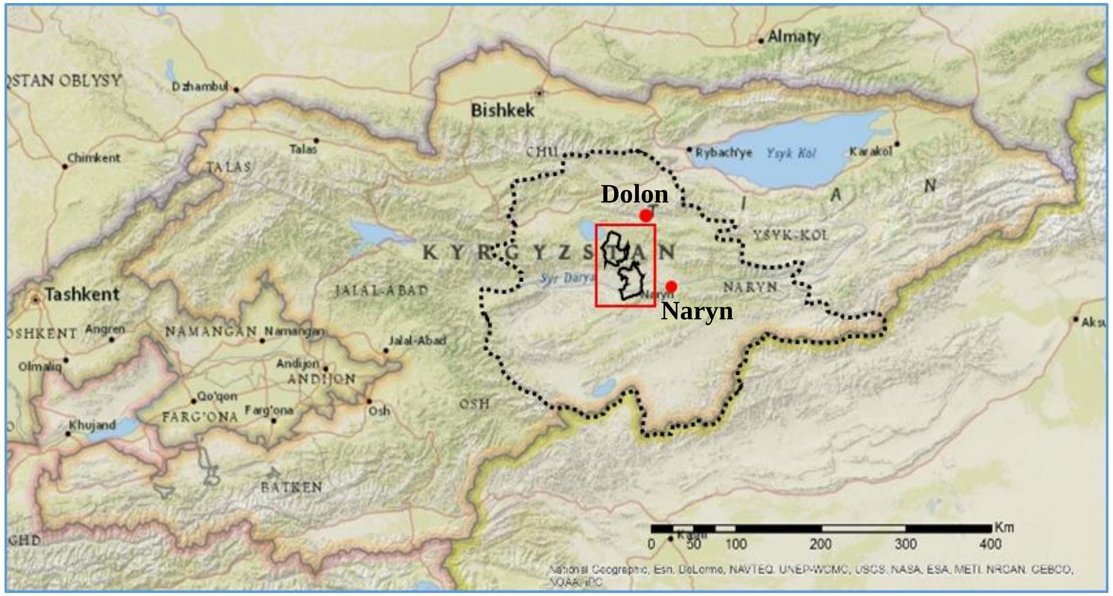
## 3. MATERIAL AND METHODS

### 3.1. Study area

The selected study area was the Jergetal A/O in Naryn district (Fig. 1). About 70% of the population is engaged in animal husbandry, mainly utilizing mountain pastures. More than 29% of the pastures of the Republic and about 15% of the total livestock are found within this region. The area is well suited for animal husbandry and grazing, both because of topography and climate (Atadjanov et al. 2012).

Jergetal A/O’s pastures cover about 42,000 ha (Bussler 2010). They range between 2,000 to 3,100 m a.s.l. and stretch along a 50 km long area. The area belongs partially to the National Forest Administration (NFA). NFA's land is generally excluded from grazing but can be leased for that purpose by livestock owners. There is, however, some ambiguity over which land belongs to the NFA and it is consequently not clear how much pastureland is available to the herders (Atadjanov et al. 2012). Most herders utilize pasture near the villages intensively all year round and only large herd owners actually relocate their livestock to the remote summer pastures. This change in land use from the traditional obligatory relocation of livestock depending on season has resulted in underuse of many remote pastures. Arable land is rare in Jergetal A/O. Total arable land is estimated at 1,650 ha, of which about 1,000 ha are irrigated. During Soviet times, all arable land was irrigated and cultivated. However, the irrigation systems have not been maintained since the Soviet's collapse, making cultivation difficult. The main cultivated fodder crops are legumes (especially sainfoin, *Onobrychis viciifolia*), barley and other grasses. The total population of Jergetal A/O is about 6,000, households number 1,164, and the total LU 12,300 (Bussler 2010).

The climate of the Naryn region is extremely continental, with cold dry winters and warm wet summers. Mean annual temperatures and precipitation are 3.8 °C and 298 mm. The corresponding numbers for Dolon are -1.67°C and 390 mm in the 3,000 m.a.s.l. The coefficients of variation for precipitation range from 66% at 2,200 m and 55% at 3,000 m.a.s.l. (Fig. 2).



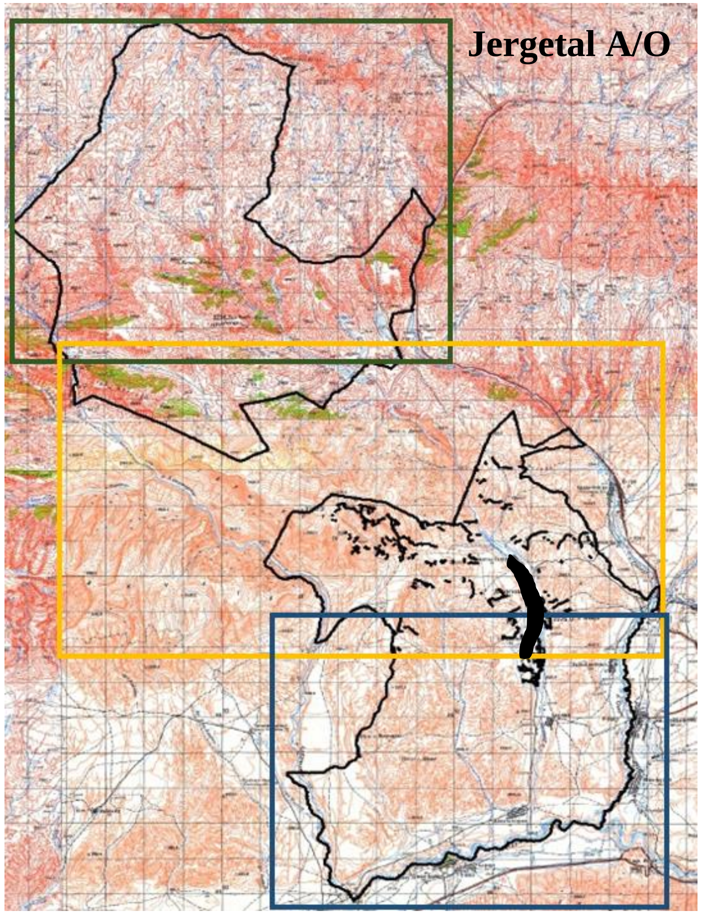




Figure 1. Left: Location of Jergetal aiyl okrug's (A/O's) pastures in Kyrgyzstan (map from National Geographic Basemaps). Borders of Naryn district shown by dotted line. Red points mark the locations of the Naryn and Dolon weather stations. Right: Map of the Jergetal A/O showing summer pastures (green frame), spring and autumn pastures (yellow frame), winter pastures (blue frame) and borders of Jergetal A/O's pastures (black lines). Map from Kyrgyz Institute of Geography.

## 3.2. Data sources

The CAMP Alatoo Public Foundation has conducted several projects since 2008 focusing on sustainable pasture management issues. As a part of that effort, a large amount of information has been accumulated and compiled for various parts of Kyrgyzstan. This includes digitization and rectification of geobotanical maps from 1986-1988. The resulting database includes information from 4,248 sites on 70 different vegetation types, including biomass and vegetation cover. Vegetation types were defined by Kygyzgiprozem during their 1986 inventory and adopted by the CAMP Alatoo Public Foundation in 2009. The database now covers more than 40,000 hectares. These data have been used to assess land condition and for working out an STM for Jergetal A/O (CAMP Alatoo Public Foundation 2012).

In order to raise the awareness of pasture users the CAMP Alatoo Public Foundation has since 2010 conducted a series of seminars on "Sustainable Pasture Management" in all regions of the country. A total of about 30 workshops involving more than 600 farmers and other stakeholders have been conducted. Seminar topics have included the assessment of pasture conditions, estimation of livestock numbers and its dynamics, and the possible solutions to the degradation of pastures and other relevant information. This has given an opportunity to discuss with those involved the issues concerning land use and management practices. Some of these data are used and presented in section 4.3.2.

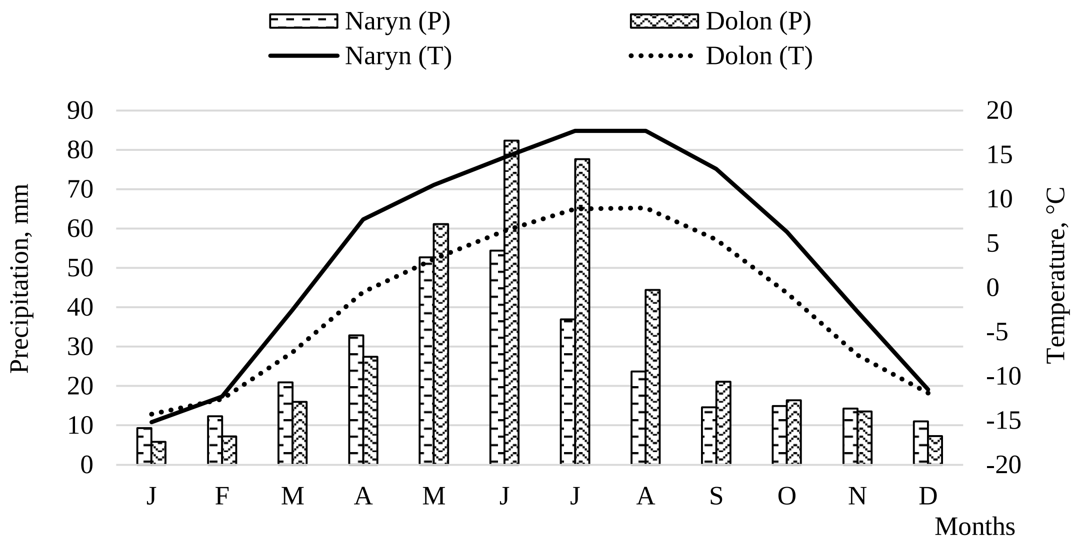



Figure 2. Mean monthly precipitation (P) and temperature (T) for two different pasture areas of Jergetal aiyl okrug for 1985-2006. Naryn is at 2,200 m.a.s.l. and Dolon at 3,000 m.a.s.l. Data from Kyrgyz Institute of Meteorology.

