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Application and Verification of Techniques for Visually Assessing Pasture Conditions in Mountainous Terrain

A Test of Three Field Assessment Methods in the Kyrgyz Republic

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The objective of this study was to determine a reliable and effective way to visually assess pastures under the site conditions that prevail in the Kyrgyz Republic, in particular the mountainous terrain. Such a method should make a visual evaluation of pasture conditions in the field possible and help build awareness among land users of soil and pasture degradation and the need for sustainable use of pasture areas. To this end, the Visual Soil Assessment (VSA) method was applied and verified in a research area in the Naryn district in the Kyrgyz Republic. This process included the application of 2 additional visual site assessment methods—the Muencheberg Soil Quality Rating and the method described in the Monitoring Manual for Summer Pastures in the Greater Caucasus in Azerbaijan *by Etzold and Neudert in 2010, referred to subsequently as the MMSP method. A comparison of the VSA results to standard field measurements and laboratory-based analysis was also performed. The VSA method was found to be only moderately applicable under the site conditions, with low correlation between the indicator ratings and the results of the standard measurements. The MMSP method showed substantially better applicability. The results of the study suggest that further research is needed to refine the MMSP method to develop an effective visual assessment method that can be used to support sustainable use and protection of pasture areas in mountain regions.*

Keywords: *Pasture management; soil; degradation; visual site assessment methods; Visual Soil Assessment (VSA); semiquantitative assessment; Kyrgyz Republic.*

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Introduction

Livestock keeping has a long history in the Kyrgyz Republic (39°–44°N; 69°–81°E), during which management practices have undergone numerous changes (Doerre and Borchardt 2012; Liechti 2012). This is especially true for recent times; Crewett (2012: 267) reported that "over the past 50 years, the procedures and responsibilities for the allocation of usufruct rights to pastures have experienced considerable modifications." After the introduction of individual pasture lease right in 2002, in 2009 a different mode of pasture access was introduced: access was to be managed by local user groups (Crewett 2012).

As one result of these changes, livestock numbers are increasing nationwide (Zhumanova 2011; FAOSTAT 2014). This increases pressure on pastures, because the pasture management system currently in use seems to be unsuitable (Gottschling 2006; USAID 2007; Baibagushev 2011). Due to the country's location at the juncture of the Tien Shan and Pamir mountain systems, it is mainly characterized by mountainous terrain; about 93% of its territory lies at elevations higher than 1000 m above sea level (Iliasov and Yakimov 2009), which creates heterogeneous site conditions. In order to protect the pastures and allow sufficient agricultural production, it is necessary to develop a pasture management system that is well adapted to local conditions (Gareeva et al 2008).

Such a system could be supported by an effective visual site assessment method that can detect pasture degradation and is well adapted to mountainous terrain. Visual methods would allow the land users themselves to assess the pastures, as they require little use of measuring devices. They are also independent of laboratory analyses, making them especially suitable for remote areas. Both of these aspects are important in the Kyrgyz Republic, because many farmers have limited incomes and cannot afford to invest in expensive site monitoring methods (Kaufmann et al 2010), and the poor state of the nation's infrastructure requires a great amount of time and money

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FIGURE 1 Location of the study area. (Map by Thomas Breu, first published in Crewett 2012: 268, adapted for this case study)

to be spent on transportation (Ludi 2003; Fitzherbert 2006).

A visual site assessment method that could be applied in the field would also ensure that the land users could be directly involved in the evaluation process, enabling greater ownership of the information and direct access to the obtained results. All of these aspects are expected to sensitize pasture users to the issues of soil and pasture degradation and to the need for sustainable use of pasture areas (Shepherd 2003).

The aim of the research conducted was the verification of potentially suitable visual site assessment methods. An introduction of land users to such a method was not part of the work but is foreseen in a next step.

Assessing pasture conditions

A wide range of methods exist to assess and classify pasture conditions. Common to all approaches reviewed by Kapalanga was an examination of soil and/or vegetation conditions (Kapalanga 2008). The details are given in the *Supplemental material,* Table S1 (http://dx.doi.org/10.1659/MRD-JOURNAL-D-15-00049.S1). Methods vary in the level at which they work (eg global, national, or local), the subject emphasized (eg land use type or nature protection), and their dependence on measuring devices (from remote-sensing technology to simple measuring tape and a spade) (Kapalanga 2008). This study focused at the level of the local farm. Taking into account the Kyrgyz Republic's heterogeneous site conditions, mountainous terrain, and transport challenges, the focus was on the use of simple methods and equipment.

