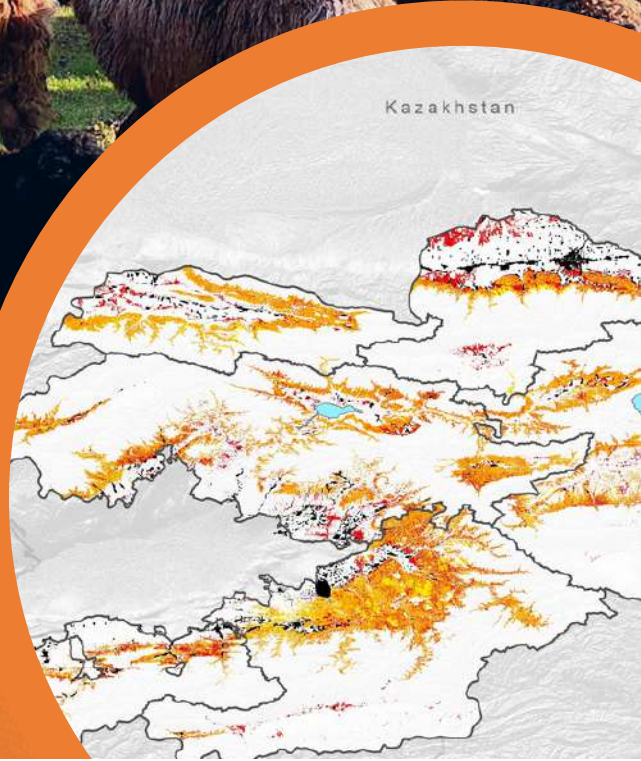




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Technical note Pasture condition maps in Kyrgyzstan



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Pasture condition maps in Kyrgyzstan

► TECHNICAL NOTE

Produced by the Climate Resilience Cluster of the Earth Observation for Sustainable Development (EO4SD CR) initiative, a programme of the European Space Agency, in partnership with the International Fund for Agricultural Development (IFAD) together with the project “Development of policy recommendations for reducing greenhouse gas emissions and climate risks in the land use sector as a contribution to the preparation of the Kyrgyz NDCs” (NDC SFF) implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German federal enterprise for international cooperation) and the State agency on land resources under the Government of Kyrgyz Republic.

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► Introduction

A large part of Kyrgyzstan's land area serves as pasture for its 1.7 million cattle and 6.3 million sheep and goats. Many pastures are subject to degradation caused by overgrazing and exacerbated by climate change. Statistics on pasture conditions at country level are outdated. This technical note summarizes the results of a study that compares the average pasture conditions of 2000–2004 and 2016–2020 using remote sensing imagery. The note presents the maps and statistics, and explains how pasture conditions in Kyrgyzstan were assessed.

► Pasture degradation maps

The study compared the average pasture conditions in the periods 2000–2004 and 2016–2020 using Landsat-based spectral indices and a digital elevation model. The remote sensing analysis took into account pasture types, grazing periods and altitudes, and a dataset of field measurements. Five-year timeframes were chosen to reduce the effects of seasons with statistically high or low rainfall or temperature. Changes of rangelands conditions were reported