## 3.3. State and Transition modelling

A State and Transition Model (STM) was constructed for selected key vegetation types as originally defined by the Kyrgyzgiprozem geobotanical maps. The STM structure was based on Briske et al. (2008). STMs are conceptual frameworks constructed around land conditions (states) and their possible changes (transitions) under a given set of conditions (e.g. disturbances). They recognize the presence of ecosystem thresholds and multiple pathways (Stringham et al. 2003).

### 3.4. Calculation of current and potential pasture carrying capacity

The current carrying capacity of pasture is defined by the following formula (Isakov 1975):

$$CC_{cur} = \frac{(Y_i * P_i + Y_{i+1} * P_{i+1} + \ldots + Y_n + P_n) * S * 0.7}{7.5 * D}, \quad (1)$$

where:

$CC_{cur}$ is the current carrying capacity,
P is the percentage of represented state within the pasture unit (Appendix 2),
Y is the palatable yield of states within the pasture units
S is the area of a given pasture unit
D is the number of pasture use days
0.7 is the coefficient of pasture use (based on Kyrgyzgiprozem recommendation)
7.5 is the required amount of dry matter for one LU per day in kg.

The formula can also be used to calculate the potential carrying capacity of pastures by replacing *palatable yield of states* with the *desirable state's palatable yield* as estimated in the field.

### 3.5. Calculation of grazing pressure

The grazing pressure (GP) is defined as the ratio of the number of livestock to the pasture carrying capacity (2):

$$GP = \frac{SR(stocking\ rate)}{CC_{cur}}, \quad (2)$$

where a value equal to 1 represents optimal grazing pressure; values less than 1 indicate low grazing pressure, and values above 1 indicate heavy grazing pressure. See also Fig. 7.

### 3.6. Statistical analyses

Data derived from the CAMP Alatoo Public Foundation database on total biomass, palatable biomass and vegetation cover were analysed for statistical differences using Kruskal-Wallis and Mann-Whitney non-parametric tests to identify the significance of variability between states of STM. These nonparametric tests were selected because of the non-normality of the data.

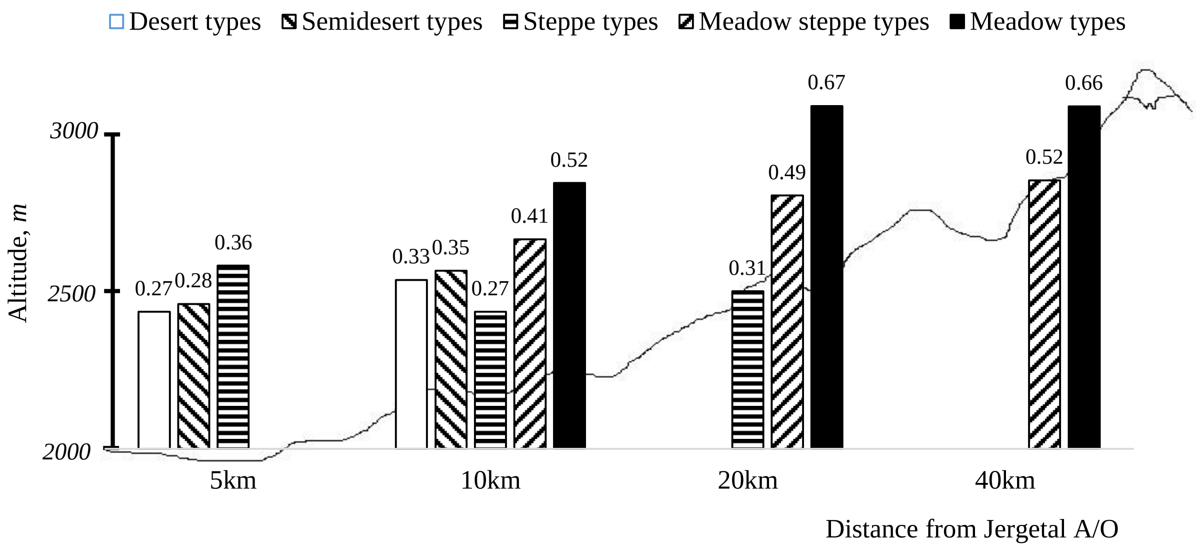


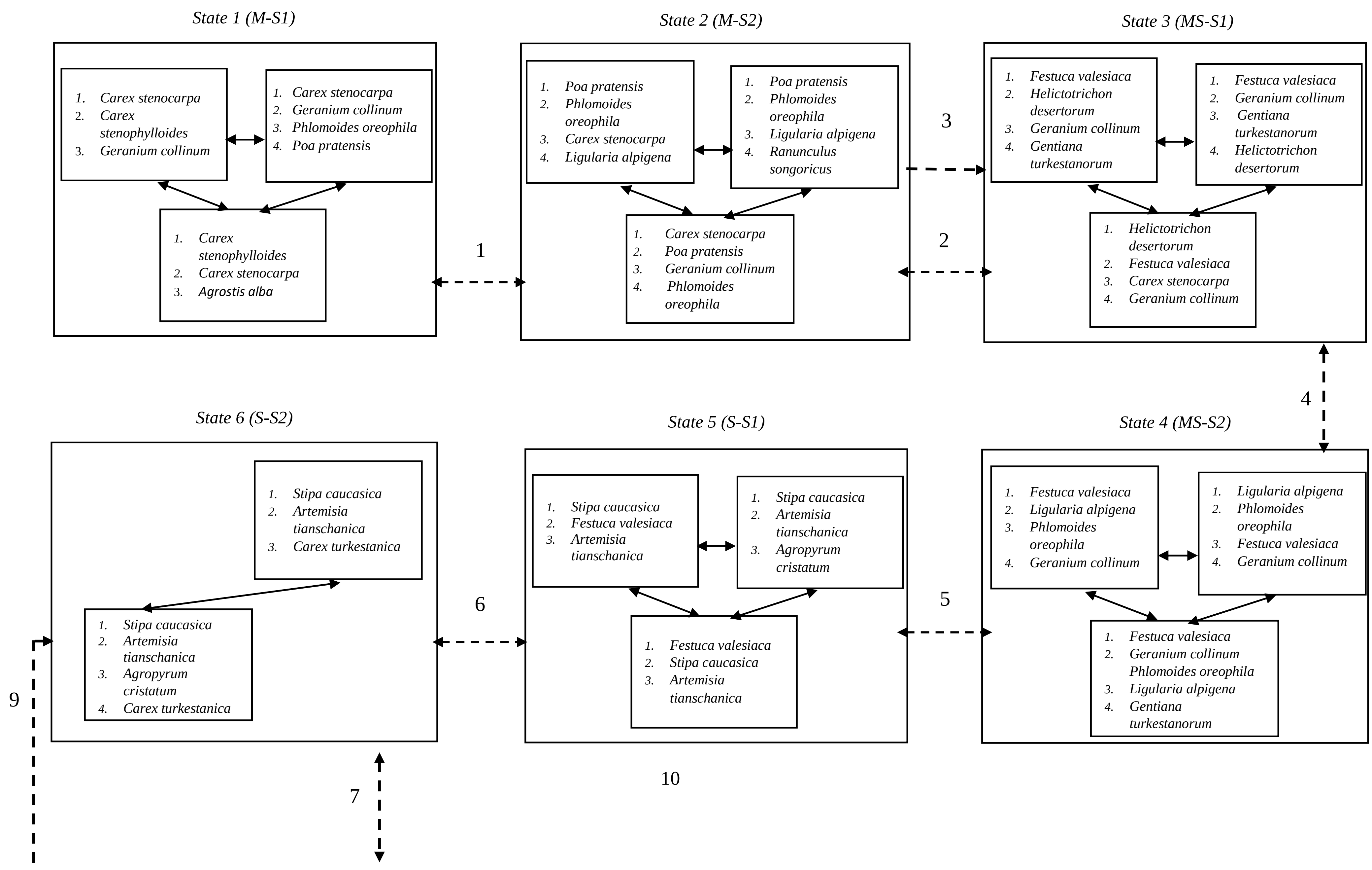

Figure 3. The horizontal and vertical distribution of Jergetal A/O's pastures types from the village and their biomass in t/ha. Deserts, semi-desert and steppe pastures are found about 5 km from the village, at altitudes between 2,000-2,600 m a.s.l. 10 km away from the village, small shreds of meadow steppe and meadow types of pastures appear. Around 20 km from the village, desert and semi-desert pastures disappear. Steppe types disappear about 40 km from the village. Meadows and meadow steppes dominate from 40 km distance, ranging from 2500-3000 m a.s.l.

## 4. RESULTS AND DISCUSSION

About 70 types of vegetation are found in Jergetal A/O according to the CAMP Alatoo Public Foundation database. Those include desert and semi-desert vegetation types as well as steppe, meadow steppe and meadow vegetation types (Fig. 3).

Figure 3 indicates the influence of altitude on the formation of vegetation types. This means, for example, that a transition from semi-desert pastures to the meadow steppe, under current climatic conditions is unlikely but might be possible by human intervention, such as constructing an irrigation system in the semi-desert. Such projects are currently unlikely and this is reflected in the proposed STM (Fig. 4). The transition from one state to another is first and foremost assumed to occur in response to natural changes such as climate factors. The STM is presented in Figures 4 and 5 and Tables 1 and 2.

Consequently, 10 states which differ from each other on a number of parameters within Jergetal A/O can be allocated. Comparison of states within similar pasture vegetation types shows that there are significant differences between states 1 and 2 when total palatable biomass is compared ($P<0.001$) but that significance does not hold for no vegetation cover (Table 3). Thus, it can be assumed that transition 1 leads mostly to species change and only to a lesser degree to a change in biomass. Vegetation cover in state 3 still high and almost the same as in state 1 (Fig.6) but significantly less than in state 4, but again, this result does not apply to the biomass ($P<0.07$; Table 3). Total biomass significantly decreased in state 4 compared to state 3, due in general to the decrease in vegetation cover, most probably because of overgrazing.