Methodology

Study area

Covering 9.2 million ha, the natural grasslands in the Kyrgyz Republic are the major feeding base for livestock such as cattle, sheep, horses, yaks, and goats. The grasslands are mostly located in the high mountains but also in steppes and semidesert areas (Kaufmann et al 2010). The field research was conducted in the Naryn *oblast* (district), which lies about 250 km southeast of the Kyrgyz capital, Bishkek, and has an area of 45,200 km^2 (Figure 1).

Naryn was selected because of its variable terrain and the presence of all of the most common livestock species (Kaufmann et al 2010). The field research was carried out in different pasture management units in the Naryn *rayon* (an administrative subdivision of Naryn *oblast*). The pasture management units were categorized as follows, based on Ludi's (2003) description:

- Pastures close to villages (also called winter pastures);
- Intermediate pastures, which are usually located in the foothills (also called winter pastures or spring–autumn pastures);
- Vast underused areas in remote parts of the Tien Shan mountains (also called summer pastures).

Within the Naryn *rayon,* pasture use problems (especially overgrazing) urgently need attention (Bussler 2010; Kaufmann et al 2010). According to Baibagushev (2011) there is an imbalance in the way livestock are placed in different pasture management units. Due to a lack of transport options and funds, livestock are often maintained close to settlements. This leads to high

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FIGURE 2 Application and verification of the VSA method in the field by Sabir Koshkonbaev (PhD student and colleague), Naryn Oblast, Kyrgyz Republic. (Photo by Peter Kirch, May 2013)

pressure on the winter and spring–autumn pastures. In contrast, the pressure on summer pastures is low.

For the field research, 3 pasture management units were chosen: 2 pastures that were primarily used as winter/spring–autumn pasture and 1 unit (located more than 2900 m above sea level) that was primarily used as summer pasture.

Methods

For the evaluation of pastures at the farm level with simple and limited equipment, the Visual Soil Assessment (VSA) (Shepherd 2009) was chosen. This method was developed in New Zealand with the aim of "providing a simple, inexpensive method to assess soil [and plant] quality semi-quantitatively, quickly and effectively" (Shepherd and Park 2003: 111). The VSA method is based on a weighted additive model, which includes indicators of soil properties (both static and dynamic) and plant performance. In this way it is designed to assess a wide range of different pasture conditions, which can be the result of multiple management regimes and land use pressures (Shepherd 2005). Since 2008, the method has been recommended by the FAO (2008). Our study was the first to use this method in a science-based approach in the Kyrgyz Republic (Figure 2).

The VSA assessment uses 20 indicators, 10 for soil and 10 for vegetation. The score of each indicator is obtained by comparing a certain aspect of the site with a reference picture and criteria given in the VSA guide. Each picture

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and set of criteria corresponds to a certain condition of the indicator in question and is equivalent to a score between 0 and 2. A specific weighting factor between 1 and 3 is then applied through multiplication to each indicator score, leading to final indicator scores between 0 and 6. Indicator results are then summed separately for soil and plant conditions; the resulting scores indicate the overall soil and plant performance at each site. In cases of discrepancy between the 2, recommendations regarding possible changes in management practices can be derived. The VSA is standardized for all land use types, but it can also be adapted to account for specialized land uses such as pastoral grazing or annual crops (BioAgriNomics 2013).

In addition to the VSA method, 2 other field methods of visual site assessment with alternative indicator sets were tested during this study. These were the Muencheberg Soil Quality Rating (MSQR) (Mueller et al 2007) and the method described in the *Monitoring Manual for Summer Pastures in the Greater Caucasus in Azerbaija*n (referred to subsequently as the MMSP method) (Etzold and Neudert 2010). They were chosen on the basis of a literature search for methods similar to the VSA method in that they were indicator based, could be fully conducted in the field, and required only a small amount of equipment.

The MSQR assesses the current condition of the soil, including the medium-term soil hydrological, thermal, geological, and terrain conditions and the human impact (Mueller et al 2012), which are all considered soil-forming factors. For grassland, the ratings assume "a minimum level of accessibility and management" (Mueller et al 2007: 5). The result of the assessment is a semiquantitative measure, which can be interpreted as a rough estimate of the local crop yield potential.