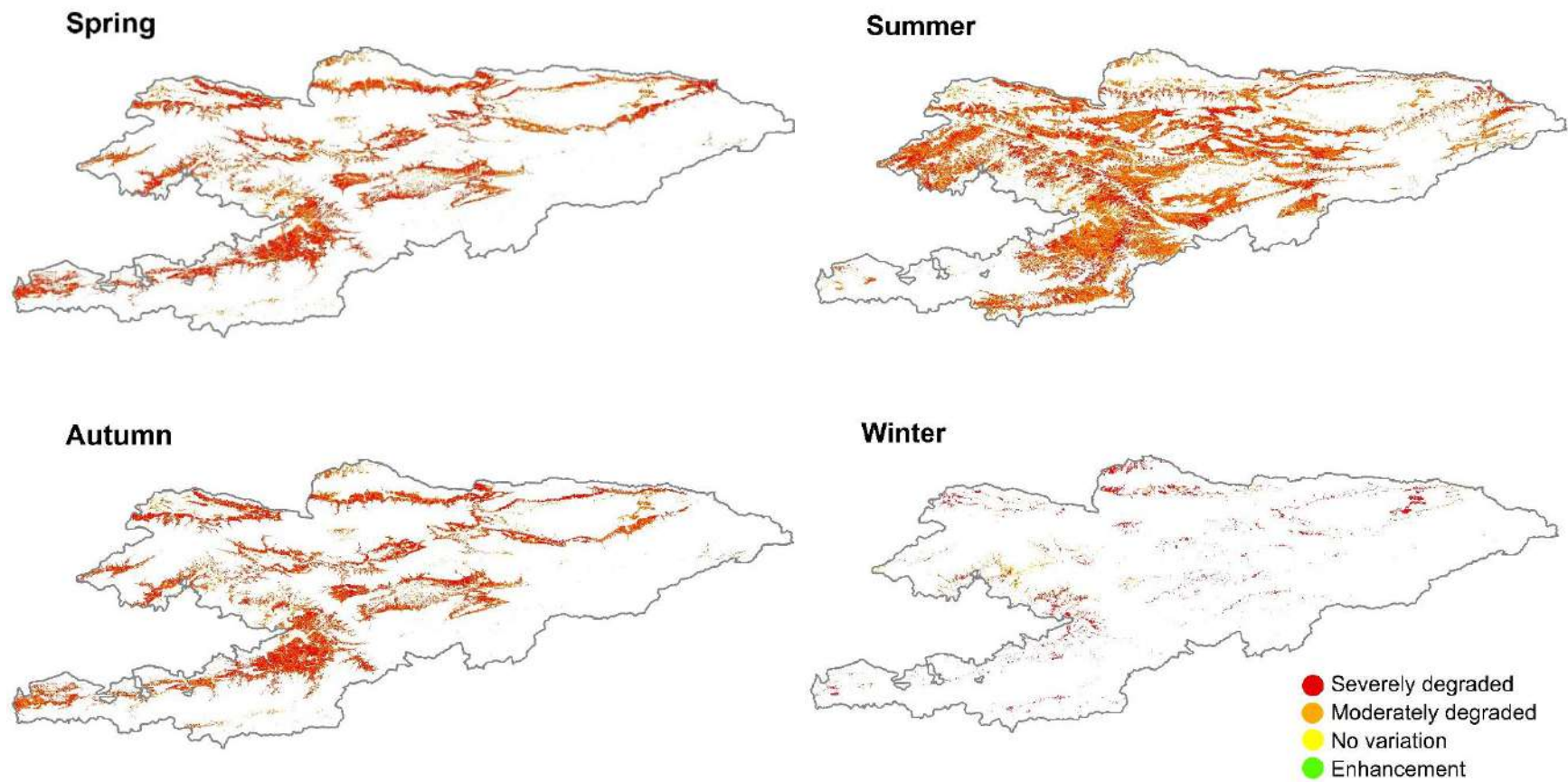
as degradation levels following IPCC's guidelines for grasslands degradation. The maps are available in raster format at 30 m resolution.

The results (Figures 1 and 2; Table 1) show that large areas of pasture were degraded moderately or severely between the start of the century and 2016–20. This study estimates that 87% of pastures (in total 85,531 km²) have been degraded at least during one season (Figure 3).

TABLE 1. Seasonal area (ha) and percentage of total grazing area in that season, by rangeland condition

Degradation level	Winter		Spring		Summer		Autumn	
	ha	%	ha	%	ha	%	ha	%
Severely degraded	533,598	81.5	1,276,714	33.0	3,347,111	43.0	1,127,757	28.9
Moderately degraded	80,723	12.3	2,116,978	54.7	3,906,920	50.2	2,427,628	62.1
No variation	38,512	5.9	470,001	12.2	525,241	6.7	349,016	8.9
Enhancement	1,802	0.3	4,328	0.1	5,803	0.1	3,462	0.1
Total	654,635	100	3,868,022	100	7,785,076	100	3,907,863	100