State 1 (M-S1)
1. Carex stenocarpa 2. Carex stenophylloides 3. Geranium collinum
1. Carex stenocarpa 2. Geranium collinum 3. Phlomoides oreophila 4. Poa pratensis
1. Carex stenophylloides 2. Carex stenocarpa 3. Agrostis alba
State 2 (M-S2)
1. Poa pratensis 2. Phlomoides oreophila 3. Carex stenocarpa 4. Ligularia alpigena
1. Poa pratensis 2. Phlomoides oreophila 3. Ligularia alpigena 4. Ranunculus songoricus
1. Carex stenocarpa 2. Poa pratensis 3. Geranium collinum 4. Phlomoides oreophila
State 3 (MS-S1)
1. Festuca valesiaca 2. Helictotrichon desertorum 3. Geranium collinum 4. Gentiana turkestanorum
1. Festuca valesiaca 2. Geranium collinum 3. Gentiana turkestanorum 4. Helictotrichon desertorum
1. Helictotrichon desertorum 2. Festuca valesiaca 3. Carex stenocarpa 4. Geranium collinum
1
2
3
4
State 6 (S-S2)
1. Stipa caucasica 2. Artemisia tianschanica 3. Carex turkestanica
1. Stipa caucasica 2. Artemisia tianschanica 3. Agropyrum cristatum 4. Carex turkestanica
State 5 (S-S1)
1. Stipa caucasica 2. Festuca valesiaca 3. Artemisia tianschanica
1. Stipa caucasica 2. Artemisia tianschanica 3. Agropyrum cristatum
1. Festuca valesiaca 2. Stipa caucasica 3. Artemisia tianschanica
State 4 (MS-S2)
1. Festuca valesiaca 2. Ligularia alpigena 3. Phlomoides oreophila 4. Geranium collinum
1. Ligularia alpigena 2. Phlomoides oreophila 3. Festuca valesiaca 4. Geranium collinum
1. Festuca valesiaca 2. Geranium collinum Phlomoides oreophila 3. Ligularia alpigena 4. Gentiana turkestanorum
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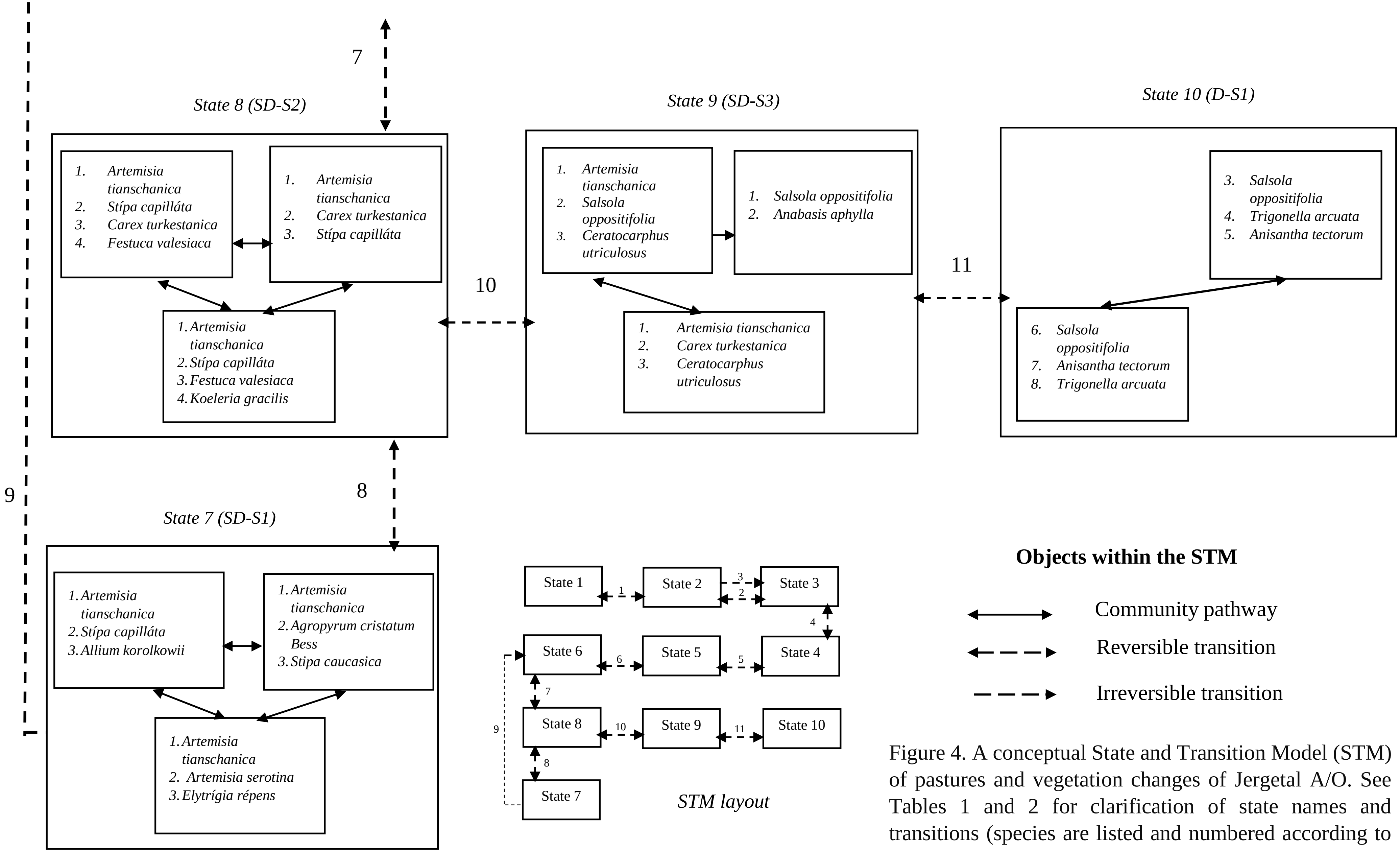


Figure 4. A conceptual State and Transition Model (STM) of pastures and vegetation changes of Jergetal A/O. See Tables 1 and 2 for clarification of state names and transitions (species are listed and numbered according to their dominance).

**Table 1.** List of states in the proposed STM model (Fig. 4). A detailed description of pasture types is presented in Appendix 1.

**State 1 (M-S1: Meadow type - state 1).** This state contains meadow pastures located in the upper mountain zone. The pasture communities are dominated by graminoids - *Carex stenophylloides, C. stenocarpa* and *Poa pratensis.*

**State 2 (M-S2: Meadow- type - state 2).** This state is one of the two meadow types. It is characterized by the appearance of hardy species, such as *Ligularia alpigena*, but the state is first and foremost dominated by *P. pratensis*.

**State 3 (MS-S1: Meadow-Steppe type - state 1).** The MS type is dominated by Poacea, especially *Festuca valesiaca.* The state occupies large areas and is one of the most productive pastures types. Beside *F. valesiaca, Helictotrichon desertorum* and miscellaneous herbs such as *Geranium collinum* are common.

**State 4 (MS-S2: Meadow-Steppe type - state 2).** The second MS state. It is characterised by the decreasing dominance of *F. valesiaca* and appearance of unpalatable and grazing tolerant species, such as *Ligularia alpigena.*

**State 5 (S-S1: Steppe type - state 1).** This state is characterized by dominance of *Stipa caucasia* and *F. valesiaca*, both typical for steppe and meadow steppe pastures of Kyrgyzstan. The fescue is a valuable pasture species. The dominance of *S. caucasica* indicates low grazing pressure in the spring, because *S. caucasica* is very palatable in spring but loses palatability in summer, and autumn.

**tate 6 (S-S2: Steppe type - state 2).** This is the second steppe state. It is characterized by dominance of *S. caucasica* as in the first steppe state, but is distinguished from it by increased appearance of *Agropyrum cristatum*and later *C. turkestanica. C. turkestanica* and *Artemisia tianschanica* are considered indicators of pasture degradation.

**State 7 (SD-S1: Semi-Desert type - state 1)**. State 7 represents the most productive vegetation state within the semi-desert vegetation type. It is dominated by perennial vegetation and presented by *Artemisia tianschanica* and *Artemisia serotina*. The herbacious layer is dominated by *S. capillata*, *S. caucasica* and *Elytrigia repens.* These species have high nutritive value in early spring.

**State 8 (SD-S2: Semi-Desert type - state 2)**. This state is dominated by *Artemisia tianschanica* but lacks. *Agropyrum cristatum* compared to state 6. However, *F. valesiaca* is present in this state. It is both palatable and grazing tolerant. This state may also contain *C. turkestanica;* its appearance is considered an indicator of pasture degradation.

**State 9 (SD-S3: Semi-Desert type - state 3).** *Artemisia tianschanica* is still common but is being replaced by *Salsola oppositifolia*, which is not feasible as a grazing plant and considered an indicator of soil degradation.

**State 10 (D-S1: Desert type - state 1).** This state is characterised by desert type vegetation, *Salsola oppositifolia, Anisantha tectorum* and *Trigonella arcuata*. In the second seral stage, the abundance of *T. arcuata* increases.

**Table 2.** List of transitions in the proposed STM model (Fig. 4).

**Transition 1 (T1).** Meadow pastures are most productive and show little sign of soil erosion. They are subject to changes in species composition where unpalatable plants increase in cover. This is reversible by regulation of the stocking rate.

**Transition 2 (T2).** The transition from state 2 to state 3 occurs in the high mountain pastures at an altitude of 3000 m a.s.l. It is driven by changes in temperature and soil hydrology, mostly on the southern slopes.

**Transition 3 (T3).** This transition describes an irreversible change from meadow types to meadow steppe types of pasture (going from state 2 to 3). It may happen in the middle altitude zone (2500-2800 m a.s.l.). States 3 and 4 are concentrated on the southern, south-eastern and south-western slope exposures. The reverse transition from state 3 to 2 is unlikely. A reversal of this transition is only possible under the influence of climate change.

**Transition 4 (T4).** Transition 4 occurs due to improper grazing management, causing unpalatable plant species such as *Ligularia alpigena* and *Phlomoides oreophila* to proportionally increase. The transition may be reversed through proper stocking.