The MMSP method is based on a preferential sampling design; pastures are assessed on the basis of representative sample areas. Information is gathered on the geographical situation, the soil, the vegetation, and the extent of erosion, and a visual appraisal is made of the state of the pasture. Figure 3 summarizes the indicators of all 3 methods and their scoring ranges.

In addition to the visual assessment methods, standard field measurements and laboratory-based analyses were conducted on the same pasture units to allow verification of the VSA indicator results. The leading selection criterion for these methods was simplicity of both the equipment and its application. This was essential due to the expected transportation challenges and working conditions in the mountainous terrain. Soil-related parameters were evaluated through the analysis of the soil samples, the measurement of the soil resistance to penetration, and the measurement of the water infiltration rate. In detail, the measured parameters were the following (the corresponding measurement standards or principles are given in brackets):

- Bulk density (DIN standard 18125-2 and DIN ISO 11272);
- Moisture content (DIN ISO 11465);
- Soil texture composition: (DIN 19683-1, using the Köhn pipette method);
- pH value (Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten-Methodendenbuch [VDLUFA A] 5.1.1);
- Carbon-related parameters (DIN ISO 10693 and DIN ISO 10694);
- Nitrogen (DIN ISO 13878);
- Soil resistance to penetration (Principales in Mueller et al 2014);
- Infiltration rate and unsaturated hydraulic conductivity (Principales in Decagon Devices 2012).

Based on the results, the overall soil condition was described.

Plant-related parameters were evaluated through the Klapp-Stählin and Braun-Blanquet methods (Dierschke 1994) and through a measurement of vegetative dry matter production. The choice of these methods also took the expected field conditions (mountainous terrain, limited transport infrastructure) and the limited field assessment time into account.

The 53 sample sites were chosen according to the catena concept (Eitel 2006). This was realized through the definition of catenas within the research units, taking the elevation gradient, moisture gradient, utilization gradient, and relief characteristics into consideration. Along the catenas, sample sites representative of certain topical vegetation units were selected.

All field assessment methods and field measurements were conducted twice during the research period (May to August 2013).

Data analysis and statistics

As a first step, the data obtained using the VSA method were interpreted with a method-specific evaluation system. During this process, each indicator was evaluated on its applicability in the field—with "applicability" defined as the extent to which the indicator could be determined in the field using the criteria in the VSA guide. Conditions in the research area such as relief, slope, and vegetation composition were particularly regarded. Each indicator was assigned to one of the following categories:

- Could be applied in the field;
- Could be applied in the field with difficulty;
- Could not be applied in the field.

The "with difficulty" category included indicators for which there was inadequate assessment time during the field research period.

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FIGURE 3 Visual site assessment methods applied during the study and their indicators.

Visual Soil Assessment		Muencheberg Soil Quality Rating		MMSP method	
Soil Quality Index	**Plant Performance Index**	**Basic indicators**	**Hazard indicators**	**Susceptibility to Erosion Index**	**Pasture Degradation Index**
Soil texture (0–6)	Pasture quality (Brix value) (0–6)	Soil texture/substrate (0–6)	Contamination (0–2)	Inclination a (0–60)	Bare soil (0–10)
Soil structure (0–6)	Clover nodules (0–6)	Depth of A horizon or of humic soil (0–2)	Salinization (0–2)	Altitude (0–20)	Rubble/scree (0–10)
Soil porosity (0–6)	Weeds (0–4)	Soil structure (0–2)	Sodification (0–2)	Inclination b (0–10)	Rocks (0–5)
Number and color of soil mottles (0–4)	Pasture growth (0–6)	Subsoil compaction (0–2)	Acidification (0–2)	Aspect (0–20)	Cattle tracks (0–10)
Soil color (0–4)	Pasture color and growth relative to urine patches (0–6)	Rooting depth and depth of biological activity (0–6)	Low total nutrient status (0–2)	Topographic position (0–20)	Erosion tracks (0–10)
Earthworms (0–6)	Pasture utilization (0–6)	Profile available water (0–6)	Soil depth above hard rock (0–2)	Slope configuration (0–10)	Browsing tracks (0–10)
Soil smell (0–4)	Root length and root density (0–6)	Wetness and ponding (0–6)	Drought (0–2)	Bedrock (0–40)	Cover grazing indicator species (0–10)
Potential rooting depth (0–6)	Area of bare ground (0–4)	Slope and relief (0–4)	Flooding and extreme waterlogging (0–2)		Flowering plants (0–5)
Surface ponding (0–6)	Drought stress (0–4)		Steep slope (0–2)		Number of plant species (0–10)
Surface relief (0–2)	Production costs to maintain stock-carrying capacity (0–2)		Rock at surface (0–2)		
			High percentage of coarse soil texture fragments (0–2)		
			Unsuitable soil thermal regime (0–2)		
			Miscellaneous hazards (0–2)		