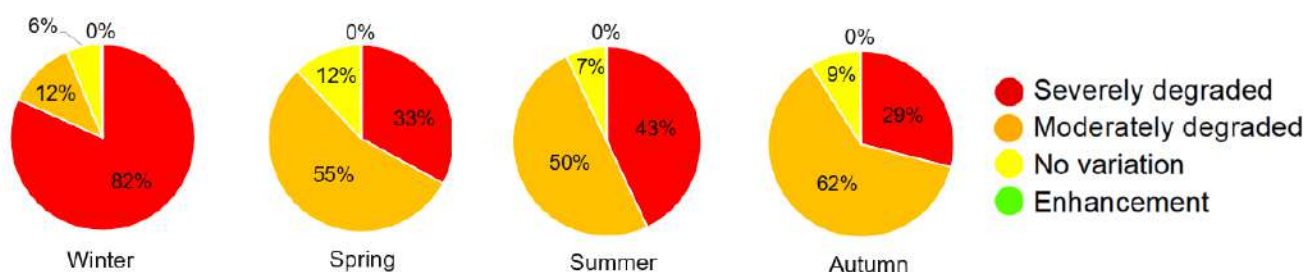
FIGURE 1. Seasonal maps of rangeland condition changes between the periods of 2000–2004 and 2016–2020 according to IPCC Guidelines of 2006



Over 40% of summer pastures have been severely degraded since 2000–2004. More than half of spring/autumn and summer pastures have been moderately degraded. Winter pastures are the worst affected, with 82% being severely degraded. Only a few areas of pasture have undergone an improvement in pasture conditions. The degradation levels per season and type of pasture are summarized in Table 1.

This study did not analyze the causes of degradation or to what extent overgrazing or the effects of climate change have contributed to pasture deterioration. The level of uncertainty can be reduced if more field data are available and pasture areas are better defined.

FIGURE 2. Percentage change in pasture condition between 2000–4 and 2014–20



► How to use the maps

The pasture condition maps can be downloaded in raster format (links provided at the end of this note) allowing spatial statistics to be generated for different administrative levels using software applications such as QGIS.

The maps were used or can be used for the following purposes:

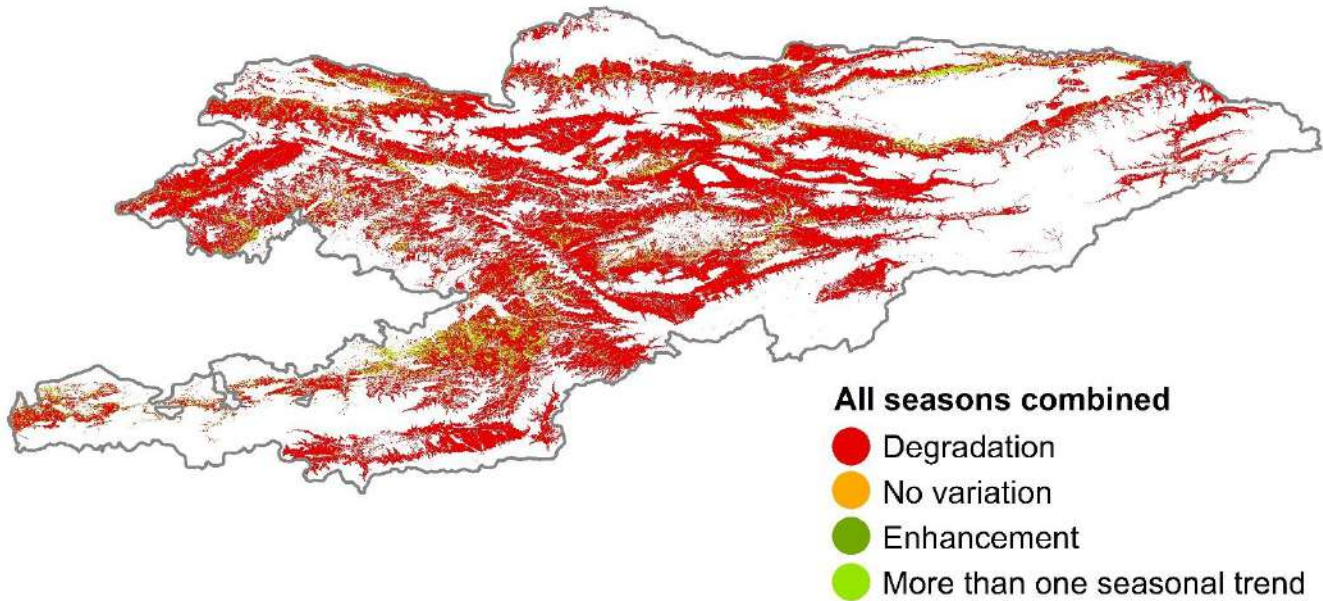
- **Informing climate policy.** The results of this study informed the 2021 update of the country’s Nationally Determined Contributions (NDCs) (Kyrgyzstan’s commitments to reducing emissions and adapting to changing climate in line with the Paris Agreement). Prior to the update of 2021, the pasture sector was not featured in the country’s NDCs.
- **Identifying priority areas for pasture rehabilitation.** IFAD-funded projects and