**Transition 5 (T5).** The transition from meadow-steppe to steppe pasture types may occur in intensively grazed areas during droughts. It will first be established on south-oriented slopes due to their temperature regime.

**Transition 6 (T6).** This transition will occur if the land is not managed properly. Recovery is possible by altering the stocking rate and/or excluding grazing for several years. Alternatively, this transition can be reversed by applying seed and fertilizer.

**Transition 7 (T7).** This transition occurs in the lower region of 2000 to 2500 m a.s.l. It is driven by a high stocking rate in combination with reduced precipitation (180 to 220 mm) coinciding high temperatures (13-15° C).

**Transition 8 (T8).** Low stocking rate on pastures in state 8 and favourable hydrological conditions (irrigation, the availability of water sources nearby, etc.) influence this transition. Overgrazing will lead to soil degradation (salinization, soil erosion, etc.). Exclusion of irrigation combined with overgrazing will reverse this transition.

**Transition 9 (T9).** Exclusion of irrigation in state 7 and compliance with the optimal stocking rate will lead to a one-way transition from state 7 to state 6. Adjustable grazing will contribute to the emergence and dominance of palatable grasses.

**Transition 10 (T10).** This transition is driven by continuous overgrazing such as is happening around the villages, resulting in pasture degradation and desertification. It leads to the appearance of unpalatable plants. The reverse process requires restoration work like seeding of desirable plant species and long-term exclusion of grazing for 5-10 years, which is very difficult to do currently.

**Transition 11 (T11)**. This transition is driven by continued overgrazing at altitudes between 2300-2400 m a.s.l. Little precipitation (<200 mm) and high temperatures during the growing season (>15° C) will further promote the transition. The reverse process requires a significant addition of resources such as seeds and fertilizer.

State 6 is derived from state 5 and characterized by decreasing total biomass from 0.47 t/ha down to 0.31 t/ha (Fig. 6). The vegetation cover and percentage of palatable biomass are not statistically different (P>0.39; Table 3). This could be because species like *Agropyrum cristatum* are highly palatable in the early stage, as represented in state 6. Later, the fibre content increases and the palatability is accordingly reduced. The Kruskal-Wallis test was used to test states within the semi-desert pastures. The results indicated that there is significant variability between three states of the semi-desert vegetation types with respect to all parameters. The results are presented in Table 4.

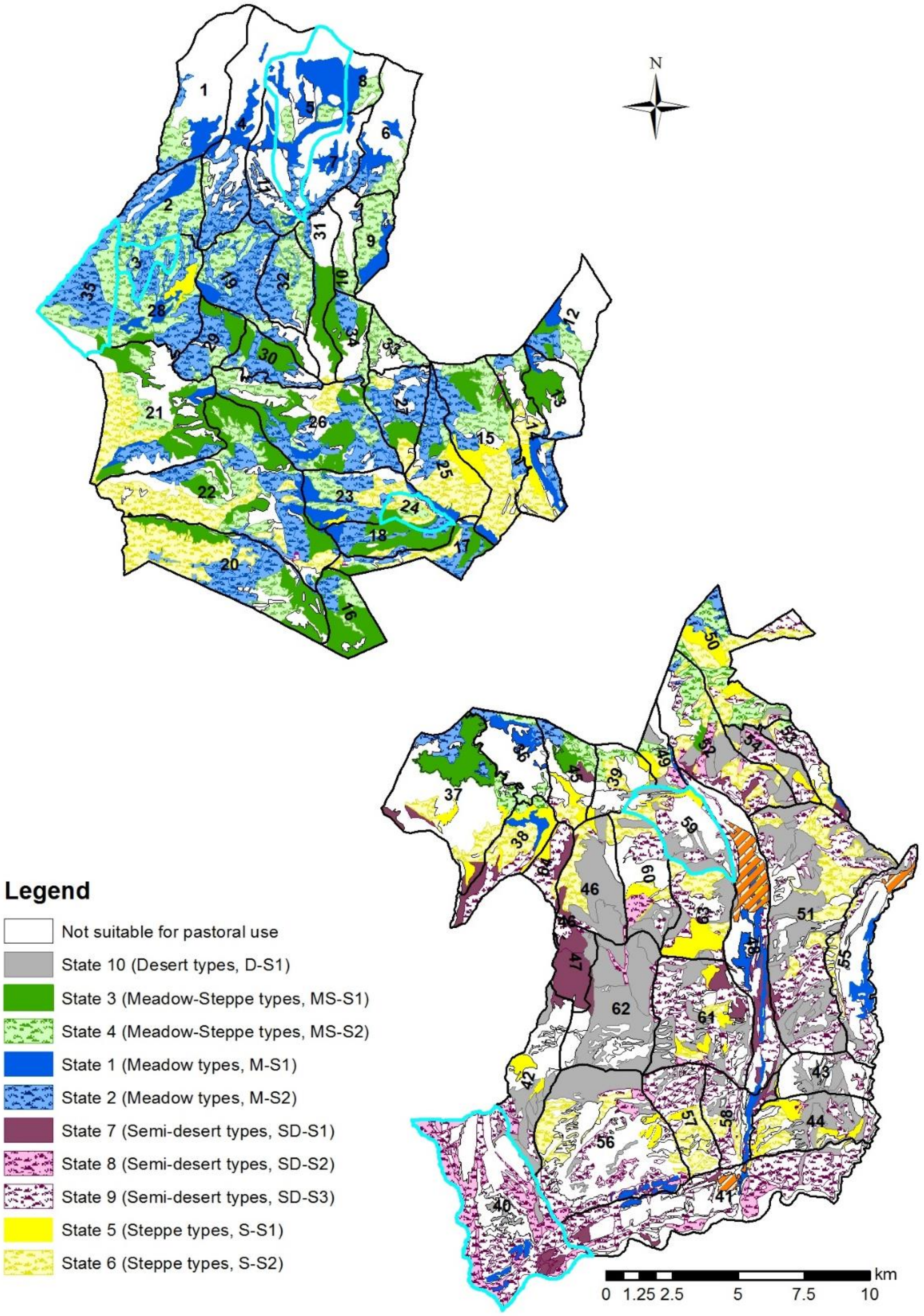


Figure 5. Distribution of states within the Jergetal A/O's pastures based on the CAMP Alatoo Public Foundation database. Black lines show borders of pasture units; figures indicate number of pasture units. Blue lines indicate pasture units which are used as an example in Table 5.

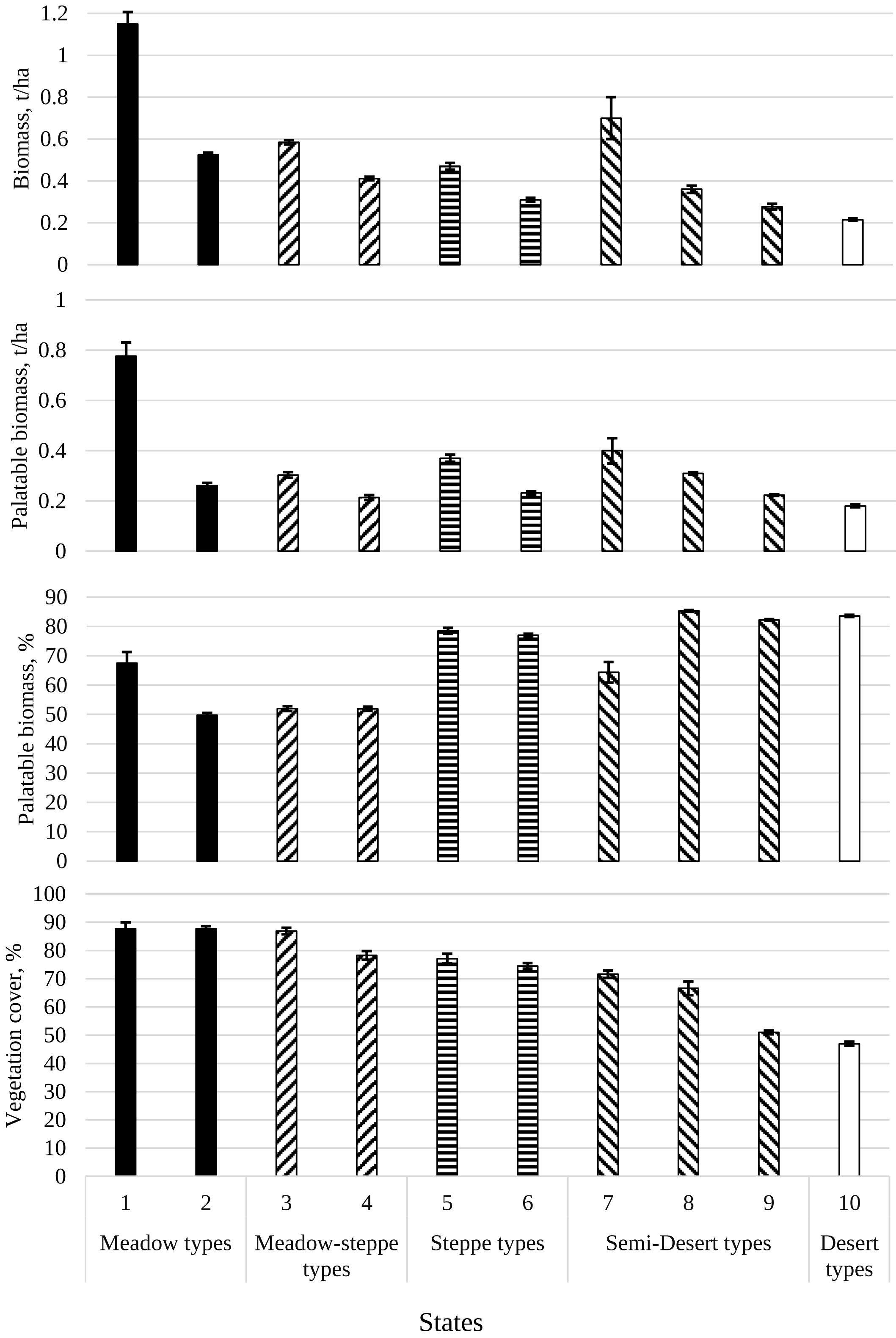


Figure 6. Distribution of biomass, palatable biomass (t/ha) and % and vegetative cover of the states within the different types of pastures. Vertical bars represent ±1 SE.