Second, the results of the first and second assessment periods were compared, with a special focus on comparison of results obtained in different pasture management units (winter/spring–autumn pasture and summer pasture).

Third, the 2 additional field methods of visual site assessment were also analyzed in the same way.

The fourth step was the comparison of the VSA results against the data obtained using standard field measurements and laboratory-based analyses. The VSA final site ratings as well as individual indicator scores were considered in this inquiry (see Table S5). To compare the results, the Kendall rank correlation coefficient τ (Kendall's tau) was calculated, as it is not sensitive for tied

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values (rank equalities). The software used during the process was the statistical package SPSS (IBM SPSS Statistics, version 22, 2013).

The results of the calculated correlation coefficient τ rank between −1 and +1. The following categories were used (based on Leyer and Wescher 2007) as no standard values for the interpretation of nonperfect values exist:

- To ± 0.25: no correlation;
- ± 0.26 to ± 0.50: weak correlation;
- ± 0.51 to ± 0.75: moderate correlation;
- ± 0.76 to ± 1.00: strong correlation.

Results

The results of the VSA method (Kirch 2015) were as follows:

- The results were similar for both assessment periods.
- The summer pasture unit was rated better than the winter/spring–autumn pasture units (see Table S2 in the *Supplemental material*, http://dx.doi.org/10.1659/MRD-JOURNAL-D-15-00049.S1).
- Out of 20 VSA indicators, 17 could be rated under the given site conditions, 11 of them only with difficulty.

The results of the MSQR method were as follows:

- The results were similar for both assessment periods (see Table S3 in the *Supplemental material*, http://dx.doi.org/10.1659/MRD-JOURNAL-D-15-00049.S1).
- Out of 21 MSQR indicators, 14 could be rated under the given site conditions, 5 of them only with difficulty.

The results of the MMSP method were as follows:

- The results were similar for both assessment periods (see Table S4 in *Supplemental material*, http://dx.doi.org/10.1659/MRD-JOURNAL-D-15-00049.S1).
- Out of 16 indicators, 15 could be rated under the given site conditions, 2 of them only with difficulty.

These results are summarized in Figure 4.

The correlations between VSA results and conventionally measured results that could be obtained by calculating the Kendall's tau coefficient were significant, but only weak to moderate for the following VSA indicators (see Table S5 in the *Supplemental material*, http://dx.doi.org/10.1659/MRD-JOURNAL-D-15-00049.S1):

- Soil porosity (correlated with the measured soil resistance to penetration);
- Soil smell (correlated with the measured soil moisture and organic carbon content);
- Potential rooting depth (correlated with the measured soil resistance to penetration);
- Root length and root density (correlated with the measured bulk density, soil resistance to penetration, and soil moisture content).

Discussion

Applicability

The moderate applicability of the VSA method and the low overall correlation between the indicator ratings and the measured data sets showed that the VSA method can neither be fully applied nor verified as adapted to the prevailing site conditions in the research area. Besides the limited applicability of the different indicator assessment processes, the performance of the indicator rating in the research area was often assessed with difficulty. Some indicator ratings could not be assessed at all, including soil color and production costs to maintain stock-carrying capacity. In its current form and under the site conditions and pasture management system in the study area, the VSA assessment method seems therefore not to be suitable. This could be explained by the fact that the VSA method was developed for enclosed pasturelands in New Zealand on flat to rolling country, while the study area consists of free rangeland with a wide range of physiographic characteristics including mountainous terrain.