other donor or state-funded programmes can identify and prioritize areas where investments are needed to restore pasture health.

- **Pasture management plans.** Pasture user unions and the agencies supporting them can use the maps in the planning of pasture management in order to determine the need and extent of activities such as reseeding or reduced grazing.
- **Greenhouse gas inventory development.** The maps can also be used to quantify the greenhouse emission sources and associated emissions using standardized methods.

Maps and statistics of this study have been included in the 2021 report “Analysis of livestock and pasture sub-sectors for the NDC revision in Kyrgyzstan” by GIZ, FAO and IFAD.

FIGURE 3. Combined pasture condition map of all four seasons comparing the periods 2000–4 and 2014–20



► Recommendations

Pastoral systems, if well managed, are the best suited and adaptive form of agriculture for the majority of Kyrgyzstan’s land area that is too dry, cold, or mountainous to practise crop farming. The production system relies on livestock mobility as a key strategy that allows herders to mitigate risks and manage pasture and water resources efficiently.

The literature indicates that unsustainable management practices are the major contributor to degradation. The new maps confirm an ongoing trend of pasture degradation. Between 2006 and 2020, the number of sheep and goats has increased by 55% and the number of cattle by 46% (National Statistical Committee of the Kyrgyz Republic).

Better pasture & herd management

The high level of degradation that the maps reveal highlights the need for more effort to sustainably

manage pastures and herd sizes. Good practices include pasture resting, rotational grazing on seasonal pastures, protection of water sources, and managing herd growth. A study of FAO and IFAD (2021) shows that it is possible to produce more meat and milk without adding more animals by breeding cows at an earlier age, improving the quality of feed, and providing better veterinary services.

Pasture monitoring

In order to improve the quality of this analysis, more field measurements on pasture conditions are needed in different areas that can feed into the map computation. The locations of these field measurements need to be geographically referenced.

The authors recommend repeating the analysis in 2026 in order to analyze the next 5-year period.

► Computing the maps

The following section explains what data were used to produce the maps and how they were computed.