**Table 3.** Summary of Mann-Whitney tests of the variability of states within the meadow, meadow-steppe and steppe types of pastures. The p value is significant at <0.05.

| ***Effect*** | ***State*** | ***P*** | ***Effect*** | ***State*** | ***P*** |
|---|---|---|---|---|---|
| Total biomass | State 1 – State 2 | 0.001 | Palatable biomass, % | State 1 – State 2 | 0.001 |
| | State 3 – State 4 | 0.001 | | State 3 – State 4 | 0.07 |
| | State 5 – State 6 | 0.001 | | State 5 – State 6 | 0.38 |
| Palatable biomass, t/ha | State 1 – State 2 | 0.001 | Vegetation cover | State 1 – State 2 | 0.57 |
| | State 3 – State 4 | 0.001 | | State 3 – State 4 | 0.002 |
| | State 5 – State 6 | 0.001 | | State 5 – State 6 | 0.39 |

**Table 4.** Summary of Kruskal-Wallis tests of states within the semi-desert pastures.

| ***Effect*** | ***DF*** | ***H*** | ***P*** |
|---|---|---|---|
| Total biomass | 3 | 110.3 | 0.001 |
| Palatable biomass, t/ha | 3 | 91.53 | 0.001 |
| Palatable biomass, % | 3 | 22.95 | 0.001 |
| Vegetation cover | 3 | 13.59 | 0.004 |

### 4.1. Influence of different stocking rates on pasture condition

Regulation of the stocking rate is one of the most important elements of sustainable pasture use and, properly managed, can allow maintenance of high productivity of pastures in the long term. According to reports from the State Agency on Environment Protection and Forestry of the Kyrgyz, the grazing pressure on pastures is growing (Atadjanov et al. 2012). Land use beyond optimal stocking rates causes amplification of degradation processes, reduction of pasture productivity and eventually makes them unusable for agriculture. The stocking rate is the only tool available to all Kyrgyz range managers that can be used to adjust the successional trend of vegetation (see e.g. Penkina 2004, Abdurasulov 2011 and others). However, it has been argued that grazing has only a minimal or no influence on the vegetation dynamics of arid environments because of pronounced interannual rainfall variability, such that these grazing systems are considered to be non-equilibrial (Ellis & Swift 1988, Fernandez-Gimenez & Allen-Diaz 1999). The notion that grazing has a minimal impact on vegetation has been extended to the pastoral systems of the semi-arid savannas of Africa and rainfall has the most marked effect on variability in herbaceous production. The depletion of biomass by heavy grazing is more pronounced when combined with drought (Fynn and O'Connor, 2010). Bayer and Waters-Bayer (2003) believe that the non-equilibrium nature of vegetation in arid areas is deliberately avoided, an opinion shared by Kerven et al. (2012).

Against the background of the dispute on the impact of livestock grazing on pasture conditions in the arid zone, it is interesting to study the effect of grazing pressure on the transition from one state to another. The current grazing pressure on the pastures in Jergetal A/O was assessed in 2011 (see Appendix 2). The results are shown in Fig. 7.

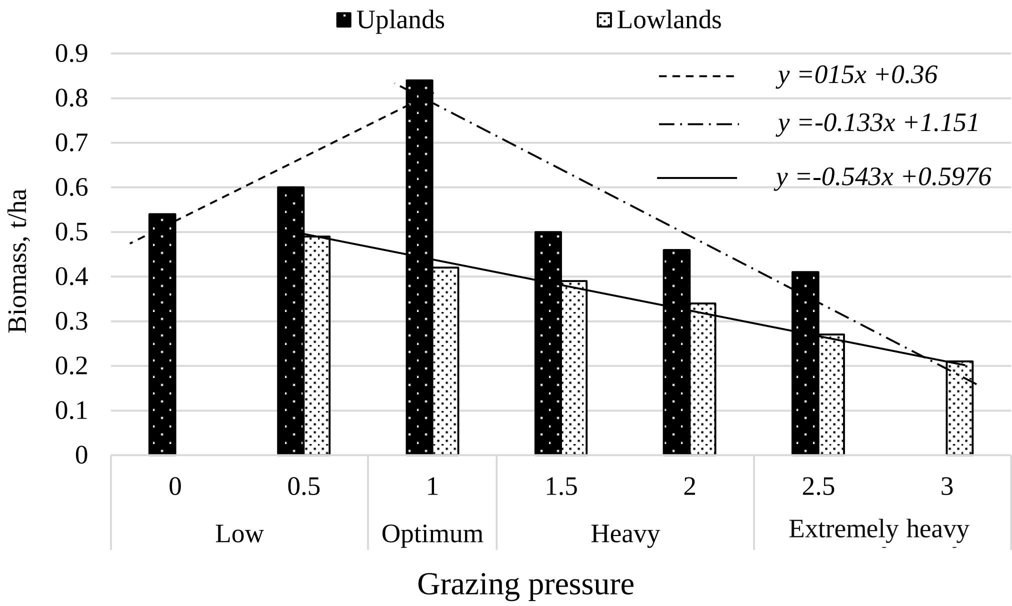


Figure 7. The influence of grazing pressure on pasture biomass. —— linear function of lowlands; - - - - linear function of uplands, the state of lack of grazing at the optimal grazing pressure; and - · - · - linear function of uplands where exceeding carrying capacity was allowed. Pastures were arranged into groups based on similar pasture ecosystems. Thus, meadow and meadow steppe pastures were combined into an upland pasture ecosystems group. Steppe, semi-desert and desert types were combined into pasture ecosystems of dry areas or lowlands. The upland pastures are generally characterized as having higher humidity and more fertile soils than the lowland pastures.

The results indicated that meadow and meadow steppe types are more productive under optimal grazing pressure. Two different trends are noteworthy. First there was an increase in biomass as the grazing pressure increased from <1 to the optimal stocking rate of 1. This trend can be described by the linear equation*: y =015x +0.36 (*$R^2$ *= 0.89)*. Further increase in the grazing pressure led to a reduction in biomass, which can be described by another linear relationship, *y =-0.133x +1.151 (*$R^2$ *= 0.77)* (Fig. 7). Grazing may temporarily lead to an increase in biomass in states 1 and 3. At a low grazing pressure the biomass of the pasture is reduced, as well as when the pressure is increasing. In conditions with optimal grazing pressure, states 1 and 3 dominate, whereas in situations with low grazing pressure the pasture was dominated by states 2 and 4 (Fig. 8). Increasing the grazing pressure led to the dominance of states 4 and 2, whilst in extreme pressure conditions there was a variety of states from 2 to 6.

Pastures of arid semi-arid zone (steppe, semi-desert and desert pastures types) followed a different pattern, with biomass decreasing constantly with increasing grazing pressure. This trend can be described by the linear equation: *y =-0.543x +0.5976 (*$R^2$ *= 0.99).* Here pastures had the highest biomass under low grazing pressures. They are presented by state 7 (SD-S1) in the STM (Fig. 4). Starting at an equal level of stocking rate with carrying capacity, biomass was gradually reduced (Fig. 8).

The results suggest that the semi-arid areas are mostly controlled by abiotic factors such as rainfall, temperature and soil conditions and that these factors have a major impact on the vegetation, species composition and biomass. However, if there is sufficient moisture, such as in the upland pastures, then biotic factors, here grazing, are the most influential factors on biomass production, or they are more resilient and those areas are more prone to land-use driven degradation than their lowland counterparts.

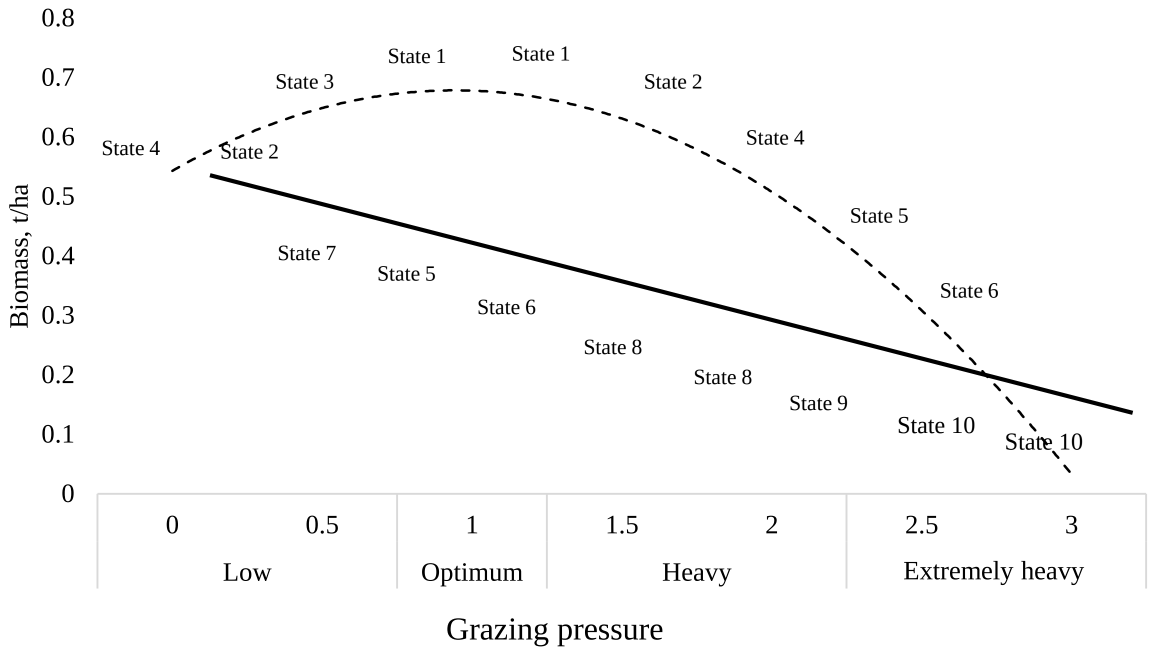


Figure 8. Suggested trajectories of biomass production for upland pastures (dashed line) and lowland pastures (solid line) under varying grazing pressures. States as proposed in Fig. 4 have been superimposed on the figure based on their biomass production and expected location in the STM framework.