The alternative visual site assessment methods proved to be equally or more applicable under the given site conditions. The applicability of the MSQR method was estimated as equal to that of the VSA method. Its overall indicator composition seemed slightly better adapted to and applicable in the research area than the VSA method, but there was a need to perform additional device-based soil quality measurements to allow for a complete site rating. Thus this method would be fully applicable only by extension workers and experienced soil scientists.

The MMSP method was very well adapted to the prevailing site conditions and showed the best applicability of the 3 visual assessment methods (see Figure 4). This could be because this method was initially developed in an area with similar site conditions—primarily free rangeland in mountainous terrain in the Greater Caucasus.

Difficulties

During fieldwork and analysis, several difficulties with the visual assessment approach were identified. A major difficulty and a possible source of error was that all assessments and measurements were carried out only twice during the 4-month research period. This reduced the statistical significance of the results and the reliability of the data. This affected the evaluation quality, for example, the calculated correlations between the VSA indicator ratings and the measured data sets. To evaluate

FIGURE 4 Indicators' applicability under site-specific conditions.

possible discrepancy between the measured data and the indicator outcomes with certainty, more extensive data sets are needed. In this study, even though the results of the measured soil and vegetation data were evaluated as plausible through a comparison with the results found in the literature, they do not necessarily reflect the actual site conditions with sufficient accuracy. This can be explained by the fact that the outcomes of many measurements of soil quality may vary because they depend on "the time of year the sample was taken for analysis, the nature of the season, the soil water content, the sampling depth, and the instrumentation and laboratory methodology used" (Shepherd 2003: 162). This reduces the reliability of the measured data.

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A second difficulty was also connected to the approach of verifying the results of the visual assessments with the measured site condition values. The choice of standard field and laboratory-based methods for assessing soil and vegetation was based on "simplicity" of the field equipment required, its ease of use under the expected field conditions (limited transport infrastructure and mountainous terrain), and the limitation of research time needed (eg limited field assessment time). To what extent the resulting combination of chosen methods can precisely depict overall soil conditions and plant performance has to be questioned. Important aspects of the soil conditions—like aggregate size distribution, air permeability, macroporosity, and aggregate stability—were not directly assessable by these methods. The close relationships between the visual scores and the laboratory-based measurements of soil properties that Shepherd (2003) found were largely based on results for the above-listed aspects of soil condition. A comparison to these outcomes and the results obtained through the fieldwork could therefore only be partially performed.

Conclusion and recommendations

Based on the results of this study, the VSA method in its current form cannot be considered a reliable visual site assessment method under the given site conditions. To develop a method that is more reliable and better adapted to free-range pasture arrangements in mountainous terrain, 2 approaches to further research are proposed, one focused on the VSA method and the other on the MMSP method.

One approach is the adaptation of the VSA method to site conditions by changing either the scoring criteria or the indicators themselves. To make this possible, more detailed site analysis and monitoring in the research area is necessary. Changes could include the following:

- Replace (or simply exclude) the indicators "soil color" and "production costs to maintain stock-carrying capacity."
- Change the reference species for the indicator "clover nodules" (possibly to a different leguminous plant or group of plants).
- Adapt the rating scales of the indicators "earthworms" and "pasture growth."
- Review the choice of indicator species for the Plant Performance Index.

Another approach focuses on refining the MMSP method, which showed the best applicability under the site conditions in the study area. Changes could include the following:

- Verify the MMSP indicator results (eg through comparison to the results of the standard field measurements and laboratory-based analyses).
- Adapt the indicator "bedrock" and its assessment procedure to the site conditions.
- Refine the assessment criteria for the indicator "flowering plants" by defining threshold values or providing reference photographs.

The latter approach seems more appropriate, as the MMSP method is already well applicable to the study site.

Additional research on a visual assessment method should also focus on introducing local land users to the method. The provision of a field guide in the Kyrgyz language and the development of a workshop series designed for land users could strongly contribute to a broad application of the method in the Kyrgyz Republic.

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REFERENCES

Baibagushev E. 2011. Recent changes in pastoral systems. Case study on Kyrgyzstan. *In:* Kreutzmann H, Abdulalishoev K, Zhaohui L, Richter J, editors. *Pastoralism and Rangeland Management in Mountain Areas in the Context of Climate and Global Change*. Bonn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit, pp 102–118.