Data inputs

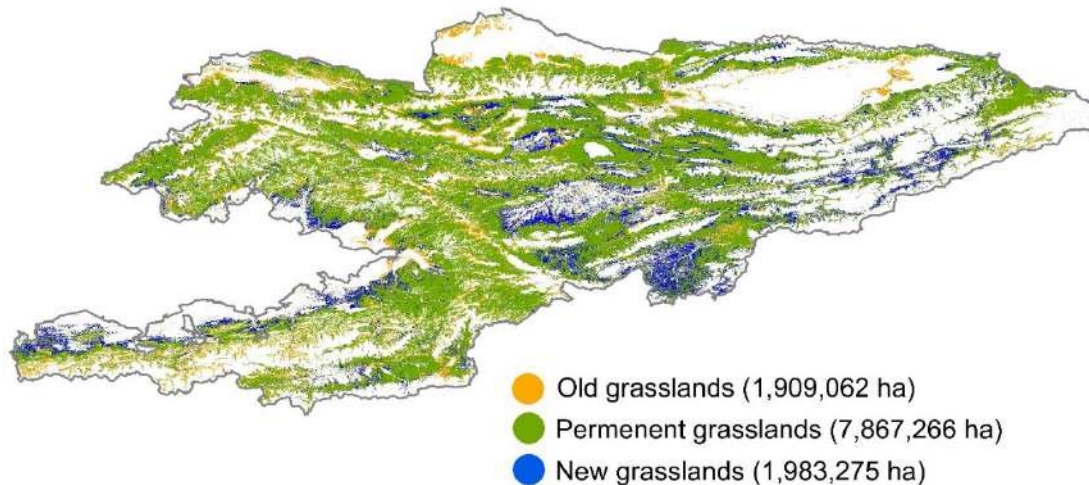
The following data sets were used to compute the pasture condition maps.

Landsat imagery. The analysis used satellite imagery, atmospherically and radiometrically corrected, from Landsat 5, 7 and 8.

Grassland maps. The Food and Agriculture Organization of the United Nations (FAO) developed a land cover map at 30 m resolution for

Kyrgyzstan in 2019. The study updated this product using information provided by CAMP Alatoo on grassland locations and characteristics. The improved map from 2019 was used to identify grassland areas and train an artificial intelligence-based model to develop a grassland map for the year 2000 from Landsat images. This was done because existing time series of global land cover maps are not detailed enough (i.e., pixel spacing is greater than 30 m) or do not cover the 2000–5 period. This approach captures grassland areas converted into cropland, bare soils or settlements and classifies them as degraded rangelands, if applicable, in the change map.

FIGURE 4. Computed grassland maps for 2000–4 and 2016–20 used in this study



Pasture types and grazing periods. Grazing practices in Kyrgyzstan differ by oblast, district or community. CAMP Alatoo provided information on grazing periods, seasonal-based altitudinal ranges for each administrative area (Table 2), plus grazing slopes and maximum distance of pastures to villages. Surface altitude was used to select the grassland areas used for grazing in every season.

Elevation model. The elevation was obtained from the Shuttle Radar Terrain Mission Digital Elevation Model (STRM-DEM) at 30 m.

Field measurements. For algorithm training and validating purposes, results from FAO's Participatory Assessment of Land Degradation and Sustainable Land management in Grassland and Pastoral Systems (PRAGA) project on the pastures state for different locations were used.