## 4.2. The possibility of applying the STM in practice

In 2009 the parliament of Kyrgyzstan enacted the Law on Pasture (N 30), which shifted the responsibility for managing pastures to new community-based user organizations. According to the law, all pasture users must now form Pasture User Unions (PUU), each of which elects its own executive body called a pasture committee. These bodies are obligated to govern the use of pastures independently from state administrative control. The PUUs hold a bundle of rights and responsibilities. They have to develop and implement a community pasture management plan and an annual pasture use plan, issue pasture use right certificates and collect payments for pasture use, resolve disputes among pasture users, and carry out investments in pasture infrastructure and maintenance.

However, the implementation of the above commitments is very difficult for pasture committees. As members of the pasture committee are elected from the local pasture users, some do not have the appropriate education and most of them even lack practical experience in pasture management planning as the planning was organized by the State Land Management Committee (Giprozem) during the Soviet period. There is a considerable need for pasture use and management plans in Kyrgyzstan that rest on a scientific base. Using STMs could serve as a basis for pasture management plans for Jergetal A/O, as is now obligatory for the local pasture committees in accordance with the new law.

If this approach is taken, then it will be necessary to take into account the fact that the current carrying capacity of the pastures, as well as the potential carrying capacity, has a very high and often unpredictable coefficient of variation (Table 5).

**Table 5.** Planing pasture use according to pasture current carrying capacity and its variability of Jergetal A/O.

| # of pasture unit | Area of pasture, ha | Season of use | Current stocking rate | Current carrying capacity, LU | Potential carrying capacity, LU | Management activities |
|---|---|---|---|---|---|---|
| 35 | 662 | Summer | 0 | 100 - 230 | 240 - 560 | *1. This pasture unit is out of use, which led to lower yields due to competition and litter production. To achieve the estimated potential carrying capacity this pasture unit will have to be grazed. It is recommended to start with relatively low stocking rates of 110-120 LU, but later a stocking rate of 400-500 LU might be achieved under careful land management.*<br>*2. It is necessary to understand why this pasture is no longer used.* |
| 3 | 290 | Summer | 0.5 | 40 - 100 | 100 - 230 | *3. Low stocking rate on pasture. Number of cattle should be increased.* |
| 5 | 596 | Summer | 1 | 230 - 530 | 400 - 940 | *4. Stocking rate here appears to be optimal given the current land condition. However, the predicted potential carrying capacity is not reached. To achieve that, it is necessary to introduce rotation grazing within in the pasture unit.* |
| 24 | 243 | Summer | 2.8 | 36 - 85 | 50 - 110 | *5. This pasture is overused due to the proximity to the village. Livestock could be moved to pasture number 35.*<br>*6. Increasing the pasture ticket cost (grazing price) for this site is also feasible.*<br>*7. For significant improvement of the pasture condition, the site should be excluded from grazing for several years.* |
| 40 | 1125 | Spring – autumn | 0.5 | 260 - 430 | 330 - 560 | *8. The area of pasture is too big and parts of it are not used as their potential allows. A rotation grazing system within the pasture unit would help improve the pasture management.*<br>*9. One reason why parts of the pasture are not used is due to lack of watering points. They need to be installed in the abandoned areas.* |
| 59 | 392 | Spring – autumn | 2.3 | 100 - 165 | 145 - 240 | *10. Overgrazed, stocking rate should be decreased.*<br>*11. Irrigation would help improve the land condition.* |

Therefore, planning of pasture use should be started with a minimal stocking rate. For example, for pasture unit 35 (Table 5) this would be 100-120 LU. Pasture condition would then have to be assessed at the end of every year, both through monitoring of the pastures themselves, but also by assessment of the condition of the livestock grazing on the site. In addition, it is necessary to include the projected future effect of each year's weather conditions on the coming years. If there were deviations from the normal year, for example, heavy rains or drought or high temperature deviations, then it may be necessary to continue with the same, or a lower, stocking rate the following year. On the other hand, if the pasture condition is good after the grazing season, the condition of the livestock is better than in the previous years and the weather conditions were not abnormal, it can be assumed that the stocking rate is not too high and therefore it is possible to increase the stocking rate cautiously. Thus, referring again to Table 5, it might be possible to increase the grazing pressure on site 35 (Fig.5), as currently there is no grazing and it is covered mostly by unpalatable vegetation. Adjustable grazing can increase the productivity of pastures. A lack of grazing during several years on pastures in the uplands leads to creation of thick senescent litter layers formed by *Ligularia alpigena* and *Phlomoides oreophila*, which reduces regeneration or growth of new seedlings. Moderate grazing of pastures will prevent formation of this layer and create conditions allowing for growth of more desirable vegetation species such as *Carex stenophylloides, Carex stenocarpa, Agrostis alba* (Penkina 2004). In such cases the transitions between states 1 and 2 would occur (Fig.4).

## 4.3. Livestock quotas as a way of combating pasture degradation

### *4.3.1. Dynamics of herd size*

In Kyrgyzstan, the number of livestock is gradually increasing. Officially, in the last 12 years the number of livestock has increased by 45.3%. Currently there are 13.8 million LU (Atadjanov et al. 2012); however, it is well known that farmers hide the real number of livestock as they fear losing various subsidies from the state. It is estimated that the actual number of livestock is at least by 30-50% higher than reported (CAMP Alatoo Public Foundation 2012).

Labour migration is also one of the reasons for the increasing number of livestock. Close to 20% of the population is seeking for better economic opportunities in Russia and Kazakhstan, sending back remittances (Sadowskaja 2008). Most of the remittances are used to buy livestock - in rural areas wealth is usually measured in terms of how many heads of livestock each household owns. Livestock serves as an investment fund that increases through natural reproduction, unlike the remittances. Livestock can also be sold whenever cash is needed and livestock is important for traditional feasts when people slaughter animals in order to serve guests or to offer gifts (Schoch et al. 2010). Owning livestock is thus of greater importance for the local people than money.

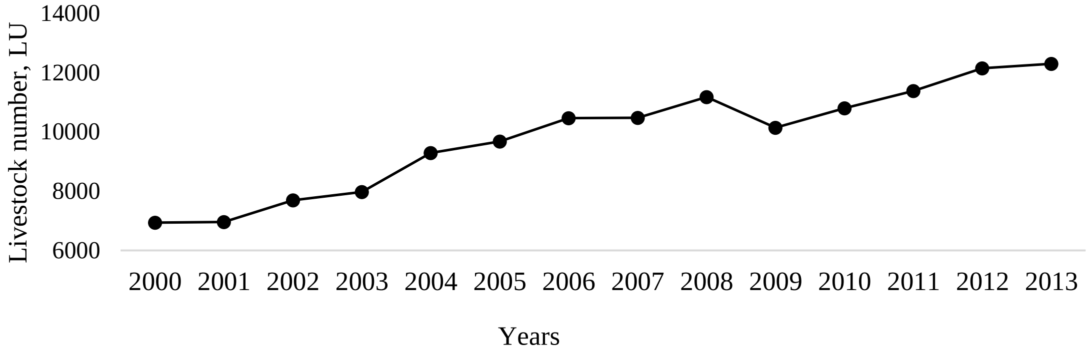


Figure 9. Changes in livestock numbers in Jergetal A/O in Kyrgyzstan from 2000 to 2013 (adapted from Bussler, 2010).

Increasing herd sizes are today's reality. In six of seven regions of Kyrgyzstan, the livestock number exceeds the permissible pasture grazing pressure (Atadjanov et al. 2012). Jergetal A/O can be taken as an example of this trend (Fig. 9).

### *4.3.2. Livestock distribution between households*

The distribution of livestock is extremely uneven. The 1.1% of households of Jergetal A/O owned 16.8% of the livestock, or 161 LU per household. At the same time, the majority of households (61%) owned only 39% of the livestock, or an average 7 of LU (Table 6).

**Table 6.** Distribution of cattle in groups of households in Jergetal aiyl okrug in Kyrgyzstan (unpublished data).

| # of group | Households | | Possessing | | Average LU per household |
|---|---|---|---|---|---|
| | number | % | LU number | % | |
| 1 | 13 | 1.1 | 2,063 | 16.8 | 161 |
| 2 | 28 | 2.4 | 1,636 | 13.3 | 59 |
| 3 | 193 | 16.6 | 3,506 | 28.5 | 18 |
| 4 | 710 | 61 | 4,797 | 39 | 7 |
| 5 | 172 | 14.8 | 299 | 2.4 | 2 |
| 6 | 48 | 4.1 | 0 | 0 | 0 |
| Total | 1,164 | 100 | 12,300 | 100 | |

Such distribution of cattle as in Jergetal A/O is typical for the vast majority of rural communities in Kyrgyzstan. Livestock owners have gradually increased their herds. This leads to overexploitation of the common pastures. In Jergetal A/O the current carrying capacity of pastures has already been exceeded (Table 7).