BioAgriNomics. 2013. *Visual Soil Assessment: Field Guide*. Palmerston North, New Zealand: BioAgriNomics. www.BIOAGRINOMICS.com/visual-soil-assessment/field-guides.html; accessed on 10 May 2013.

Bussler S. 2010. *Community Based Pasture Management in Kyrgyzstan—A Pilot Project in Naryn Region*. http://www.naturalresources-centralasia.org/assets/files/Community_based_pasture_%20management_in_%20KR_EN.pdf; accessed on 24 March 2014.

Crewett W. 2012. Improving the sustainability of pasture use in Kyrgyzstan: The impact of pasture governance reforms on livestock migration. *Mountain Research and Development* 32(3):267–274. http://dx.doi.org/10.1659/MRD-JOURNAL-D-11-00128.1.

Decagon Devices. 2012. Mini Disk Infiltrometer—User's manual—Version 10. http://manuals.decagon.com/Manuals/10564_Mini%20Disk%20Infiltrometer_Web.pdf; accessed on 16 May 2013.

Dierschke H. 1994. *Pflanzensoziologie—Grundlagen und Methoden*. Stuttgart, Germany: Eugen Ulmer.

Doerre A, Borchardt P. 2012. Changing systems, changing effects—Pasture utilization in the post-Soviet transition. Case studies from southwestern Kyrgyzstan. *Mountain Research and Development* 32(3):313–323. http://dx.doi.org/10.1659/MRD-JOURNAL-D-11-00132.1.