TABLE 2. Grazing periods and pasture types

Oblast	District	Aiyl okmotus	Grazing periods				Pasture types (altitude, m)			Distance to villages*
			Winter	Spring	Summer	Autumn	Winter	Spring/autumn	Summer	
Jalalabad	Aksy	Jergetal	11 Nov–31 Mar	1 Apr–20 May	20 May–1 Sep	1 Sep–10 Nov	900-1000	1300-1500	1400-2200	500 m
		Kerben	11 Nov–31 Mar	1 Apr–20 May	20 May–1 Sep	1 Sep–10 Nov	1300	1500-1800	1700-3200	500 m
	Toguz-Toro	Atay	16 Nov–31 Mar	1 Apr–31 May	1 Jun–31 Aug	1 Sep–15 Nov	1500-1800	1500-1900	1900-3100	200 m
Osh	Aravan	Too-Moun	1 Dec–31 Mar	1 Apr–30 May	1 Jun–1 Oct	1 Oct–30 Nov	600-700	700-1600	1160-3000	200 m
		Chek-Abad	1 Dec–19 Mar	20 Mar–30 May	1 Jun–1 Oct	1 Oct–30 Nov	700	700-1200	2200-2400	700 m
		Usupov	1 Dec–19 Mar	20 Mar–30 May	1 Jun–1 Oct	1 Oct–30 Nov	700-800	800-1000	2100-2600	200 m
	Kara-Kulja	Kara-Guz	1 Nov–31 Mar	1 Apr–30 May	1 Jun–1 Sep	1 Sep–1 Nov	1260-1900	1260-2300	1800-2800	100 m
		Kara-Kochkor	1 Nov–31 Mar	1 Apr–30 May	1 Jun–1 Sep	1 Sep–1 Nov	1300-2000	1300-2300	2300-2500	200 m
		Kara-Kulja	1 Nov–31 Mar	1 Apr–30 May	1 Jun–1 Sep	1 Sep–1 Nov	1200-2100	1200-2500	2500-3500	100 m
	Nookat	Kara-Tash	1 Dec–31 Mar	1 Apr–30 May	1 Jun–1 Oct	1 Oct–30 Nov	1000-1300	1200-1300	1600-3000	100 m
		Toolos	1 Dec–31 Mar	1 Apr–30 May	1 Jun–1 Oct	1 Oct–30 Nov	1000	1000-2000	3000	100 m
Batken	Batken	Kara-Bak	Nov–Mar	Sep–Oct	Jun–Aug	Apr–May	850-1200	850-1200	2700-3800	100m
		Suu-Bashy	Nov–Mar	Sep–Oct	Jun–Aug	Apr–May	1200-1600	1200-1600	1800-2000	100m
	Leilek	Beshkent	Nov–Mar	Sep–Oct	Jun–Aug	Apr–May	650-1100	650-1100	650-1100	100 m
		Katran	21 Nov–9 Apr	10 Apr–10 Jun	11 Jun–20 Aug	21 Aug–20 Nov	1200-2000	1200-2000	1200-2000	100 m
Naryn			1 Dec–1 Feb	1 Apr–31 May	1 Jun–31 Aug	1 Sep–31 Nov	2000-2500	1800-2500	2500-3300	500 m
Issyk-Kul			Dec–Apr	May–Jun	Jun–Sep	Oct–Nov	1800-2200	1800-2500	2400-3300	500-1000m
Chui			Dec–Mar	Apr–Jun	Jun–Sep	Oct–Nov	1000-1500	1000-2000	2000-3000	500-1000m
Talas			Dec–Apr	May–Jun	Jun–Sep	Oct–Nov	1500-2000	1500-2200	2000-300	500-1000m

*of winter pastures around villages

Source: Camp Alatoo

Processing steps

Experts from GMV (the company leading the EO4SD CR cluster) developed the following methodology to compute the pasture condition maps using Python and QGIS.

1. Satellite imagery corrections. This step entails the atmospheric correction of satellite images and intercalibration of sensors. As spectral bands of the imagery from different sensors have distinct bandwidths, the first step was to adjust reflectances radiometrically in order to ensure time series consistency. Radiometrically stable targets, e.g., bare soil, were selected and used as reference for the intercalibration exercise.

2. Calculation of Landsat-based spectral indices. Vegetation, moisture and burn indices from Table 4 were calculated over Kyrgyzstan for every grazing period in each season in both five-year timeframes. The five-year average of 15-day spans in each seasonal grazing period were calculated to reduce the effect of meteorological-driven vegetation anomalies. The maximum value of the 15-day spans averaged indices in each seasonal grazing period were used as proxy to assess the pasture condition changes over time following the IPCC's guidelines (2006) of grasslands degradation (Table 3).

FIGURE 5. Shuttle Radar Terrain Mission Digital Elevation Model (STRM-DEM) at 30 m resolution