**Table 7.** Estimated carrying capacity of Jergetal aiyl okrug's pastures within different STM states. Current LU numbers from CAMP Alatoo Public Foundation (2012): current and potential carrying capacity were derived from equation 1. Last column shows the potential capacity of the pastures at the appropriate moisture content of pasture land. The calculation is based on the yield of state 7 where the moisture content is high. (Fig. 4).

| Pastures | Current livestock number, LU | Current carrying capacity | Potential carrying capacity with appropriate management | Improvement of hydrological conditions of pasture |
|---|---|---|---|---|
| Spring pastures | 13,000 | 4,400-7,300 | 5,000-8,400 | 5,800-9,600 |
| Summer pasture | 11,700 | 3,150-7,400 | 5,500-12,800 | 5,500-12,800 |
| Autumn pastures | 10,400 | 6,300-10,000 | 7,300-12,000 | 8,600-14,000 |
| Winter pastures | 12,300 | 2,000-3,500 | 2,300-3,900 | 2,700-4,400 |

In all seasons, the current capacity is lower than the number of livestock. However, it must be noted that around 3,000 LU registered in Jergetal A/O are not grazed on Jergetal pastures. They are grazed on pastures belonging to the Forestry Agency or other aiyl okrugs. It is estimated that about 9,300 LU use Jergetal pastures (CAMP Alatoo Public Foundation 2012). This number of livestock can only be kept without degrading the pastures if their carrying capacity can be increased. Farmers are well aware of what is happening:

> *"Currently the number of livestock is increasing; all of us are trying to get more income from livestock products, thus mercilessly using natural resources. We rarely think that these resources will start to be exhausted and, in my opinion, it will occur very soon. Therefore, we should make every effort not to let it happen. For this we need to join efforts and introduce pasture use rules." (Farmer 54 years old, Jergetal village, 2011)*

Some farmers perceive an improvement of pasture condition, with increased infrastructure to access remote pastures, increased production of winter forage for winter-feeding and so on. However, there are those who are suggesting measures that are more drastic:

> *"There is an increase in livestock, which has an impact on the state of pastures. According to the law on pastures, we who are members of the pasture committee (PC) have to control the livestock numbers according to the carrying capacity of the pastures. This means that we are authorized to limit the number of cattle. However, I see that the number of livestock exceeds the capacity of the pastures, but how can I come and tell the farmer that he should reduce the number of livestock? They will not listen because there is no mechanism for this. We need at least a decision of the local parliament on quotas, only then we can do something." (50 years old, chair of PC of Yrys A/O. 2012).*

> *"We urgently need to introduce quotas and reduce livestock. In the past mudflows occurred in the early spring, when the grass had not grown, nowadays mudflows occur even in the autumn! All this because we are overusing pastures. There is no vegetation on pastures in the autumn, so pastures are not able to soak up even a small amount of precipitation. Even in Soviet times, there were no such mudflows when pastures were considered as degraded!"(55 years old chair of PC of Aflatun, 2012).*

Obviously, increasing livestock numbers is a serious problem for the sustainable management of pastures in Kyrgyzstan. There is no precedent in Central Asia for this kind of reference quotas for livestock. On the contrary, in Kazakhstan and Uzbekistan, increasing the number of livestock is encouraged (Golovina 2011). The approach taken by European countries (Arnalds & Barkarson 2003; Bayer & Waters-Bayer 2003; Arnalds et al. 2011) is also not representative for Kyrgyzstan because there animal husbandry is subsidized. There is no planning for such scenario in the near future in Kyrgyzstan.

Many farmers believe that quotas are the most suitable tool for regulating the number of livestock. However, the government is not ready to take that step, fearing that limitation in the number of livestock would lead to confusion on the part of farmers and they would not support such a step. Instead, the state has delegated authority on these issues to the local administrative levels (A. Egemberdiev, 21 November 2012, Pasture Departament of Kyrgyzstan, personal communication).

#### *4.3.3. Possible quota system, the case of Jergetal aiyl okrug*

The only tool currently available to control livestock numbers in Kyrgyzstan is a livestock quota at the local government level. Jergetal A/O can be taken as an example. As already mentioned above, in Jergetal A/O there are 12,300 LU but 3,000 of them graze outside of Jergetal A/O. The carrying capacity of pastures is presented in Table 7. The lowest carrying capacity of pastures is in the winter time, but many farmers harvest winter fodder and keep animals in confinement for the winter months and therefore the winter capacity may not be decisive for the quota. The spring and summer carrying capacities are approximately the same and are both below the autumn carrying capacity. As has already been said, determining stocking rate must be conservative in nature. This could result in a total quota for Jergetal A/O of about 3,000-3,500 LU. However, such a drastic reduction in livestock numbers can cause a lack of understanding on the part of farmers and as a result the risk that the system will not work will increase dramatically. Therefore, the initial carrying capacity could be set at 7,400 LU (Table 7). Even in this case, it would be possible to reduce the livestock numbers by 20%, and, if the land is managed appropriately, its carrying capacity could increase.

Thus, the quota for Jergetal A/O could be set at 7,400 LU according to Table 5. There are 1,164 households and respectively, each household is entitled to keep up to seven LU. A total of 930 or 80% of households (groups 4-6, Table 6) have livestock within the quota or fewer, respectively, 234 or 20% of households (groups 1-3) exceed the limit (Table 6). If the pastures can be improved, then the quota could be increased to as much as 12 LU per household.

At present, the number of livestock that each household can own is not regulated. One village household may not be able to purchase livestock due to lack of funds, but at the same time another household may own 300 LU. However, both households have the same rights to grazing, as the pastures are a common resource - a recipe for a classical example of the tragedy of the commons (Hardin 1968). However, no one is responsible for the improvement of the common pasture condition. The introduction of payments for exceeding a quota would help create a fund for restoration of pastures and hopefully increase land use responsibility. The following options for households that exceed the quota are suggested:

1. Households exceeding their quota can rent a quota from households that have fewer livestock than their set quota allows (from groups of 5 and 6).
2. A local committee fines households that exceed their quota. The cost could be different for different groups. For example, group 1 would have to pay more than groups 2 or 3 (Table 6). In addition, the cost of the payments should be affected by the remoteness of pastures and any private contributions of a farmer for the improvement of infrastructure and pasture conditions. Under such circumstances, the payment should be minimal.

The government has no plans for allocating any funds for pasture improvements. Local funding is thus the only option and must be based on numbers of livestock for each household. In the case of Jergetal A/O, 80% of the population has less livestock than the quota allows them. It is hoped that 80% of the population will be able to convince the remaining 20% to invest proportionally in pasture improvement. In addition, there is a hope that the big cattle owners will start investing in other sources of income which are not related to grazing, because they already have accumulated sufficient capital in the form of livestock in order to start a private business, thereby enabling others to their fellow villagers to improve their welfare. The proposed system is gender-sensitive. Reducing livestock numbers will make the women’s work easier because most of the work of processing livestock products is carried out by women.

## 5. CONCLUSIONS

Kyrgyzstan’s landscapes are diverse. They range from lowlands to mountainous ranges with steep slopes of varying aspect and exposure. Pasture types are equally diverse, requiring different approaches and flexibility in land management. A conceptual tool that has been suggested under such circumstances is the State and Transition Model (STM). This is flexible and easily adaptable to various management approaches, different landscapes and pastures of varying conditions. STMs models are based on land conditions (states) and transitions between states, given certain disturbances or conditions. The developed model can be used to predict pasture responses under certain management criteria.

The assessment presented here of the current and potential carrying capacity of Jergetal A/O's pastures indicates that the current carrying capacity accounts for about 40-50% of what could be the potential carrying capacity if the land was managed in an optimal way. Long term exploitation has locked the pastures in a degradation cycle which must be broken.

The lowlands and the uplands possess different properties with respect to system resilience. The lowland areas are dry with vegetation well adapted to climate-driven disturbances, e.g. long term droughts. Such systems can also show resilience to grazing, as shown by Milchunas et al. (1988). It appears indeed that grazing is not the driver of the land conditions in the lowlands; climate is the main driver.

The situation is different for the upland pastures. They are less resilient than the lowlands and consequently affected to a larger extent by land management. These peculiarities must be taken into account when planning management activities taking place in the region. Regulation of the stocking rate should prevail in this zone as the most effective approach to control degradation of pastures.

Land use planning based on the STM approach can help to achieve sustainable pasture management. Regulation of livestock will help to achieve the potential carrying capacity of the pastures. The introduction of the quota system of livestock management and payments by any household exceeding their quota will create funds at the local government level which can be used to restore pastures and the area's infrastructure. Trading of quotas between households will also help to improve their financial situation.

Land management needs to be based on opportunistic approaches that rest firmly on an understanding of the ecosystem's response to disturbances, including climatic and anthropogenic disturbances. Using STM as a tool for land management meets these goals and provides, additionally, a comprehensive way to identify landscapes at risk.

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# APPENDICES

**APPENDIX I.** Description of pasture types

***Meadow type pastures***

A sedgy poaceous meadow pasture types (state 1) is mostly located on the upper mountain zone within altitudes 2,600 – 3,100 m a.s.l. State 1 is a referent site for the meadow type of vegetation and dominated by grasses - *Carex stenophylloides* and *Carex stenocarpa.* This state is most productive and gives more than one t/ha biomass, of which about 67% or 0.77 t/ha is palatable. The amount of bare soil is the smallest, about 12% (Fig. 6). The state is achievable by regulation of the stocking rate, which should be appropriate to the carrying capacity of such pastures. A high or low level of stocking rate leads to state 2.

State 2 is dominated by *Carex stenocarpa*. Continued high level of grazing leads to an increasing number of hard plants such as *Ligularia alpigena* and *Phlomoides oreophila.* Such changing of species composition still maintains a high vegetation cover (87.7%) but less biomass, 0.52 t/ha, and only 50% of them palatable species.

*Kobresia stenocarpa* meadow in Jergetal A/O on 3,050 m a.s.l., Son-Kol valley.

***Meadow steppe pastures***

Meadow steppe pastures located at altitudes from 2,400 up to 3,000 m a.s.l. and mostly on south, south-west and south-east facing slopes of mountains. They occupy large areas and are one of the productive pasture types. Meadow steppe pastures have two states – state 3 (or state 1 within the meadow steppe types or MS-S1) and state 4 (state 2 within the meadow steppe types or MS-S2). State 4 is named “poaceous with miscellaneous herbs” and dominated by *Poaceous*, represented by *Festuca valesiaca, Helictotrichon desertorum,* and miscellaneous herbs represented by *Geranium collinum.* Total biomass is about 0.6 t/ha and 52% of it is palatable (Fig. 6). Continued overgrazing can lead to transition of state 4 into state 5. Soil trampling together with a decrease in precipitation and increasing temperature in the middle zone (2,400-2,700 m a.s.l.) can gradually change vegetation and finally vegetation composition from meadow steppe to steppe types.