Eitel B. 2006. *Bodengeographie*. Braunschweig, Germany: Westermann Verlag.
Etzold J, Neudert R. 2010. *Monitoring Manual for Summer Pastures in the Greater Caucasus in Azerbaijan*. Bonn, Germany: Gesellschaft für Internationale Zusammenarbeit, : http://biodivers-southcaucasus.org/wp-content/uploads/2015/02/Monitoring-manual-for-summer-pastures-in-the-Greater-Caucasus-in-Azerbaijan_EN.pdf; accessed on 20 April 2015.
FAO [Food and Agriculture Organization of the United Nations]. 2008. *Visual Soil Assessment (VSA) Fieldguides*. Rome, Italy: FAO. www.fao.org/docrep/010/i0007e/i0007e00.htm; accessed on 20 April 2014.
FAOSTAT [Food and Agriculture Organization of the United Nations, Statistics Division]. 2014. *Number of Heads by Country*. Rome, Italy: FAOSTAT. http://faostat3.fao.org/browse/Q/QA/E; accessed on 19 September 2014.
Fitzherbert A. 2006. *Country Pasture/Forage Resource Profiles*. Rome, Italy: Food and Agriculture Organization of the United Nations. www.fao.org/ag/agp/agpc/doc/counprof/PDF%20files/Kyrgyzstan.pdf; accessed on 14 May 2013.
Gareeva A, Maselli D, Berdova K, Bortsova S, Shoimardonov F, Skorintseva I, Karsymbek A, Wellings T. 2008. *Natural Resource Management for Sustainable Livelihoods—Challenges and Trends in Central Asian Mountain Regions*. Bishkek, Kyrgyzstan: Triada Ltd. Typography.
Gottschling H. 2006. *Die Naturräume des Biosphärenreservates Issyk-Kul in Kirgisistan. Eine landschaftsökologische Studie an Transekten* [PhD dissertation]. Greifswald, Germany: Ernst Moritz Arndt University.
Iliasov S, Yakimov V. 2009. *The Kyrgyz Republic's Second National Communication to the United Nations Framework Convention on Climate Change*. Bishkek, Kyrgyz Republic: United Nations Development Programme.
Kapalanga TS. 2008. *A Review of Land Degradation Assessment Methods*. Walvis Bay, Namibia: Gobabeb Training and Research Centre. www.unulrt.is/static/fellows/document/taimi-1-.pdf; accessed on 12 January 2015.
Kaufmann O, Zeitz J, Ellmer F, Aenis T. 2010. *Project Application. Utilization and Protection of Agricultural Ecosystems in Central Asian High Mountains—Case Study Kyrgyz Alpine Pastures*. Berlin, Germany: Faculty of Agriculture and Horticulture, Humboldt University.
Kirch P. 2015. *Application and Verification of the Visual Soil Assessment Method for Pastoral Grazing (according to SHEPHERD, 2009) in Kyrgyzstan under the Given Specific Site Conditions* [MSc thesis]. Berlin, Germany: Humboldt University. http://edoc.hu-berlin.de/master/kirch-peter-2015-01-10/PDF/kirch.pdf; assessed on 30 March 2015.
Leyer I, Wescher K. 2007. *Multivariate Statistik in der Ökologie: Eine Einführung*. Berlin, Germany: Springer Science+Business Media.
Liechti K. 2012. The meanings of pasture in resource degradation negotiations: Evidence from post-Socialist rural Kyrgyzstan. *Mountain Research and Development* 32(3):304–312. http://dx.doi.org/10.1659/MRD-JOURNAL-D-11-00113.1.
Ludi E. 2003. Sustainable pasture management in Kyrgyzstan and Tajikistan: Development needs and recommendations. *Mountain Research and Development* 23(2):119–123. http://dx.doi.org/10.1659/0276-4741(2003)023[0119:SPMIKA]2.0.CO;2.
Mueller L, Schindler U, Behrendt A, Eulenstein F, Dannowski R. 2007. *The Muencheberg Soil Quality Rating (SQR)—Field Manual for Detecting and Assessing Properties and Limitations of Soils for Cropping and Grazing*. Muencheberg, Germany: Leibniz-Zentrum für Agrarlandschaftsforschung. http://www.zalf.de/de/forschung_lehre/publikationen/Documents/Publikation_Mueller_L/field_mueller.pdf; accessed on 12 January 2015.
Mueller L, Schindler U, Shepherd TG, Schad P, Zeitz J. 2012. *A Framework for Assessing Agricultural Soil Quality on a Global Scale*. London, England: Taylor & Francis.
Mueller L, Suleimenov M, Karimov A, Oadir M, Saparov A, Balgabayev N, Helming K, Lischeid G. 2014. *Novel Measurement and Assessment Tools for Monitoring and Management of Land and Water Resources in Agricultural Landscapes of Central Asia*. Bern, Switzerland: Springer International Publishing.
Shepherd TG. 2003. Assessing soil quality using Visual Soil Assessment. *In:* Currie LD, Hanly JA, editors. *Occasional Report No. 17*. Palmerston North, New Zealand: Fertilizer and Lime Research Centre, Massey University, pp 153–166.
Shepherd TG. 2005. Visual Soil Assessment (VSA) TG Shepherd, Landcare Research, Palmerston North, New Zealand. *In:* Boizard H, Batey T, McKenzie D, Richard G, Roger-Estrade J, Ball B, Bradley I, Cattle S, Hasinger G, Munkholm L, Murphy B, Nievergelt J, Peigné J, Shepherd G, editors. *Field Meeting—Visual Soil Structure Assessment—Detailed Report*. Estrées-Mons, France: National Institute for Agronomic Research (INRA) Research Station, pp 20–24.
Shepherd TG. 2009. *Visual Soil Assessment. Volume 1: Field Guides for Pastoral Grazing and Cropping on Flat to Rolling Country* 2nd edition. Palmerston North, New Zealand: Horizons Regional Council.
Shepherd TG, Park SC. 2003. Visual soil assessment. A management tool for dairy farmers. *In:* Brooks IM, editor. *Proceedings of the 1st Dairy Conference. Dairyfarming Annual*, *Volume 55*. Rotorua, New Zealand: Massey University, pp 111–123.
USAID [United States Agency for International Development]. 2007. *Pasture Reform: Suggestions for Improvements to Pasture Management in the Kyrgyz Republic*. Bishkek, Kyrgyzstan: USAID. http://pdf.usaid.gov/pdf_docs/PNADN532.pdf; accessed on 23 March 2013.
Zhumanova M. 2011. *A Study on Livestock and Land Management in Kyrgyzstan*. Hiroshima, Japan: Hiroshima University, Graduate School for International Development and Cooperation. http://ir.lib.hiroshima-u.ac.jp/ja/00031956; accessed on 7 January 2015.

Supplemental material

TABLE S1 Summary of the methods for assessing pastureland conditions reviewed by Kapalanga (2008).
TABLE S2 Results of the VSA method.
TABLE S3 Results of the MSQR method.
TABLE S4 Results of the MMSP method.
TABLE S5 Correlation of VSA indicators with the soil data.

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