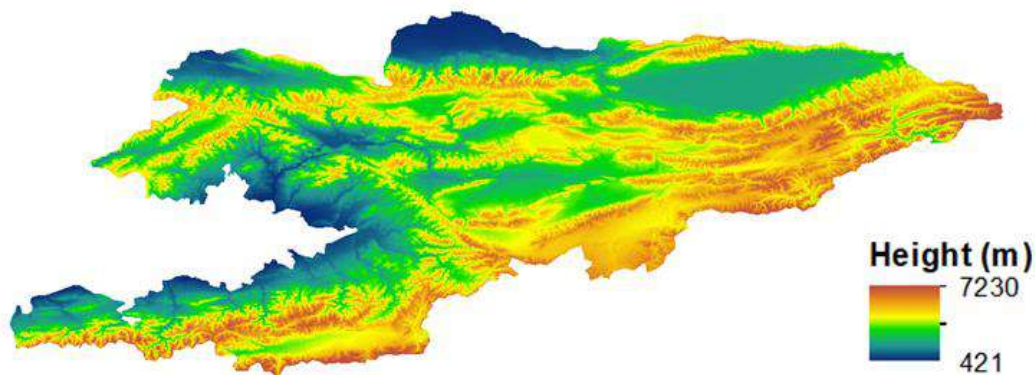


TABLE 3. Classes of rangeland condition changes from IPCC's guidelines from 2006

Qualitative classes	Index variation of post-period with respect to pre-period
Severely degraded	<70%
Moderately degraded	70.1–95%
Non-variation	95.1–105%
Enhancement	>105%

TABLE 4. Spectral indices used to estimate changes in rangeland condition

Index	Formula*	Reference
NDVI Normalized Difference Vegetation Index	$\frac{NIR - RED}{NIR + RED}$	Rouse Jr et al. 1974
EVI Enhanced Vegetation Index	$G \times \frac{NIR - RED}{NIR + C1 \times RED - C2 \times BLUE + L1}$	Liu and Huete 1995
SAVI Soil Adjusted Vegetation Index	$\frac{NIR - RED}{NIR + RED + L2} \times 1 + L2$	Huete 1988
MSAVI Modified Soil Adjusted Vegetation Index	$\frac{2 \times NIR + 1 - \sqrt{(2 \times NIR + 1)^2 - 8 \times (NIR - RED)}}{2}$	Qi et al. 1994
NDMI Normalized Difference Moisture Index	$\frac{NIR - SWIR_1}{NIR + SWIR_1}$	Gao 1996
NBR Normalized Burn Ratio	$\frac{NIR - SWIR_2}{NIR + SWIR_2}$	López-García and Caselles 1991
NBR2 Normalized Burn Ratio 2	$\frac{SWIR_1 - SWIR_2}{SWIR_1 + SWIR_2}$	Key and Benson 2004
VCI Vegetation Condition Index	$\frac{NDVI_i - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$	Kogan 1990
VHI Vegetation Health Index	$\frac{VCI + TCI}{2}$	Kogan 1995

* *BLUE*, *RED*, *NIR*, *SWIR₁* and *SWIR₂* correspond to bands 1, 3, 4, 5 and 7 as well as 2, 4, 5, 6 and 7 for Landsat 5, 7 and 8, respectively.

For *EVI* and *SAVI*, $G = 2.5$, $C1 = 6$, $C2 = 7.5$, $L1 = 1$ and $L2 = 0.2$,

For *VCI*, i refers to a specific date of a considered temporal period.

TCI = Thermal Condition Index, expressed as $(LST_i - LST_{min}) / (LST_{max} - LST_{min})$, where *LST* is the Landsat-based Land Surface Temperature.

3. Analysing index-based degradation.

Changes observed by the spectral indices in the two periods for each sub-district were analysed. Indices showing redundant information were discarded. Results with observed similarity greater than 75% were discarded. The significance of each index to assess degradation is obtained by using a random forest model (feature importance calculation) with in-situ state of observed pastures from FAO's PRAGA project. This approach allowed estimating how effective each index is for representing condition changes in grasslands.

4. Creating metric to assess pasture degradation. A composite of the non-correlated index-based pasture condition changes was computed by weighting the results by their estimated significance and applying a weighted sum model (Equation 1).

$$\text{Rangeland condition changes}_i = \sum_{j=1}^n w_j c_{ji} \quad (1)$$

where i is a single geospatial observed unit (i.e., an image pixel), n is the number of considered indices, w is the weight of the index j , and c is the qualitative class of the rangeland condition change of the index j . This approach is widely used in geospatial applications (e.g., Belenguer-Plomer 2016; Rahman and Saha 2008). Additionally, a level of confidence product was also derived considering the weighted differences of each index-based product with respect to the combined result.