Motley grass meadow steppe in Jergetal A/O on 2,900 m.a.s.l., Sarjonsuu valley.

***Steppe pastures***

Steppe pastures located at 2,000 up to 2,700 m a.s.l. These pastures are mostly used by farmers as spring and autumn pastures. They are able to grow in dry areas (180 mm) with a high average temperature during the vegetation period (15º C). State 5 (or S-S1) is dominated by *Festuca valesiaca*, which is typical for steppe and meadow steppe pastures. The dominance of *Stipa caucasica* in the later stages indicates a lack of enough grazing pressure on these areas in the spring, because *Stipa caucasica* is quite palatable in the spring, but unpalatable in summer and autumn. Total biomass of the state is 0.47 t dry matter per hectare. A steppe type of pasture has a high percentage of palatable biomass (78.5%) and almost the same percentage of vegetation cover as the previous state (77%) (Fig. 6). Mismanagement and climatic conditions like precipitation are the main thresholds for transition of state 5 into state 6 (S-S2). High stocking rate on the state with a dry summer can lead to transition from state 6 – steppe pastures into state 8 – semi-desert type of pasture.

Steppe pastures of Jergetal A/O on 2,450 m.a.s.l., Teshik valley.

***Semi-desert pastures***

Semi-desert pastures occupy lowlands between 2,000-2,400 m a.s.l., with low precipitation (180 – 220 mm). State 7 (or SD-S1) - the sagebrush-herbs occupied a few land sites with good humidity due to nearby rivers. State 7 is able to produce a high total biomass of about 0.7 t dry matter per hectare which is the second highest biomass after state 1, but the smallest percentage of palatable biomass within the semi-desert types (Fig 6). It shows the potential of land in appropriate hydrological conditions. However, state 7 is not typical due to its small area of distribution and we should to try avoid overestimation of its pasture potential. State 7 is dominated by perennial vegetation represented by *Artemisia tianschanica* and *Artemisia serotina*. The grass layer is dominated by *Stipa capillata*, *Stipa caucasica* and *Elytrigia repens.* Excluding hydrological well conditions and overgrazing in state 7 and overgrazing and several dry summers in state 6 will lead to state 8. The sagebrush-grass types of pastures or state 8 (SD-S2) are dominated by *Artemisia tianschanica* and *Artemisia serotina* as in state 7. Additionally *Festuca valesiaca* appears, which is a valuable species in terms of grazing and characterized by the ability to withstand heavy pressure. With moderate intensity of grazing *Festuca valesiaca* can survive for many years. The total biomass is almost half that of state 7, but the percentage of palatable biomass is high (85%).

State 9 (SD-S3) is created due to continuous overgrazing in state 8. *Ceratocarphus utriculosus* appears – a palatable species but it is a typical representative of the desert vegetation. In the last step the dominant plant changes; instead of the perennial plant *Artemisia tianschanica* comes an annual - *Salsola oppositifolia*. In this state the total biomass decreases (0.27 t/ha) as well as vegetation cover. However, the percentage of palatable biomass remains relatively high or 82%.

Semi-desert pasture in Jergetal A/O on 2,200 m a.s.l., Tarsuu valley.

***Desert pastures***

Desert types of vegetation occupy a fairly large area around villages at low altitudes (2,000-2,300 m.a.s.l.). Desert types of pasture consist of one state – state 10 (D-S1) which is dominated by annual species like *Salsola oppositifolia, Anisantha tectorum* and *Trigonella arcuata*. This state has the lowest biomass (0.21 t/ha), lowest percentage of vegetation cover (47%), but a high percentage of palatable biomass (Fig 6).

**APPENDIX II.** Pressure on pasture units and distribution of states

| Pasture unit number | Pressure on pasture unit | Dominating states | | | | | Area % | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| **1** | *0.97* | *State 1* | *State 4* | | | | 58 | 42 | | | |
| **2** | *0.66* | *State 4* | *State 2* | *State 1* | | | 60 | 30 | 10 | | |
| **3** | *0.50* | *State 2* | *State 4* | | | | 51 | 49 | | | |
| **4** | *0.70* | *State 2* | *State 1* | *State 4* | | | 60 | 30 | 10 | | |
| **5** | *1.03* | *State 1* | *State 2* | *State 4* | | | 70 | 16 | 14 | | |
| **6** | *1.56* | *State 4* | *State 2* | *State 1* | | | 45 | 30 | 25 | | |
| **7** | *1.56* | *State 2* | *State 1* | | | | 60 | 40 | | | |
| **8** | *1.56* | *State 2* | *State 1* | | | | 55 | 45 | | | |
| **9** | *2.87* | *State 4* | *State 1* | | | | 70 | 30 | | | |
| **10** | *1.37* | *State 3* | *State 4* | *State 2* | | | 69 | 19 | 12 | | |
| **11** | *0.60* | *State 2* | *State 4* | *State 1* | | | 59 | 24 | 17 | | |
| **12** | *1.30* | *State 1* | *State 3* | *State 2* | *State 4* | | 35 | 25 | 22 | 18 | |
| **13** | *1.25* | *State 3* | *State 4* | *State 2* | | | 61 | 21 | 18 | | |
| **14** | *1.10* | *State 1* | *State 5* | *State 6* | | | 40 | 35 | 25 | | |
| **15** | *1.91* | *State 6* | *State 4* | *State 5* | *State 2* | *State 3* | 30 | 25 | 15 | 15 | 15 |
| **16** | *0.93* | *State 3* | *State 2* | *State 4* | | | 70 | 16 | 14 | | |
| **17** | *1.19* | *State 2* | *State 3* | *State 6* | | | 50 | 30 | 20 | | |
| **18** | *0.00* | *State 3* | *State 2* | *State 1* | | | 40 | 35 | 25 | | |
| **19** | *0.50* | *State 2* | *State 4* | *State 2* | *State 3* | | 45 | 34 | 13 | 8 | |
| **21** | *0.90* | *State 3* | *State 4* | *State 5* | | | 40 | 35 | 25 | | |
| **22** | *1.20* | *State 6* | *State 2* | *State 4* | *State 3* | | 34 | 29 | 22 | 15 | |
| **23** | *2.07* | *State 2* | *State 4* | *State 6* | *State 1* | | 35 | 30 | 20 | 15 | |
| **24** | *2.78* | *State 4* | *State 6* | *State 3* | | | 45 | 33 | 22 | | |
| **26** | *1.03* | *State 3* | *State 4* | *State 2* | *State 1* | | 34 | 26 | 24 | 16 | |
| **27** | *1.14* | *State 3* | *State 1* | *State 2* | | | 50 | 30 | 20 | | |
| **28** | *0.00* | *State 2* | *State 4* | *State 1* | | | 45 | 40 | 15 | | |
| **29** | *0.73* | *State 2* | *State 3* | *State 4* | | | 67 | 19 | 14 | | |
| **30** | *1.79* | *State 2* | *State 3* | *State 4* | | | 50 | 40 | 10 | | |
| **31** | *1.00* | *State 1* | | | | | 100 | | | | |
| **32** | *0.40* | *State 2* | *State 4* | | | | 53 | 47 | | | |
| **33** | *2.29* | *State 4* | | | | | 100 | | | | |
| **34** | *1.09* | *State 3* | *State 2* | *State 4* | | | 44 | 31 | 25 | | |
| **35** | *0.00* | *State 2* | *State 4* | | | | 60 | 40 | | | |
| **36** | *1.15* | *State 1* | *State 2* | *State 4* | | | 42 | 34 | 24 | | |
| **37** | *0.95* | *State 3* | *State 6* | *State 5* | | | 64 | 25 | 11 | | |
| **38** | *0.80* | *State 6* | *State 7* | *State 8* | *State 5* | *State 1* | 30 | 20 | 21 | 19 | 10 |
| **39** | *3.19* | *State 4* | *State 6* | *State 5* | | | 40 | 38 | 22 | | |
| **40** | *0.60* | *State 8* | *State 9* | *State 1* | | | 50 | 35 | 15 | | |
| **41** | *1.30* | *State 9* | *State 8* | *State 7* | | | 63 | 22 | 15 | | |
| **42** | *2.01* | *State 10* | *State 5* | | | | 70 | 30 | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **44** | *5.74* | *State 10* | *State 6* | *State 5* | *State 9* | | 50 | 25 | 15 | 10 | |
| **45** | *3.19* | *State 4* | *State 5* | *State 3* | *State 2* | | 30 | 27 | 22 | 21 | |
| **46** | *1.74* | *State 10* | *State 9* | *State 7* | *State 6* | | 49 | 21 | 16 | 14 | |
| **47** | *0.50* | *State 7* | *State 8* | | | | 83 | 17 | | | |
| **49** | *3.19* | *State 6* | *State 5* | *State 4* | *State 8* | *State 8* | 29 | 27 | 20 | 18 | 6 |
| **50** | *0.70* | *State 5* | *State 6* | *State 4* | *State 2* | | 43 | 29 | 18 | 10 | |
| **52** | *0.45* | *State 10* | *State 6* | *State 9* | *State 4* | *State 7* | 28 | 22 | 20 | 19 | 11 |
| **53** | *0.52* | *State 8* | *State 6* | *State 5* | | | 45 | 40 | 15 | | |
| **54** | *2.30* | *State 10* | *State 9* | *State 8* | *State 5* | | 50 | 25 | 15 | 10 | |
| **56** | *1.07* | *State 6* | *State 8* | *State 5* | | | 42 | 31 | 27 | | |
| **58** | *2.20* | *State 9* | *State 6* | *State 10* | | | 56 | 23 | 21 | | |
| **59** | *2.28* | *State 10* | *State 9* | *State 6* | *State 5* | | 49 | 22 | 18 | 11 | |
| **60** | *2.50* | *State 10* | *State 6* | *State 9* | *State 8* | | 30 | 25 | 25 | 20 | |
| **61** | *1.18* | *State 9* | *State 10* | *State 7* | *State 5* | *State 6* | 45 | 35 | 8 | 7 | 5 |
| **63** | *2.59* | *State 9* | *State 6* | *State 5* | | | 51 | 28 | 21 | | |