5. Masking pasture areas. The final step was to create and apply a pasture mask over the two grassland maps to target pasture areas. The mask followed the restrictions posed by the grazing practices gathered per district. These include grassland areas with non-steep slopes (i.e., below 45°), with close distance to villages for winter results and with DEM-based altitudes (see Figure 5) within the ranges given for season and per district.

The CHIRPS (Rainfall Estimates from Rain Gauge and Satellite Observations) precipitation product was used to discard areas where the coefficient of variation of annual precipitation exceeds 33% because greenhouse gas emission/absorption models cannot provide realistic results for higher values.

Strengths and weaknesses

Box 1 summarizes the strengths and weaknesses of the methodology. The results of this assessment can be improved with:

- ▶ More field measurements of pasture conditions covering the whole country that are geo-referenced and standardized;
- ▶ More precise and complete information on grazing periods for each season (even at pasture user union level);
- ▶ Better definition of the location of pasture areas.

BOX 1. Strengths and weakness of the calculation methodology

Strengths

- ✓ Adaptability to specific regional-based grazing patterns
- ✓ Low-cost production when compared to field campaigns
- ✓ Replicability for some other time periods or regions

Weaknesses












- ☒ Precise local information is required. The method is not applicable to areas where no grazing information is available.
- ☒ Unbalanced availability of satellite data depending on the period. The more recent, the more data available.
- ☒ Local measurements on rangeland status are required to calculate the weights in the index composite.

► Download maps and further information

The following products listed in Table 5 have been developed. All products can be downloaded here: <https://www.ifad.org/en/web/knowledge/-/pasture-condition-maps-in-kyrgyzstan>

A presentation and webinar recording on how the pasture conditions maps were calculated are available under this link: <http://eo4sd-climate.gmv.com/content/capacity-building-kyrgyzstan>

TABLE 5. List of mapping products

Thumbnail	Product name	Description
	EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_WinterDegradation_winter.tif	Winter rangeland condition changes
	EO4SD_KGZ_RangelandConditionUncertainty_2000-2004vs2016-2020_Winter.tifUncertainty_winter.tif	Winter rangeland condition changes uncertainty
	EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_SpringDegradation_spring.tif	Spring rangeland condition changes
	EO4SD_KGZ_RangelandConditionUncertainty_2000-2004vs2016-2020_Uncertainty_sSpring.tif	Spring rangeland condition changes uncertainty
	EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_Degradation_sSummer.tif	Summer rangeland condition changes
	EO4SD_KGZ_RangelandConditionUncertainty_2000-2004vs2016-2020_Uncertainty_sSummer.tif	Summer rangeland condition changes uncertainty
	EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_ADegradation_autumn.tif	Autumn rangeland condition changes
	EO4SD_KGZ_RangelandConditionUncertainty_2000-2004vs2016-2020_Uncertainty_aAutumn.tif	Autumn rangeland condition changes uncertainty
	EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_AllSeasonspasturelands_status.tif	Combined rangeland condition changes considering all seasons
	EO4SD_KGZ_Grasslands_2000-2004	Grassland map 2000-04
	EO4SD_KGZ_Grasslands_2016-2020	Grassland map 2016-20

About the Earth Observation for Sustainable Development (EO4SD) initiative

The programme funded by the European Space Agency aims to promote the usage of Earth observation-derived information in sustainable development. The initiative is organized in seven thematic consortia of companies that provide geospatial tools, data and services to international finance institutes such as IFAD. The “Climate Resilience” cluster of the programme has supported IFAD’s portfolios in Kyrgyzstan, Tajikistan and Lesotho. The cluster holds expertise on geospatial assessments on climate change adaptation and hosts a data platform called [ADAM](#). The collaboration between IFAD and the Climate Resilience cluster of the programme started in 2019. Click [here](#) for more information.

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